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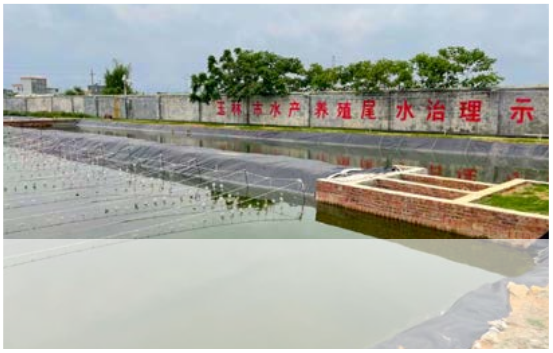
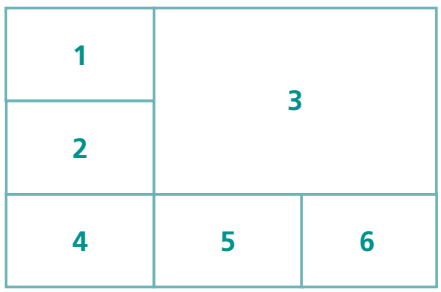
The establishment and operation of aquaparks

Experiences from China





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Preparation of this document

In 2021, the Food and Agriculture Organization of the United Nations (FAO) and the Ministry of Agriculture and Rural Affairs of China (MARA) jointly convened a high–level, roundtable meeting on "South–South and Triangular Cooperation (SSTC) for Sustainable Aquaculture Development" during the 4th Global Conference on Aquaculture, Shanghai, China. It was recommended that the successful practices for the industrialization of aquaculture in China should be documented and shared for the benefit of innovative aquaculture development. The establishment of aquaparks helps to improve the organization of small–scale aquaculture farmers, provide technical services and inputs to aquaculture production and extend the value chain for better market competitiveness and risk management. This manual focuses on the establishment and operation of aquaparks, featuring comprehensive case studies based on experiences from China. It serves as a practical compendium of techniques and strategies tailored specifically for aquapark management and development.

After consulting with the Freshwater Fisheries Research Center of the Chinese Academy of Fishery Sciences (FFRC–CAFS), which is the FAO Reference Centre for Aquaculture and Inland Fisheries Research and Training, a working group was formed to discuss the objectives, outline and methodology for the documentation. Under the FAO Regional Technical Platform, the FAO Fisheries and Aquaculture Division (NFI), the FAO regional office in Asia–Pacific (FAO–RAP) and experts from FFRC–CAFS developed a work plan and assigned the following tasks: a desk study and information collection; the conduction of case studies and field surveys; and the finalization of the drafts accordingly. During the whole process, and in the face of the undoubted challenges faced by the ongoing pandemic, the working group were active and industrious. Discussion and debate via virtual meetings greatly facilitated the writing process. The preparation of this document was coordinated by Xu Pao, Ge Xianping, Zhu Jian and Jing Xiaojun, and the lead authors were as follows; Lin Zhang and Yiran Hou (Chapter 1), Wei Ye (Chapter 2), Yuan Yuan (Chapters 3, 5), Quanjie Li (Chapter 4), Shulun Jiang (Chapter 6), Hongxia Li (Chapter 7), Jun Qiang and Siqi Lu (Chapter 8) and Bing Li (Chapter 9).

The manual could not have been completed without the strong support and leadership of the NFI and the South–South and the Triangular Cooperative Division (PST). Great thanks are extended to colleagues in FFRC–CAFS and RAP, especially to Xu Pao and Xinhua Yuan, for their overall coordination and guidance, and Weimin Miao and Tipparat Pongthanapanich for their detailed administrative and technical support. We would like to acknowledge Xinhua Yuan, Lionel Dabbadie, Fersoy Haydar, Dismass Mbabazi, Alessandro Lovatelli and Junning Cai for their kind reviews and comments. Special thanks are extended to Teri Neer, Lisa Falcone, Nathalie Perisse and Paola Magarini for their support in the publishing process, Sophie Fridman for editing, and José Luis Castilla Civit for the layout design.

An earlier draft of the manual was reviewed and used as reference by the participants of the training workshop on the establishment and operation of aquaparks in Wuxi, China, 23–29 October 2023.

Abstract

The term “aquapark” refers to an innovative aquaculture organizational model designed to facilitate and empower small-scale aquafarmers at every stage of the aquaculture value chain. This model encompasses comprehensive planning, zoning, and infrastructure development for roads, water and electricity, as well as vital aquaculture inputs like seed, feed, extension services and access to markets. The aquapark model is an important innovation to improve environmental, social and economic performance of aquaculture as a mean of sustainable development, which needs support from government aquaculture development strategy and policies, and investment from the public sector and private companies.

This technical manual provides detailed descriptions and classification of the various stages of the development of aquaparks, along with a systematic, step-by-step approach to planning, establishing and effectively managing aquaparks. This technical manual consists of two major components. Part I of the manual gives a concise global overview of aquapark development, followed by an exploration of best practices related to the required steps and common approaches towards the establishment, planning process, basic principles of design and main infrastructure and operation and management of aquaparks in China. This is followed by Part II which outlines successful case studies of aquaparks, including the Chinese largemouth catfish (*Silurus meridionalis*), Aquaculture Industrial Park in Guangxi, the Integrated rice-fish culture in the Hani Terraces, Yunnan, the Guangdong Tilapia Farming Aquapark and the Guangdong Zhanjiang Shrimp Comprehensive Industrial Park. The notable success of aquaparks has demonstrated significant positive impacts on local aquatic food production, supply chains, as well as aspects of social, economic and environmental development. This success serves as a guiding model for the establishment and sustainable operation of aquaparks, especially in developing countries.

This manual also contributes to FAO's efforts in advancing the Blue Transformation initiative. It offers valuable insights to FAO and its Member Nations, enhancing their comprehension of the aquapark concept and enabling the formulation of effective strategies for the implementation of this model to foster sustainable aquaculture development.

Keywords: aquaparks, planning, establishment, infrastructure, operation and management, case studies.

Contents

Figures

Tables

Boxes

Abbreviations and acronyms

AAZ	allocated aquaculture zones
ACC	Aquaculture Certification Council
ALSC	Aquaculture Livelihood Service Centres
APP	application
APWG	aquaculture policy working group
ASEAN	Association of Southeast Asian Nations
BAP	Best Aquaculture Practice
BCR	benefit-cost ratio
BMI	body mass index
BRC	British Retail Consortium
CAC	Codex Alimentarius Commission
CIQ	China Inspection and Quarantine
CNY	Chinese Yuan
EM	effective microbial
EMS	early mortality syndrome
ES	Ethical Standards
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FCR	feed conversion ratio
FFRC-CAFS	Freshwater Fisheries Research Center of Chinese Academy of Fishery Sciences
GB	Mandatory National Standards of China
GIAHS	Globally Important Agricultural Heritage Systems
GIFT	Genetically Improved Farmed Tilapia
HACCP	Hazard Analysis Critical Control Point
IBM	International Business Machines Corporation
IFAD	International Fund for Agricultural Development
LPA	Local Productive Arrangements
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries of Uganda
MARA	Ministry of Agriculture and Rural Affairs of China
NACA	Network of aquaculture Centres in the Asia-Pacific
NFI	FAO Fisheries and Aquaculture Division
OECD	Organization for Economic Co-operation and Development
PPP	public–private partnership
PVC	polyvinyl chloride
SDGs	Sustainable Development Goals
SGS	Société Générale de Surveillance
SPF	specific pathogen free
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations International Children's Emergency Fund
USA	United States of America
USD	United States dollar
WFP	World Food Programme
WHO	World Health Organization
WTO	World Trade Organization

Foreword

In 2021, the Food and Agriculture Organization of the United Nations (FAO) and the Ministry of Agriculture and Rural Affairs of China (MARA) jointly convened a high-level, roundtable meeting on "South-South and Triangular Cooperation (SSTC) for Sustainable Aquaculture Development" during the 4th Global Conference on Aquaculture, Shanghai, China. One of the proposed activities was to share more successful, science-based innovations in sustainable aquaculture development. Under the SSTC strategy, FAO and its Reference Centre for Aquaculture and Inland Fisheries Research and Training, the Fisheries Research Centre of the Chinese Academy of Fishery Sciences (FFRC-CAFS), and through the technical support of the Fisheries and Aquaculture Division (NFI), has jointly produced a series of case studies, technical manuals and knowledge-sharing products.

"*The establishment and operation of aquaparks: Experiences from China*" is a comprehensive document which features invaluable insights derived from extensive experience in sustainable aquaculture in China. The benefits of aquatic products are widely recognized, in terms of providing the necessary dietary requirements for the ageing and young population, and also due to their affordability and availability. The term 'Aquapark' refers to an organizational model, designed to support small-scale aquafarmers throughout the sustainable aquaculture value chain. It includes the input of essential resources, such as infrastructure, water, roads and electricity, and critical elements, such as seed and feed, as well as extension services and market access, embodying the essence of sustainable aquaculture development.

This technical manual, divided into two significant components, serves as an in-depth guide for those interested in this model and its establishment and operation in practice. Part I offers an insightful global overview of aquapark development and delves into the best practices that underpin the planning, design, infrastructure and management of these aquaculture clusters in China. Part II showcases real-world success stories of aquaparks in China, such as the impressive Chinese largemouth catfish Aquaculture Industrial Park in Guangxi and the harmonious Integrated rice-fish culture in the Hani Terraces, Yunnan. These case studies serve as living testaments to the transformative power of aquaparks, not only in enhancing local food production and supply chains, but also in driving positive social, economic and environmental change.

This manual aligns with FAO's commitment to advancing the Blue Transformation, an endeavour to promote the expansion and intensification of aquaculture and sustainable practices and initiatives within this vital sector. By sharing this wealth of knowledge and experiences obtained in China, it will help to empower small-scale aquafarmers and foster fruitful collaboration between public and private partners on a global scale. In conclusion, let me share an African proverb: "If you want to go fast, go alone; if you want to go far, go together". I hope that this book will benefit the decision-makers, farmers, extension officers and all stakeholders in the aquatic food value chain.

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PART I
Introduction to aquaparks

1. Aquapark development

1.1 GLOBAL AQUACULTURE DEVELOPMENT

Over the last five decades, the global demand for aquatic products has steadily risen, due to economic growth, population expansion and improved living standards worldwide. As capture fisheries production stagnates, aquaculture emerges as the potential means to augment global aquatic food supplies. In 2021, aquaculture contributed 49.9 percent of aquatic animal products, and overall farmed aquatic food, including algae, accounted for 57 percent (FAO, 2023).

The State of World Fisheries and Aquaculture (FAO, 2022) of the Food and Agriculture Organization of the United Nations (FAO) reports the total output of capture fisheries has been stagnating, since reaching a high of 90 million tonnes in the 1990s. On the other hand, the total global aquaculture output increased from 7.8 million tonnes in 1980 to 122.6 million tonnes in 2020, including 35.1 million tonnes of algae and 87.5 million tonnes of aquatic animals, with the latter having increased more than 18 times from 4.7 million tonnes in 1980. Annual per capita consumption of aquatic foods (excluding algae) grew from 9 kg in 1961 to 20.5 kg in 2019, having increased at an average annual rate of 3 percent in this period, almost twice that of annual world population growth (FAO, 2022). Fish also continues to be one of the world's most traded food commodities and fish trade is playing an increasingly important role in improving the robustness of local and global fish food systems for developed and developing countries (Wang *et al.*, 2018).

In previous decades, aquaculture has contributed to bridging the gap between supply and demand of aquatic food and has played an important role in global food security, job opportunities and rural development (FAO–MARA–NACA, 2021). Global aquaculture output is estimated to surpass capture fisheries output in 2027, and, by 2030, fish production is projected to increase to 103 million tonnes, with around 52 percent of the world's aquatic food coming from aquaculture (OECD–FAO, 2021). It is expected that the total consumption of aquatic food will increase by 15 percent to 21.4 kg in 2030 and this projection will be achieved primarily through the intensification and expansion of sustainable aquaculture ensuring a global food supply and promoting the fulfillment of the Sustainable Development Goals (SDGs) (FAO, 2022).

The 2030 United Nations Agenda for Sustainable Development is a plan of action for people, planet and prosperity and, through its integrated and indivisible 17 Sustainable Development Goals and 169 targets, covers the three dimensions of sustainable development: economic, social and environmental. The first United Nations Food Systems Summit in 2021 called for joint efforts to foster inclusive and transformative food systems that encourage progress to achieve zero hunger. Among the three objectives of Blue Transformation, aquaculture focuses on sustainable aquaculture expansion and intensification, as well as upgraded value chains (FAO, 2022). However, current global aquaculture development faces unbalanced regional development and provides an insufficient aquafeed supply (FAO–MARA–NACA, 2021). In addition, small-scale aquaculture is still dominating the global aquaculture sector, and there is a need to improve arbitrary aquaculture planning, inconsistent standards, inadequate supporting facilities and weak organization and marketing capacity of farmers. Decentralized and small-scale, self-employed aquaculture farms are vulnerable and not able to cope with various risks and challenges, restricting their ability to reach the optimum output and sustainable development of aquaculture. Meanwhile, around a third of all food produced for human consumption in the world is estimated by

FAO as lost or wasted, and fishery production is no exception, especially when it is conducted at small-scale without access to sufficient preservation and processing techniques. In order to enable aquaculture to provide the necessary livelihoods and well-being and enhance biodiversity and ecosystem conservation, it is essential to foster industrial aquaculture clusters that upgrade the value chain and offer improvement at management and organizational levels.

1.2 CONTRIBUTION OF AQUACULTURE TO SOCIETY

1.2.1 Human food and nutrition

Aquatic foods, a good source of high-quality protein, are rich in various essential fatty acids and important micronutrients, such as omega-3, iron, zinc, calcium, iodine, vitamins A, B12 and D (Golden *et al.,* 2021). When consumed together with plant-based foods, they can balance the nutrients and improve the absorption of micronutrients (Barre *et al*., 2018), and improve human nutrition and health, especially for children suffering from a poor diet, such as micronutrient deficiency, undernutrition and obesity (FAO, IFAD, UNICEF, WFP and WHO, 2022).

According to The State of Food Security and Nutrition in the World 2021 (FAO, IFAD, UNICEF, WFP and WHO, 2021) the number of people affected by hunger globally rose to as many as 828 million in 2021, with an increase of around 46 million since 2020 and 150 million since the outbreak of the COVID-19 pandemic. Nearly one-third of the global population were unable to obtain nutritious food, and about one-quarter of children under the age of five were chronically malnourished. There is currently an increase in moderate or severe food insecurity both globally and regionally, presenting a challenge to achieve zero hunger according to the 2030 Sustainable Development Goals (SDGs) launched by the United Nations (FAO *et al.*, 2022). Aquaculture has thus become an integrated component of the global food supply system, with rapid growth in production and major transformations in feed ingredients, production technologies, and industrial chains (Naylor *et al.*, 2021). Sustainable aquaculture will continue to play an important role in food supply and nutritional security, and must strongly support countries to achieve the goals in terms of eradication of poverty, hunger and malnutrition.

1.2.2 Economic and social benefits

While providing food and nutrition, aquaculture plays an increasingly important role in economic and social development, especially in developing countries. According to the State of World Fisheries and Aquaculture (FAO, 2022), the global output value of cultured aquatic animals exceeded USD 260 billion in 2020, with a total global export volume of aquatic products at around 60 million tonnes, with a value of USD 151 billion. It was estimated that, by 2030, around 35 percent of the total output of aquatic animals will be exported in the forms of various food products or non-food commodities, and that the international trade volume of aquatic food in the world will increase by 9 percent.

In 2020, around 58.50 million full-time and part-time workers were engaged in fishery and aquaculture activities, of which 35 percent (more than 20 million workers) were involved in aquaculture; this percentage was much higher in Asia (39 percent) and lower in Africa (11 percent). In recent years, most aquaculture development is practiced in developing countries, mainly by small-scale aquaculture operators (FAO, 2022). Compared with capture fisheries, the aquaculture sector provides more jobs and employment opportunities for women; at present women account for around 21 percent of the employment in the primary production sector of capture fisheries and aquaculture, but as high as 28 percent in aquaculture compared with 18 percent in fisheries (FAO, 2022). Within the processing sector of aquatic products, women account

for over 50 percent of full-time employment and 71 percent of part-time employment. In 2021, the gender gap in food insecurity continued to widen; 31.9 percent of women in the world were moderately or severely food insecure, compared with 27.6 percent of men, a gap of 4 percent, increasing from 3 percent in 2020. Further development of aquaculture activities, particularly the whole aquaculture value chain, will provide more employment and decent work for women, and help to narrow the gender gap of food insecurity (FAO, 2022).

1.2.3 Environmental and ecological benefits

With the increasingly severe global environmental and climate issues, transitioning into a low-carbon economy has become a strategic choice for governments in coping with frequent and serious climate change events. Aquaculture is a low-carbon emission industry and can also capture and sequester carbon, with its carbon footprint tradable by carbon sinks (Jones *et al.*, 2022). Studies have shown that cultured shellfish, filter-feeding fish and algae have significant potential as carbon sinks, and can play a certain role in reducing greenhouse gas emissions, alleviating water eutrophication and ocean acidification and restoring ecological environment (Hamilton *et al.*, 2022). Freshwater filter-feeding fish feed by filtering and digesting suspended particulate organic carbon (plankton, organic detritus) in the water and, when harvested, removes a large amount of carbon, for example, the filter-feeding fish silver carp (*Hypophthalmichthys molitrix*) and the bighead carp (*H. nobilis*) can absorb 121.5 g and 115.7 g of carbon from the water, respectively, for every 1 kg increase in body mass. Filter-feeding shellfish, such as the Asian freshwater clam (*Corbicula fluminea)*, intake algae and particulate organic debris and transform them into shells (mainly $CaCO_3$) and organic matter, directly or indirectly absorbing carbon in water; when farmed shellfish are harvested, removable carbon sinks can be formed (Yuan *et al.*, 2022). Seaweed culture, which plays an important role in the ecosystem of marine pasture, can fix carbon, release oxygen, utilize carbon dioxide, reduce eutrophication and remove heavy metals (Ye, Jin and Jia, 2018). Therefore, mariculture systems not only serve as an excellent habitat to maintain high species diversity, but also to intensify marine carbon sinks and improve the atmospheric environment (Zhang, 2019).

It is essential to build an aquaculture system where humans may harmoniously coexist with the natural environment in order to maintain biodiversity, adapt to climate change, mitigate the threat posed by climate change, cope with a series of abiotic and biotic environmental stresses such as disease outbreaks and water environment degradation, while safeguarding human livelihoods and quality of life and reducing or mitigating the adverse impacts of the global climate crisis on the natural environment.

1.3 THE AQUAPARK CONCEPT

An aquapark, also known as an "aquaculture park", "aquaculture cluster", "aquaculture village" or "aquaculture industrial park", refers to a modern aquaculture organizational model developed to support small-scale farmers in a sustainable aquaculture value chain. It conforms to the development policy, regulations and scope of aquaculture zonation and planning, supporting clusters of relevant aquaculture industry chains within a certain geographical landscape. In general, an aquapark involves the main elements of aquaculture production, such as suppliers of aquatic seed, feed, and growout, and extends to the related functions of processing, transportation, marketing and trade. The major objectives are to provide a supply of quality inputs, services, and scaled growout production, within a framework of available industrial clusters and organized stakeholders in production and operation, knowledge exchange and innovation enabling.

Aquaparks have been introduced and practiced worldwide. The main development models for aquaparks are based on local conditions, such as: "aquaculture enterprises + farmers" (basic stage); "aquaculture enterprises + cooperatives + farmers" (intermediate stage); and "leading aquaculture enterprises + demonstration bases + cooperatives + farmers" (advanced stage). In Republic of Korea, the aquapark is referred to as an aquaculture village, which is a transformed traditional fishing community. In the Philippines and Brazil, an aquapark refers to an aquaculture community in a certain costal, reservoir area.

The principle of the establishment of aquaparks is to achieve efficient resource utilization, sustainable production, mitigate technical and disaster risks and maximize the benefits of associated stakeholders. The establishment of aquaparks helps to improve the organization of aquaculture farmers, provide technical service and input to aquaculture production, and extend the value chain for better market competitiveness and risk resistance.

1.3.1 Support for small-scale farmers

Small-scale farmers face enormous challenges in aquaculture development, such as limited knowledge and skills in production and management, limits in land and water access, insufficient investment in infrastructure, low capacity of marketing, trade and value addition and insufficient capacity for risk mitigation. Establishing an aquapark is to support decentralized, small-scale aquaculture through organized production chains and enhance infrastructure for aquaculture industrialization. In many successful cases, aquaparks may effectively solve the key bottlenecks in the aquaculture supply chain, such as hatchery, feed supply, technical service and shared marketing facilities. Second, a government lead could help identify allocated aquaculture zones (AAZs) for aquaculture development and integrated environmental management following the national and local standards. Third, the partnership with leading enterprises and technical support from scientific research institutes, farmers, cooperatives, and other business entities are linked and shared with common interests through a contract/organized production model. Fourth, aquaparks help to implement a quality management scheme, product branding and improved risk mitigation capacity, etc.

In summary, aquaculture parks allow for the coordination of aquaculture production activities, such as seed, feed, growout, marketing, and transportation, and the establishment of industrial cluster that could greatly improve the aquaculture organization and industry scale, the enhance overall productivity and economic benefits and the promotion of the local economy and employment.

1.3.2 Inclusive organizational models

In the development process of aquaculture parks, in view of their different business objectives and their main business entity structures and extension functions, their internal driving forces or leading actors are also different. Thus, aquaculture parks can also be categorized into government-led and enterprise-led types. The main business entities of the aquaculture parks are farmers, family farms, cooperatives and leading enterprises.

Aquaparks have various business models that vary from place to place and are based on the local conditions. Table 1.1 summarizes the major development models of aquaparks in China.

Under the organizational model of "cooperatives + farmers" and "enterprises + farmers", farmers and family farms are mainly responsible for standardized aquaculture production. Cooperatives and enterprises have quick access to inputs, providing farmers with high-quality seed and feeds and even commercial loans or advanced capital support to carry out production activities when there is lack of cash flow. Cooperatives and enterprises regulate farmers' aquaculture production by monitoring

TABLE 1.1
Patterns and characteristics of aquaparks at different development stages

Development stage	Organization or business model	Advantages	Disadvantages
Primary stage	Aquaculture Enterprises + Farmers + Farmers' cooperatives	1) Stable and quick access to production inputs, such as seed and feed 2) Good aquaculture management processes and technology 3) Sales channel of products is effectively guaranteed through contract-based aquaculture	1) Weak linkage of economic interest and guarantee mechanism 2) Low degree of organization 3) Risk resistance mechanism need to be improved
Intermediate stage	Aquaculture Enterprises + Farmers' cooperatives + Farmers	1) Clear supply chain/component among business entities 2) Increased negotiation power, overall profitability and risk resistance of cooperatives and farmers 3) Unified and strict production management, aquaculture technologies, seed and feed supply, etc. 4) Professionalism required by the production supply chain, technical training, and branding 5) Greatly improved and guaranteed products and quality	1) Reliance on the professionalism of labour in the industrial chain and reasonable benefit distribution mechanism; higher requirements for the enterprises' industrial supporting facilities, regional marketing, financial strength, supply; and marketing scale and brand reputation 2) Standardization and popularization of aquaculture technologies relying on technical training; need of established standardized aquaculture farm bases, and high human resources input needed for unified and standardized management
Advanced stage	Leading Aquaculture enterprises + standardized aquaculture demonstration base + Farmers' cooperatives + farmers	1) Well-established industrial management alliance with strict management regulations regarding aquaculture technologies, daily management, use of inputs, environmental monitoring, product quality control, etc. 2) Technology demonstration and driving effects achieved through the construction of demonstration bases, guiding farmers to upgrade farm facilities and gradual learning of new aquaculture models and technologies 3) Partnership with scientific research institutes, universities, etc., and adoption of innovations 4) Greatly improved management efficiency of leading enterprises and the production level of aquaculture parks by modern technology, facilities and equipment, such as virtual sharing of scientific research technology, intelligent management and control, and environmental monitoring	1) Requirement for government's policy-based guarantee and financial support 2) Reliance on continuous technological innovation in scientific research for sustainable development and risk mitigation of aquaparks

management processes and providing real-time technical guidance, so as to effectively support the small-scale farmer's participation. As a result, cooperatives and enterprises are connected to the market upstream and farmers downstream by collecting product and orders to facilitate the aquaculture value chain and share benefits.

Under the organizational model of "enterprises + cooperatives + farmers", the production chain is extended to processing and trade. Cooperatives connect enterprises with farmers, coordinating transactions and production batches with processing and trade enterprises, in order to maximize the shared benefits and competitiveness of aquaculture products. In this model, cooperatives provide advanced technologies,

information, seed, feed and services, and enable the setting up of standardized aquaculture production practices, training farmers in modern aquaculture production methods, and ensure that aquatic products meet the quality and quantity of processing enterprises in the aquapark. When there are commercially oriented practices, the organizational model could be "leading enterprises + bases + cooperatives + family farms (farmers)". The leading enterprises, instead of the cooperatives, take the responsibility for technical and capital support for farmers in aquaculture production, and conduct aquaculture with fixed contracts in organizing production, input supply, technical service, and unified marketing and branding. This model is also known as unified production, with standard management, aquaculture technology, seed, feed supply and market branding. With the partnership of scientific research institutes and universities, the aquaparks enjoy technological innovation and demonstration of advanced aquaculture practices and management.

Aquaparks provide an opportunity for single and decentralized farmers to enjoy participation in modern aquaculture, in terms of resource acquisition, infrastructure, supply of inputs, shared benefits, technical support, marketing and trade and risk reduction and resilience.

1.4 THE DEVELOPMENT OF AQUAPARKS

1.4.1 Aquaparks in China

The development of aquaparks in China has shown a diverse pattern and coexistence with the local characteristics, in terms of cultured species, organizational models and business entities. The common goal of an aquapark is to pursue mutual benefits through resource sharing and overcoming limiting factors in input supply, scale of production, quality and standard and marketing. In the last decades, aquaparks have been recognized as an important model for supporting a sustainable and organized aquaculture sector, and have developed rapidly in China in areas with various fishery resources and communities. There are aquaparks in coastal provinces, for example, Jiangsu and Shandong, and in inland provinces in the central and western regions. Aquaparks in China have become the main organization model for promoting the modernization and industrialization of aquaculture. The Chinese authority has provided significant support for the vigorous and regulated development of aquaparks in terms of investment, policy and innovations.

Shandong province has established 66 provincial-level modern aquaparks since 2012, and has shown strong support for infrastructure construction and business development of these parks (Liu, 2018). The major models are "leading enterprises + bases + cooperatives + family farms (farmers)" and "leading enterprises + farmers + cooperatives". In terms of investment, Shandong province has successfully integrated public investment, such as funds for fishery resource restoration, as well as private and social investment. At the same time, it has innovated the fishery tenure system and supported the mortgage financing on mudflat users' rights, and encouraged financial institutions to increase credit support for aquaculture enterprises in the aquaparks. In terms of technological innovation, it has launched pilot projects with partnership with research institutes and universities, and carried out mutual insurance scheme in the aquaparks, in order to improve the resilience of small-scale farmers.

Yunnan province adopted an aquapark business model of "enterprises + cooperatives + farmers" in the Honghe Hani and Yi autonomous prefectures, in order to support the traditional rice farmers in terrace paddy. The aquaparks have taken advantage of the introduced professionalism in fish seed production and marketing capacity of the enterprises, and, with the partnership of research institutes, has provided training in aquaculture technologies to farmers with a free supply of seed and feed, and collected harvested aquatic products at guaranteed prices.

1.4.2 Aquaparks in other countries

There are reports of successful aquaparks in other countries and regions, from Asia, Africa to Latin America. The development stages vary from country to country, and some of them are still in the planning stage, while some have adopted similar organizational models of "cooperatives + farmers" and "enterprises + farmers".

In Southeast Asia, aquaculture parks in Thailand, Indonesia, India and other countries are mainly production-oriented, and their leading business model is "cooperatives + farmers" (Kassam, Subasinghe and Phillips, 2011). For example, Samroiyod Shrimp Aquaculture Cooperative, located in Changwat Prachuap Khiri Khan, Thailand, was established in 2006, including 158 farmers, most of which are small-scale farmers with one or two ponds each (Kassam, Subasinghe and Phillips, 2011). Farmers enjoy cooperative services by purchasing cooperative shares and paying management fees, and must abide by cooperative regulations formulated by the executive committee, so as to improve the productivity and quality of shrimp aquaculture. A total of 158 farmers could receive higher and more stable prices through the cooperative, and the quality of their products were effectively guaranteed.

In 2009, Indonesia established four Aquaculture Livelihood Service Centres (ALSCs) (Kassam, Subasinghe and Phillips, 2011). These centres are owned and managed by community-based milkfish (*Chanos chanos*) and shrimp farmers with members from various aquaculture communities. The leader farmers are responsible for cooperating with various relevant service providers, such as seed, feed suppliers, processing and trade companies, promoting their aquaculture business and ensuring the interests of farmers and the quality of aquatic products. At the same time, aquaculture service centres also provide aquaculture technologies and business expertise for farmers in their communities or extended areas.

Aquaculture parks in Viet Nam are still in the developmental stage, using the "cooperatives + farmers" and "enterprises + farmers" model, and also the business model of "Cluster". "Clusters" as a form of cooperative production to improve the environmental performance of farmers and facilitate them to upgrade their position in the global value chain. Although the principles of cooperative and clusters are similar, the main differences are in terms of organization and management levels; clusters can then be seen a simpler form of a cooperative with less legal liability for members (Ha, Bush and Van Dijk, 2013).

In Latin America, Brazil's aquaculture parks have been developed rapidly, with their operating models transforming from "cooperatives + farmers", "enterprises + farmers" and "enterprises + cooperatives + farmers" guided by the government (Bueno *et al*., 2015; Ribeiro *et al*., 2016; Marco and Aldara, 2017; Valenti *et al*., 2021). The government has continuously promoted the development of Brazil's aquaculture parks through policy formulation, guidance to enterprise and policy support. For example, in Piauí of Brazil, the Companhia de Desenvolvimento dos Vales do São Francisco e do Parnaíba (CODEVASF), a Brazilian national enterprise, has continuously promoted and led small-and medium-sized enterprises and cooperatives to participate in the construction of aquaculture clusters and created a new Local Productive Arrangement (LPA) cluster (Bueno *et al*., 2015; Ribeiro *et al*., 2016; Marco and Aldara, 2017; Valenti *et al*., 2021). The cluster is comprised of business entities (farmers, cooperatives, enterprises, etc.), which carry out the same or related aquaculture activities in the same region. All entities have established mutual cooperation and conducted technical exchanges with common economic goals, and have become important players in improving the local economy. Meanwhile, a recent study by the Brazilian Federal Government has identified sites for aquaculture parks in different regions, based on a series of multidisciplinary studies covering social, environmental, and economic aspects. The study's main objectives are to determine the optimal location for aquaculture parks, estimating their capacity and avoiding

conflicts with other users, without affecting the local aquatic ecosystem. In this way, an effective aquapark plan is determined, and then the land is allocated to farmers, cooperatives, enterprises, and other production entities.

In Africa, aquaparks are still in developmental stages, and there are pilot in the form of "cooperatives + farmers" and "enterprises + farmers ". However, some African countries, for example, Egypt and Uganda, have made efforts to develop aquaculture parks, with operating model transforming from "cooperatives + farmers" and "enterprises + farmers" to a more organized form of "enterprises + cooperatives + farmers".

The Ugandan government has established a special aquaculture policy working group (APWG) to formulate policies in consultation with major aquaculture regional and national stakeholders (Mugabira, Borel and Wilson Mwanja, 2013). The aquaculture policy working group is comprised of the National Ministry of Fishery Resources, the Fishery Resources Research Institute, the Uganda Investment Authority and the Uganda Fish Processing and Exporters Association, and aims to create a favourable environment for aquaculture development and increase the output of national aquaculture by building aquaculture parks (Dalsgaard *et al*., 2012; Mugabira, Borel and Wilson Mwanja, 2013). It puts forward a number of policy recommendations and strategies, including those on the identification, evaluation and classification of aquaculture parks, the comprehensive impact assessment of aquaculture parks on the environment and the provision of aquaculture park infrastructures. Under the strategic framework of the APWG, the Ministry of Agriculture and the Animal Industry and Fisheries (MAAIF) will take the lead in cooperating with existing aquaculture producers and producers' associations to promote, guide, and regulate the development of aquaculture parks. All operators interested in participating in aquaculture parks should be registered with MAAIF and receive compulsory training in aquaculture management and utilization. All individual farmers must be members of production cooperatives and/or belong to core aquaculture enterprises (Mugabira, Borel and Wilson Mwanja, 2013). The government supports the business entities in the aquaculture park through core aquaculture enterprises or cooperative organizations/ groups. Big-scale aquaculture entrepreneurs/companies must demonstrate their commercial viability and sophisticated technologies. In this way, the links between farmers, cooperatives and enterprises can be effectively strengthened, and the overall aquaculture production and level in Uganda can be significantly improved.

In Egypt, two aquaparks were reported for tilapia and shrimp, with the backing of China and local enterprises, contributing greatly to the food security both in Egypt and globally. One of the aquaparks was fully funded from investment from the Chinese government and technical support from the Evergreen Group.

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2. The establishment of aquaparks

2.1 STAGES OF THE ESTABLISHMENT OF AN AQUAPARK

An aquapark is an organizational model of small-scale aquaculture farmers and the associated supply chain for modern aquaculture practices in an identified area. It is the result of the transformation from individual, decentralized aquaculture practices to an organized, specialized and business-oriented model. Farmers in the region are connected with economic, technical and business relations, forming an organizational pattern of professional cooperation of aquaculture inputs, labour and technical services and shared risks, for their mutual benefit. This organizational model can effectively boost aquaculture industrialization, reduce risk of failure and enhance rural economic development, help to introduce and widely apply new aquatic species, new technologies, new models and equipment, and also improve the commercial marketing of aquatic species in order to guarantee farmers' income and economic benefits (Zheng, Liu and Zheng, 2016).

2.1.1 Organization of aquaculture practices and facilitation of the industrial chain

Modern aquaculture requires a highly organized structure and supply chain, necessitating professional knowledge and skills and the differentiation of labour within the industrial supply chain. There is a need to enhance the technical cooperation within the supply chain and share this with the aquaculture industry in a more inclusive, efficient, resilient and professional manner.

The production of aquatic products is the main, fundamental activity in aquaculture parks, hence the aquapark organization is centred around the major farmed aquatic products and their extended supply chain. Leading aquaculture cooperatives and enterprises in aquaculture parks are key players in supporting small-scale farmers within the production chain. The aquapark should make full use of manpower, material and financial resources to organize individual farmers and improve the organizational degree of aquaculture production. The other advantages include adopting standards for good aquaculture practice, unifying procurement of aquaculture inputs, harvesting and marketing and utilization of modern aquaculture equipment and technical assistance, etc. (Joffre, Poortvliet and Klerkx, 2019).

2.1.2 Infrastructure support

Aquaculture-centred planning is required for the better operation of aquaculture parks, and should include infrastructure supported production, transportation, electricity etc. as outlined below. Infrastructure investment could be supported by the government and leading enterprises involved in the development of the aquapark.

- Transportation: existing roads in the aquapark need to be upgraded, and this should include road widening and hardening, providing improved conditions for transportation of aquaculture inputs and harvest. In addition, there is a need to upgrade the roads connected to the main roads, both inside and outside the aquapark, which support the smooth passage of large machinery and transport vehicles, allowing large-scale transportation of feed, aquatic animal veterinary products, fertilizer and fingerlings, and also facilitate the transportation of large batches of marketable fish after harvest.
- Water and electricity supplies: mechanized equipment should be installed in modern aquaculture farms to facilitate efficient management practices, automation,

and reduce labour intensity. These may include aquaculture sheds, greenhouses, and all kinds of aquaculture equipment and facilities, automatic fish feeders, inductive oxygen-increasing devices, recirculation systems, mechanized harvest machinery, etc., all of which requires electricity and power supplies and greatly improve production efficiency and take advantage of modern aquaculture scientific and technological innovations.

2.1.3 Management mechanisms

An organized management system should be introduced, to achieve inclusive and democratic management in order to provide full support to small households in the aquapark. The management mechanism could provide, in time, consultation and decision-making on the aquaculture production models, attracting leading enterprises, as well as quality and standards to ensure the sustainable development. There is a continuous need for capacity building and extension of advanced and best practices in aquaculture for better production and better profit for all. To improve market demand, the parks could standardize aquaculture operations and ensure product quality meets the requirements of the market through strict aquaculture management, in accordance with international and national quality standards.

In general, the success of an aquapark relies on experienced talent or skilled farmers who work as leaders and take the initiative to provide technical services. There is always a demand for the continuing improvement of farmers' skills and capacity in areas such as seed production, feed production, aquatic animal disease prevention, growout culture, and market development, etc., with these well-trained farmers becoming the core team for the aquapark management and decision-making, and contributing to the adoption of good aquaculture standards and building brands of local, superior agricultural products. The people-centred process also requires professional expertise and partnerships with scientific research institutes for scientific guidance and technological innovations.

2.1.4 Financial arrangements and business orientation

Flexible financial arrangements are essential for the successful operation of aquapark. As there is always a challenge for financial arrangement for small-scale farmers in aquaculture, flexible arrangements with government funding, project support and private investment is encouraged. Together with government offices, farmers, cooperatives and related enterprises, the management team of aquapark could mobilize more available resources in supporting the aquaculture supply chain, shared benefits, and organized marketing facilities. In the long run, all stakeholders in the aquapark will be united with shared goal of sustainable aquaculture (Bolman *et al.*, 2018).

The operation of the aquapark should be business oriented. The parks secure the maximum benefit through their committees' organization and coordination, as well as the success of aquaculture business model. With the consultation of experts and the consent of farmers, participatory decision-making can be implemented for the introduction of new species, new technologies and new models, according to the aquaparks' business development model. Meanwhile, the aquapark should seek more cost-effective aquaculture inputs and try to increase its market price bargaining power. At the same time, there is need to exchange the best business knowledge, technology, as well as sharing of facilities and equipment, etc. Regular communication and sharing among farmers and champions could improve the business management experience and skills too.

2.1.5 Aquapark upgrading and diversification of functions

The aquapark development could be categorized into three stages: primary, secondary and tertiary. At the primary development stage, the aquapark focuses on aquaculture

production organization and improvement of the operational efficiency, in order to enhance the aquaculture industry chains and achieve sustainable production capacity. At the secondary stage, the aquapark seeks to improve the standardized aquaculture production and scaling-up, according to market demand, ensuring significant improvement in farmers' production standards and products. At the tertiary stage, the aquapark aims for a more diversified function and to fulfill the industrialized, high-quality aquaculture development, which could integrate food production, tourism, education, leisure and other sectors together.

In terms of the diversified functions of an aquapark, the basic and main function is to organize small-scale farmers for better aquaculture production with shared infrastructures, supply chain and market services. With continuous development, more functions shall be gradually developed, such as aquatic products processing, trade, extension, training and education, technology research and development, leisure tourism, etc.

2.2 COMMON APPROACHES FOR THE ESTABLISHMENT OF AN AQUAPARK

2.2.1 Renovation of traditional fishing villages

Under the policy of regulated capture fisheries, many traditional fishing villages have to face the challenges of transformation for aquatic food production. Aquaculture is the common practices for traditional fishing villages, in particular for the small-scale fishery householders (Tietjen and Jørgensen, 2023). The aquapark built on traditional fishing villages should fully utilize the advantages of their relatively concentrated fishery population and aquatic resources, as well as the knowledge of aquatic food production. In most cases, the favoured policy, land and water use could be advantageous in the fishing village, with a need to enhance the planning, farmer's organization, infrastructure of fish seed and feed supply chains and the marketing facilities. The management team should play a leading role in coordination with scientific research institutes for science-based solutions, for the adoption of new aquaculture technologies and models.

2.2.2 Establishing new aquaparks in allocated aquaculture zones (AAZs)

The new aquapark should be guided by national and local policy and established, under the guidance of local government. The site selection should follow the allocated aquaculture zones (AAZ) and permit regulations. While the approval process is completed, the planning and implementation could be developed with professional agencies or research institutes. The planning should be based on the investigation of the local natural, human and market resources. The aquapark establishment should focus mainly on infrastructure construction, provision of public services, and development and introduction of corresponding preferential policies. Construction of standardized ponds, roads, irrigation systems and biological effluent treatment components should be encouraged, and, at the same time, relevant enterprises should be introduced, such as seed enterprises, feed enterprises, and processing enterprises, in order to provide a full supply chain. The common operational model is called "government guide + enterprises lead + farmers join".

The management team is comprised of representatives of all stakeholders, and coordinated by the local government or cooperatives. Farmers with an interest in pursuing aquaculture as a business should be encouraged to participate in the organized training before they join the aquapark. Once the aquaculture supply chain is formed in the aquapark, the production will be organized by the professional cooperatives to meet the market demand, as well as the implementation of certification and brand schemes. When there is need to upgrade the function of the aquapark, the processing, trade, eco-tourism, education and leisure components could be established after consultation from all stakeholders.

2.2.3 An enterprise-driven industrial aquaculture park

When there is favoured policy for enterprises to invest in an aquapark, a single enterprise or an enterprise group could lead the aquapark development. The common model is "enterprise + base + farmers"/"enterprise + cooperatives + farmers". This model allows large- and medium-sized enterprises to invest and support the infrastructure, as well as the aquaculture production, processing and marketing in the aquapark. Enterprises are the core organizers of industrialized production and cooperate with professional cooperatives, individual farmers, or the community. Generally, to facilitate the participation of small-scale farmers, the companies provide technical training and free of charge on-site technical guidance, solve and deal with all kinds of aquaculture production-related problems, and purchase growout fish in a guaranteed price based on a contract. This model greatly enhances the confidence of farmers that join the aquapark and reduces the risk of failure. This contracted aquaculture also guarantees the supply of growout fish to the processing factories and for commercial orders. Lead enterprises in the aquapark can easily organize production with international and local standards and certification schemes, through technical training and pond-side technical support for quality control. This well-organized aquaculture production could greatly improve the competence of the enterprise in marketing, as well as an environment friendly and economically sound business. It also enables the scaling-up of the aquaculture value chain, both upstream and downstream, the processing, cold-chain, international trade, etc. and also helps develop recreational fisheries, catering, leisure and ecotourism(Wan, 2022).

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3. Aquapark planning

The planning of an aquapark should be developed in accordance with local environmental, social, and economic conditions, according to a programmatic document, to guide the development of the aquapark's implementation and management (Wang and Wang, 2011). In general, the first step of the planning is to analyze the baseline profile and capacity, clarify the gaps and strengths, advantages and disadvantages and opportunities and challenges, through a field survey and interview of stakeholders. The second step is to develop an overall development plan, establish the development goals, identify the priority of construction and functions and publish a spatial layout based on science and technology. The third step is to develop investment arrangements and invite the leading companies to join and invest in the aquapark. The fourth step is to establish an operational and management modality, mechanisms of monitoring and inspection, as well as the branding and marketing strategy (Feng, 2014). The following aspects elaborate the key activities of the aquapark planning process.

3.1 SITE SELECTION

For the site selection of an aquapark, many aspects need to be comprehensively considered, such as economics status, resource endowment, the ecological environment, infrastructure conditions, markets etc. It is necessary to focus on the investigation of the aquatic environmental and its carrying capacity, water resources, aquaculture technical gaps and potential, as well as an investigation of use of land, water, manpower, electricity, transportation and the related production chain, including the seed, feed and medicine supply. In general, the site selection should follow the national policy and regulations on allocated aquaculture zones (AAZs), and take consideration of investment priority and competitive advantage. A safe and reliable supply of land, water and engagement of small-scale farmers should be prioritized in selection of the site for establishment of an aquapark (Sun, 2018).

3.2 THE PLANNING PROCESSES

3.2.1 Project initiation

The project initiation is the first step for aquapark planning. The process includes a consultation in order to understand the relevant development plans and regulations of national and local governments, the development needs of the local social and economic conditions, and the theory of change. First, the background, necessity and significance of the establishment of the aquapark should be clarified. Second, the orientation, objective and scale, site, functional composition, management model and action plan should be prioritized. Third, the feasibility study of the project should be conducted and risk management plan should be prepared (Jiang, 2013).

3.2.2 Feasibility study

First of all, the local conditions for the building of aquaculture parks, the environmental carrying capacity, the production of local aquaculture inputs and local aquatic product consumption market should be investigated, in light of local natural resources, climatic conditions, aquatic resources, economic development and the development of the aquaculture industry with distinct characteristics (Jiang, 2019). Second, based on the profile of the selected site, it is necessary to identify gaps in the production chain and the aquaculture park layout, formulate a development plan, and evaluate the park's

development potential. Third, it is encouraged to evaluate the leading companies, who join the planning and investment, jointly identifying the suitable species, determining aquaculture models, gaps in supply chain (seed, feed and technical service), as well as the marketing opportunities. It is important to understand the small-scale farmers in the aquapark and organize production in a targeted manner. Finally, it is necessary to analyze the management team supporting the implementation plan, and provide regular monitoring of economic, ecological and social impacts, enhancing the investments and risks management. For details, please refer to the feasibility analysis framework in Figure 3.1.

FIGURE 3.1
A typical feasibility analysis framework of an aquapark

CHAPTER 1
Context, necessity and feasibility of aquaculture park construction
- 1.1 Context of the construction/ development
- 1.2 Necessity
- 1.3 Feasibility
- 1.4 Analysis and summary

CHAPTER 2
Analysis and forecast of supply and market demand of aquatic products
- 2.1 Current development of local fishery
- 2.2 Current market demand and forecast
- 2.3 Analysis and summary

CHAPTER 3
Analysis of site selection and construction conditions of aquaculture park
- 3.1 Current land use
- 3.2 Analysis of construction conditions
- 3.3 Summary and analysis of site selection

CHAPTER 4
Construction of the aquaculture park
- 4.1 Function
- 4.2 Layout
- 4.3 Major projects
- 4.4 Construction scale

CHAPTER 5
Investment estimate and financing
- 5.1 Investment estimate
- 5.2 Financing
- 5.3 Fund management

CHAPTER 6
Benefit analysis
- 6.1 Economic benefits
- 6.2 Social benefits
- 6.3 Ecological benefits

CHAPTER 7
Risk Analysis
- 7.1 Technical risk
- 7.2 Ecological risks
- 7.3 Economic benefit and risks
- 7.4 Market risks
- 7.5 Human resources risks
- 7.6 Construction and operational risks
- 7.7 Policy risks

CHAPTER 8
Organization management and operation
- 8.1 Management and operation during construction
- 8.2 Management and operation after completion

3.2.3 Validation of planning

The planning validation needs professional expertise or agency. It could be led by the local government or implemented by an invited expert group. The following key aspects are required:

- **Compliance**: the aquapark planning should be aligned with the local land use planning, urban and rural development planning, agricultural development planning, etc. (Tu, 2014).
- **Technical feasibility**: the planning rationale should be based on specified site selection, investment, construction and operation arrangements, the industrial chain, construction plans, spatial layout, project support, timetable for the construction, fundraising, policies and measures and environmental impact assessment.
- **Economic soundness**: the investment and return, cash flow estimation and financial forecast, cost and benefit analysis should be reasonable.

- **Risk controlled**: the risk of investment, technical, environmental, operational, quality and market should be evaluated and controllable.

3.3 IMPLEMENTATION MODEL

The success of the implementation of an aquapark relies on strong and efficient management and operating mechanisms.

For the transformation of a traditional fishing village into an aquapark, the aim of the implementation plan is to carry out actions to improve capacity improvement of the cooperatives and fishers, as well as to introduce a hatchery and feed-mill for the supply of seed and feed. The construction of fishponds or cages should be skilled and receive technical support from professionals and experts. The implementation model could be "government + cooperatives + farmers" or "government + cooperatives + academia + farmers". This model could help to unify organized production, sales and other services, and the local scientific research institute could provide technical support for the development of the park, to improve the standardization, scale and organization level of the production and enhances market competitiveness.

For **government-led aquaparks,** the government should have funds to invest in infrastructure and attract specialized investment in aquaculture in order to improve the professionalism and production chain in the aquapark (Kong, 2016). The common implementation model is "government-guided + enterprise-led + farmer participation". Enterprises are encouraged by the government to sign contracts with farmers on input supply and harvest collection, which could ensure the benefits of the company as well as the farmers. The government should also publish favourable policies to ensure the model can operate more efficiently and provide guarantees to participating farmers. The local government should also be engaged in branding and promotion of the aquatic products in the aquapark.

For **enterprise-driven aquaparks**, the implementation model is "enterprise + base + farmer" or "enterprise + cooperative + farmer". The company should be the leading company in aquaculture in the area and should provide farmers with services such as fish seed, feed and training of aquaculture technical skills, in order to assist farmers participating the aquaculture production with their own land or renting ponds. Participating farmers should be provided with seed and feed supplies, as well as technical services. After harvest, the company should promise to collect aquatic products from cooperative farmers with guaranteed price. In this model, the local government may enjoy the active role of a private company by introducing a public–private partnership (PPP) in supporting the local community in aquaculture development. The government (the public sector) could encourage private companies to invest in infrastructure in the aquapark, and attract enterprises to get involved in aquaculture production, processing, distribution and marketing, and share risks and benefits in the aquapark development (Li, 2012).

There upgrading of the aquapark should be highlighted using advanced technologies in order to produce good quality, hygienic and safe aquatic food, and even aim for high quality and added values products to meet the high-end markets. Apart from the core function of an aquapark, it could also extend to a multifunctional modern aquaculture industrial park, integrating technological research, production, processing and circular economy, education, tourism, leisure activities and a cultural experience (Jian, 2017).

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4. Aquapark infrastructure

The infrastructure of an aquapark forms the basis of the sustainable utilization of natural resources, the organization of small-scale farmers and support to all the value chain components. When establishing an aquapark, the following elements should be taken into account: the baseline of aquaculture-related social and economic development in the planned area, the needs for aquaculture sector development, as well as the policy towards and advantages of local aquatic resources. The most advanced aquaculture technologies and modern systems should be adapted, modern aquaculture industrialization explored, and jointly, the technology transfer of scientific and research achievements realized. The aquapark should aim for centres for modern aquatic food production, technology demonstration and aquatic food marketing.

4.1 THE BASIC PRINCIPLES OF AQUAPARK DESIGN

4.1.1 An ecosystem approach to aquaculture development

An ecosystem approach is required when formulating the planning and design of the aquapark, based on the results of the feasibility study and the conditions of the natural resources and social development in the planned area. The aquaculture species and model selection should be decided upon, based on the local natural aquatic resources, and the local community should be consulted regarding the farmers' involvement, while the value chain should be determined according to social and market demands.

In consultation with a professional agency or research institutes, the best option should be selected following a comprehensive evaluation process. Participatory approaches with all stakeholders should be adopted for the process of decision-making.

4.1.2 Identification of gaps and capacity building

At the planning and design stage, local conditions and their characteristics should be thoroughly analyzed, highlighting "one product for one country, one industry for one village", and focus should be on a certain type of aquatic product to ensure the supply of more competitive marketable products. Gaps in production, management and marketing should be identified based on expertise. Emphasis should be on the following areas: upgrading of aquaculture facilities, equipment and technology; enhancing the aquaculture production chain and production environment; improving aquaculture productivity; strengthening the supply capacity of high-quality formulated feed and animal health products; improving feed quality and animal health products; standardizing the operation and management mechanism of the parks; attracting the investment of social capital; organizing regular training to improve farmers' skills and knowledge; and promoting sustainable development of modern aquaparks.

4.1.3 Business expansion and advanced management

Business expansion could be expected to cover the full industrial chain therefore it is necessary to review the short-term goals and take into account the long-term interests. At the beginning, the aquapark should focus on the supply chain and leading companies in the park, such as the hatchery for seed supply, feed-mill for feed supply, one-stop diagnostic and aquatic animal health facilities, etc. Gradually, when there is market demand, components of processing, leisure fishing, catering, tourism, education and training could also be developed. In the process of planning and design, it is necessary to identify the priorities according to different development stages of the aquapark,

which may extend from meeting requirements for basic operation to a comprehensive industrial chain within the aquapark. Based on the sustainable use of land and water, as well as the finances and labour, the advanced management should be introduced and capacity improved. There is a need to enhance the awareness of environmental carrying capacity, and science-based, high-quality solutions for sustainable development of the aquapark.

4.2 THE MAIN INFRASTRUCTURE OF AN AQUAPARK

4.2.1 Master plan

It is necessary to collect and review documents related to a master plan for the development of aquaculture, validated by an on-site survey, ensuring that the planning and design comply with national regulations. The detailed construction plan of the leading companies' and farmers' pond modification should also be reviewed and archived. The surveying and baseline data should include the landscape, distribution of water bodies, and pond conditions, roads and workshops and energy supply (such as electricity and gas stations), etc. When irrigation canals and a desilting facility is required, earthen works and a water sediment facility should be also taken into consideration. Meanwhile, it is necessary to understand the property rights and usage rights of all resources and investigate the practical operation and production protocols.

4.2.2 Selection of farming models and aquaculture investment

With the consultation of expertise and professional agencies, the farming models should be decided, based on local resources, climate and market demand. The most common and popular aquatic species should be introduced and the production chain should be established and improved.

In most cases, the traditional farmed species could be the first selection for the aquapark, however the introduction of alien species with high market demand could also work for the purpose. Once the species is decided, the aquaculture models should be adopted with the most advanced and up-to-date technology.

For inland aquaculture, pond fish farming is still the most common aquaculture model and there are some general requirements for consideration. For aquaculture farmers, the local and national standards are recommended for adoption and farm modification. The fish growout ponds should be designed to be large and deep, while shrimp and crab ponds are relatively small and shallow. There are common fish ponds with intensive, semi-intensive and extensive models. Taking the intensive fish pond as an example, the recommended requirements are shown in Table 4.1.

TABLE 4.1
Standards and requirements for fish growout pond

Items	Description
Layout	Larger ponds are usually arranged with a shorter edge in the direction of strong prevailing winds.
Area and shape	The area of intensive fishponds ranges from 0.1 ha to several hectares. The landform, fishpond type, production management conditions, irrigation and drainage time, and other factors should be considered when determining the size of the area.
Depth	1.5–3.5 m.
Slope	Slope ratio 1:2.
Width of pond crest	The width of the pond surface located on the main traffic road should be determined according to the regulations of the traffic department on highway classification/categories of road class. When there is no traffic requirement, the width of the flood control embankment/dykes and river wave barriers is 2.5–4 m. The width of embankments for stopping water from overflowing is generally more than 2 m, calculated according to the size of the allocated area.

TABLE 4.1 (CONTINUED)

Items	Description
Top elevation of pond embankment	In order to ensure that the water does not overflow, the height of the pond should be above the highest flood level and crest levels of the dykes need to be raised to avoid waves overtopping.
Intake and drainage of fish ponds	In principle, water intake and drainage should be independent of each other; water should enter the pond from one end and drain from the other. This can not only prevent the spread of aquatic animal pathogens, but also improves broodstock cultivation. In addition, water intake facilities divert water to fish farms, and each fishpond should be provided with water intake gates. The drainage collection of each fishpond should lead to drainage facilities, and drainage facilities should be provided with drainage sluices.

Source: Huang, C.X. 2009. Fishery Engineering. Beijing, Higher Education Press.

Farms must include a water treatment system to ensure that effluent discharge follows the requirements of modern aquaculture. Constructed wetland and extensive ponds are commonly used in many farms. For intensive hatcheries, intensive culture ponds and indoor recirculating aquaculture systems, water purification devices should be installed as required to provide sufficient purification capacity to ensure the safe operation of production.

4.2.3 Irrigation systems and water canals

Irrigation systems refer to water supply and drainage facilities and equipment, as well as water related management, and should include pumps, canals, sluices, culverts, cascades, slopes, simple aqueducts, and other irrigation units. It is necessary to investigate available water sources and carry out detailed water quality tests and hydrological profile investigations. The water reservoir is commonly in a high place, and an elevated reservoir may be built to facilitate gravitational water supply. The park should also include water treatment, recycling and wastewater treatment. According to water quality requirements for aquaculture, there is a need to comply with the national and local standards. When the effluent fails to meet the discharge standard, water treatment facilities or equipment should be installed, such as aquaculture effluent treatment units, such as a sedimentation tank, filtration tank and biological purification tank. Equipment for disinfection and pure oxygen enhancement should be installed, wherever appropriate, for a recirculation system. The common unit of effluent treatment in pond aquaculture is constructed wetland, with a design of water flow through the constructed wetlands to include aeration, plantation, filtering species, etc. The commonly used substrate for purification includes soil, sand, slag, clay, stone (gravel or pebble), etc. The reed bed is considered a biological treatment system for nutrient rich water. The requirement of water quality for aquaculture are shown in Table 4.2.

TABLE 4.2
Water quality requirements for aquaculture

Items	Description
Appearance	no oil film or floating foam should appear on the water surface
Suspended solids	should not exceed 10 mg/L
pH	should be 6.5–8.5 for fresh water, 7.0–8.5 for seawater
Dissolved oxygen	should not be less than 5 mg/L for more than 16 consecutive hours in 24 hours and should not be less than 3 mg/L at any other time

Source: Water Quality Standard for Fisheries, Mandatory National Standards of China (GB 11607-1989).

4.2.4 Power supply system

An electricity supply is required for modern aquaculture systems and industries, especially for hatcheries and feed-mills, as well as processing factories. For most

power-driven machinery, three-phase electricity with a voltage of 380 V is required. There is also a requirement for the electricity supply for householder use and office appliances of single-phase with a voltage of 220 V. The electricity supply office should be consulted regarding the total required electricity capacity.

4.2.5 Road construction

The roads in the aquapark are constructed for transportation and movement of operational machinery. In general, they are categorized into trunk roads and branch roads. Passage of large trucks used for the transportation of feed and harvested products requires a hard pavement with a width greater than 3.5 m. The branch road should also be a hard pavement, with reduced hardness to meet the requirements of vehicles for light weight transportation, and the width should be greater than 1.5 m. Parking lots and other facilities should also be provided for vehicle loading and offloading.

4.2.6 Other supporting facilities

The work on other supporting facilities mainly involves housing construction, systems for garbage disposal, greening and landscape design and display of signs. Housing facilities mainly meet the needs of management, storage, living, and laboratory. An office building is usually required for management. Storage is required for inputs (such as pellet feeds, complementary feed and medicines), nets, pumps and other equipment. Residential houses are built for staff with accommodation, kitchens, canteen, washing rooms and toilets, etc. In terms of laboratory space, a water quality testing facility and disease diagnosis laboratory are required. Signs for danger, electricity, deep water and roads should also be displayed, if applicable.

For the expansion of an aquapark's function, infrastructure for conferences, training, cold storage, processing laboratory, tourism, restaurant, meeting rooms could also be constructed.

5. Operation and management of an aquapark

Good operation and management are important for achieving an optimal allocation of land, use of capital, technology and talent and information sharing in the aquapark. The operation of all parts of the aquapark should be coordinated to play their respective role and function efficiently and should be result-oriented, in order to promote a beneficial and distinctive industrial cluster, and to better organize small-scale farmers in the production chain (Liu, 2018). The operation and management of an aquapark mainly includes the following four aspects: scientific planning and a feasibility study; organization and implementation; preparation and finalization of technical proposal; and operation and management of the Aquapark.

5.1 SCIENTIFIC PLANNING AND FEASIBILITY STUDY

The scientific operation and management of aquaculture parks require scientific and rationale planning, to ensure the industrial production and supply chain can efficiently and effectively meet the demand.

There are three ways to make a scientific plan (He, 2006):

First, to hire a professional team/agency; the professional team/agency may do the planning based on an evaluation of local natural resources, climatic conditions, technical capacity, production model and organization, market and trade. This may also include an implementation plan, based on science and updated technology.

Second, to set up an expert advisory group; the expert advisory group may conduct field research and discussions, guide the design of overall production plan of the park and propose the best option or solutions for the establishment, operation and management of the aquapark.

Third, to use a government-led participatory approach; this approach is led by the government office who may organize discussions and meetings with stakeholders, including the local farmers, private sector, research institutes, etc. The planning process should include, but not be limited to, a survey and evaluation of available natural resources, involving farmers, private sectors, market and trade operators, etc. This method enables farmers to actively participate in the discussion and express their expectations and needs, helps to determine the aquaculture production and supply chain capacity and ensures that the plan meets the needs of directly engaged stakeholders.

The feasibility study is usually carried out by a professional team/agency. A feasibility study aims to provide an independent assessment that examines all aspects of a proposed project, including technical, economic, financial, legal, and environmental considerations.

5.2 IMPLEMENTATION PLAN AND MODEL

5.2.1 Formulation of an implementation plan

When the planning for the establishment of the aquapark is in place, there is a need to clarify task objectives and develop an implementation plan. The implementation plan should include a coordinating mechanism (steering group), task teams and scheduled milestones. Planned tasks should be broken down, for instance, to distribute and assign

a set of tasks, according to the plans for the aquapark construction and operation. From physical and financial to technical components, the more detailed and practical the plan and the milestones, the more effective is the implementation process.

The coordination mechanism (steering group) is crucial for the implementation process. In order to monitor the risks and allocate resources to achieve the milestones, it is important to strengthen the supervision and coordination of the implementation process, and solve problems in a timely manner. A risk control plan ensures that risks in the implementation process could be mitigated and managed efficiently (Wang and Zhou, 2019).

Learning by doing and holding regular exchange meetings may help to make improvements throughout the implementation process, especially for the technical capacity building in the production models, and will continuously improve production and management capabilities and levels.

5.2.2 Implementation model

Based on the priority activities for the establishment of the aquapark, the aquapark steering group should determine the implementation model according to the implementation plan. To realize the functions of the aquapark, the implementation model could be decided on the existing nodes and infrastructure construction, such as hatchery and feed-mill for seed and feed supply, farmers organization in aquaculture production, value chain facilities of market and processing, etc. The following is a detailed description of basic functions, service functions and upgraded functions of the aquapark (Liu, 2015).

Basic functions

The main basic functions of the aquapark include seed production and growout of aquatic animals.

Seed supply system

As aquatic animal seed production requires professional skills, it is usually carried out by a professional team or enterprises. Good quality aquatic animal seed requires access to convenient transportation and rich freshwater resources, and water quality should meet the required standards for aquaculture. Broodstock with a fast growth rate, strong disease resistance and suitability for local natural conditions should be selected and maintained. The provision of aquatic animal seed should be well managed in order to satisfy the aquapark's requirements, according to the production cycle. Farmers should be trained to stock sufficient and good quality fingerlings, to carry out daily management skills, and be capable of evaluating the growth and the quantity of stock in a timely way.

Growout aquaculture

The growout phase of aquaculture activities could include ponds, reservoirs and tanks, depending on availability of water resources and farmers' interests.

The following are key areas:

- Species selection: this should be determined according to local climate and resource conditions, and the selected species should have growth advantages, disease resistance, good market prospects, etc.
- Formulation of a production plan: this should include the operational inputs for production, the production cycle and an annual market supply plan of aquatic products.
- Choice of advanced aquaculture techniques: professional recommendation and guidance should be sought regarding stocking times, stocking size, stocking

density, harvest scheme and supply to market. The feeding strategy should be refined, oxygenation equipment provided, and the stability of the pond ecosystem maintained through sediment and water quality improvement.

- Set-up of operational standards/procedures: the operational and quality standards should be defined and followed in order to satisfy safety and inspection, according to market requirements. It is necessary to track and monitor aquaculture production, and provide timely technical guidance on water quality control, feeding and disease prevention and control under weather changes.
- Improved farm management: the keeping of records and documents, including daily records of farm activities, financial statements, construction of infrastructure, etc. should be maintained. It is necessary to track and analyze the growth of fish and water quality for each production season and implement a ledger system for pond management, to ensure the traceability and quality assurance of the whole process of aquaculture production.

The functions of technical services

The functions of technical services of the aquapark mainly include the procurement of inputs, such as feed, seed and veterinary medicines, the value-added processing and marketing of aquatic products, and other technical services.

Aquaculture input services

A professional purchasing team or coordination group should be set up to purchase and distribute quality-guaranteed seed and feed for the members of the aquapark. The hatchery and feed-mill established in the aquapark are always a priority supplier for seed and feed. When an outsourced seed and feed supply is required, a collective procurement and negotiation process are encouraged. The use of farm-made feed should strictly abide by requirements and standards published by the competent authority at the aquapark level. Veterinary medicines should be used and also uniformly purchased and distributed by the members of the aquapark management team, and their usage in each growout pond should be subject to the unified quality supervision of the aquapark. In addition, seed and feed must be inspected, quarantined and disinfected before stocking, to ensure biosecurity safe to exogenous pathogens.

Processing facilities

In order to establish the whole value chain, processing facilities are required to support the value adding process. Using the farmed species in the aquapark as raw materials for processing, forms of processed products should be determined by species and target markets, and corresponding standards of processing should be adhered to. Using adapted technology, standardized workshops and processing lines should be updated, and the capacity of processing plants and the quality standards of processed products should similarly be updated accordingly. Based on the technology and investment, deep processing should be encouraged to achieve zero waste; surimi, fish fillets, dried salted products, smoked products, and seasoning products could be developed to maximize added value to processed products.

Marketing services

To support the small-scale farmers, marketing services are required in the aquapark. Unified branding and collective marketing could provide valuable support in enhancing the negotiating power of small-scale farmers. The coordination could be carried out by a trade company for aquatic products, or reliable leading enterprises in the park. Long-term supply and sales contracts of aquatic products could be introduced with a minimum guaranteed price and amount. Harvested aquatic animal products could also be collected by the processing enterprises in and out of the aquapark.

Extended/associated services

The extended/associated services of the aquapark mainly include the implementation of quality standards, irrigation and effluent treatment, provision of operational funds, technical support, branding and market promotion, etc.

Implementation of quality standards

The aquapark should establish and implement relevant standards associated with aquaculture, conduct strict supervision of the compliance of activities with standards and comprehensively improve its quality control capacity.

According to national, provincial or local standards, it is required to formulate technical regulations for standardized aquaculture and modifications, actively promote standardized aquaculture operations and carry out a strict quality management scheme, including processing, packaging, storage, transportation and sales of aquatic products. The certification scheme should cover relevant environmental, ecological and safety standards, as well as diseases and quarantine standards.

As a cluster of aquaculture practices, all production entities in the aquapark should be instructed and trained to follow the same quality standards and gradually improve the safety management system, input procurement, and establish the aquatic animal disease prevention and monitoring system.

Record keeping and the establishment of a traceability system are also important, and should cover the whole value chain, from input supply (seed and feed) to post-harvest and marketing. A quality management certification system should be actively promoted, when applicable, and the adoption of international certification for export products and enterprises encouraged, so as to leverage the quality management level of aquaculture.

Comprehensive assessments of compliance of standards should be regularly conducted, as well as ecological environment indicators. The use of aquatic veterinary medicines should also be monitored, to avoid any violation of regulations. An aquaculture disease prevention and control laboratory in the aquapark is also required, in order to provide timely and convenient technical and testing services to farmers. In addition, a remote expert diagnosis system may be established, if there is available connection and expertise.

Irrigation and effluent treatment systems

A comprehensive water inlet and drainage system with separated water intake and drainage canals should be built. Regular monitor facilities for hatcheries, growout ponds, cages and others, are required to strictly follow the water quality standards and exchanges water efficiently. If recirculating aquaculture systems are installed, regular maintenance of water supply and drainage pipes is required.

For environment friendly aquaculture practices, the aquapark is required to have around 15 percent (8–20 percent) of the total aquaculture area for water purification facilities. The common approach is to establish an ecological water purification system: comprised of an ecological ditch system - constructed wetland (substrate) - purification pond - back to the aquaculture pond. The purification segment should consist of a sedimentation area, aeration area, aquatic plants, etc. The purification area and methods have to be determined by farmed species, intensity, models and systems, in order to maximize the water utilization and minimize discharge.

Supporting financial arrangements

The aquapark is encouraged to establish a diversified investment mechanism. It is proposed to use the government policy and investment, as well as private investment. Bank loans and financing guarantees should be facilitated for the farmers in the aquapark.

Government policies and support measures are essential for promoting investment in the park, especially for introducing enterprises to the aquapark, including equity investment, incentives, subsidies, interest subsidies, bonus, tax reduction and exemption, development projects, etc.

Rural financial services are critical for small-scale farmers, as the inclusive financial assistance provided by rural banks and credits could help farmers in the application of loans. These services include enterprise guarantee, aquaculture development funds and microfinance, available through multiple channels.

The public–private partnership (PPP) model, which is a combination of government guidance and attracting private sector investment to the aquapark, should be developed. Available government financial funds, through the business partnership or private sector could actively join the aquapark and benefit from technical guidance, training, favourable policies to engage farmers, technology transfer and service and management, etc. A docking mechanism of social capital investment and financing cooperation, encouraging credit and insurance institutions to intensify the innovation of financial products and services, should be established.

Technical support

The capacity of aquaculture production and management, and also the quality of labour, could be improved through technical training and guidance for farmers in the park, thus improving production efficiency. It should cover the following aspects:

- Training of farmers: training for farmers in the park should be conducted, to acquire knowledge of aquaculture, including hatchery, seed nursery, the growout of aquatic animals, input and farm management, effluent control, disease prevention and control, as well as business operation models.
- Technical support from partners: partnerships with aquaculture-related universities, research institutes and other technical units should be established, to provide technical capacity building in the aquapark. Aquaculture experts and scholars and local technical experts should be invited to train and guide farmers on disease prevention and control, water quality improvement, and the adoption of new technologies, according to production cycle and on demand.
- Extended technical services by aquafeed companies: feed enterprises should provide technical services to client farmers, enabling improvements in farm management, and on-site technical and professional guidance for best aquaculture practices.
- 24 hours technical services: lead farmers and technical personnel in the aquapark should be selected to provide immediate technical support when there is request on the site, which could help farmers solve problems and issues encountered in aquaculture production in a timely manner.

Branding and marketing services

A brand strategy should be established for the quality development of the aquapark and should include publicity, standards, trademark and packaging. The aquapark is encouraged to build its own and unique brand of aquatic products (Liu, 2020). It should cover the following aspects:

- Aquapark trademark: a creative and unique trademark should represent aquatic products produced in the aquapark, and could be used in various scenarios, such as publicity, product promotion, expositions, festivals, thus enabling traceability in the production chain and packaging design.
- Quality assurance: a famous brand/trademark represents quality products and a unique origin, and obtaining a local, national and international certification is suggested to establish a high-quality assurance mechanism, and further enhance the publicity and trust of consumers and markets.

- Brand promotion: it is necessary to participate in expositions, trade fairs, television and radio shows, cultural exchange, etc., and cooperate with large catering enterprises and commercial companies for aquatic products, to jointly explore the markets and attract consumers, in order to improve the diversity of products and quality production in the aquapark.

5.3 TECHNICAL CAPACITY AND RISK MANAGEMENT

During the implementation of the aquaculture parks and operational production and management, the technical capacity on best practices should be regularly updated. First, the organization of farmers and production arrangements and efficiency of the whole value chain of aquaculture production, processing, and marketing should be improved. Second, aquaculture standards and related quality management practices should be updated, especially regarding aquaculture biosecurity, the application of veterinary medicines, disease quarantine and risk management mechanisms. Third, there should be continued training on the adoption of new aquaculture technologies, new models and innovations, aquatic disease diagnostics, disease prevention and control, the responsible use of aquafeed, water quality control, digitalization and animal health products, etc. Fourth, exchange activities on knowledge sharing and good practices should be strengthened, including amongst the management team, representatives of leading industries, farmers, consumers and other stakeholders, through field visits, technical training, exposure to new technologies and cultural festival, brand promotion, and other activities. Fifth, the quality management and certification scheme and standards should be updated, and the latest quality management system and certification requirements implemented, to ensure the compliance with the latest requirements (Long, 2018).

The aquapark should also establish a corresponding risk management mechanism, which is an important means to mitigate and adapt aquaculture production risks, protect enterprises and farmers' lives and property. It is encouraged to introduce a commercial insurance scheme in the aquapark, with coverage of life, medical and property. There also a need to set up risk mitigation facilities, such as life jackets, a fire station, medical clinic and other common items. Besides frequent training, increased awareness and knowledge sharing on risk management could help to build the capacity on risk mitigation and adaptation. It is also encouraged that the stakeholders, including the medical and pension programme, if applicable, participate in the national social security program, to ensure the basic livelihood of members, relieve the pressure caused by natural disasters and pandemics, and effectively help them resume production as soon as possible (Feng and Zhao, 2020).

5.4 IMPACT EVALUATION OF THE AQUAPARK

A regular impact evaluation is required to be conducted in order to guide the sustainable development of the aquapark. Usually, the evaluation includes the impact of economic, social and environmental aspects (Ye, 2016).

5.4.1 Economic benefits

Economic benefits refer to the input-output ratio of aquaculture production and management activities and its associated activities. Economic benefit indicators mainly include total production costs, annual output value, annual profit, income growth, benefit-cost ratio and net profit margin, etc. Table 5.1 shows some common detailed indicators for economic benefits.

5.4.2 Social benefits

The social benefit indicators mainly analyze contribution to the local community and associated farmers and include the livelihood improvement, employment growth rate,

TABLE 5.1
Calculation of common detailed indicators of economic benefits

	Description
Total production cost	Sum of operational cost (seed, feed, energy, labour, transportation, maintenance and repairs) + depreciation of fixed cost + taxes + interest
Annual output value	yield × price of species 1 + yield × price of species 2 + yield × price of species…
Annual profit	Annual output value – total production cost
Income growth	(Income generated by participating aquapark – income before)/income before
Benefit-cost ratio	Annual profit/total production cost × 100 (benefit cost ration (BCR) greater than 1.0, an aquapark is expected to deliver a positive net present value)
Net profit margin	Revenue – the cost of goods sold – operating and other expenses – interests – taxes/Revenue × 100

training and education, proportional gender growth rate, proportional youth growth rate and rate of malnutrition, etc. Table 5.2 shows some common detailed indicators for social benefits.

TABLE 5.2
Calculation of common detailed indicators of social benefits

Social benefits indicators	Calculation
Livelihood improvement	Engel's Coefficient (amount spent on food / amount spent on total living consumption), capacity to work and adapt, secure shelter and building
Employment growth rate	(number of aquapark employees at end-number of aquapark employees at start) / number of aquapark employees at start
Training and education	Growth in the number of people attending professional training [(number of training participants – number of training participants before) / number of training participants before]
Proportional gender growth rate	(Number of women participants – number of women participants before) / number of women participants before
Proportional youth growth rate	(Number of youth participants – number of youth participants before)/ number of youth participants before
Rate of malnutrition	Weight, height, body mass index (BMI)

5.4.3 Environmental benefits

The environmental impact assessment of aquaculture in the aquapark mainly includes biodiversity, water quality, discharge treatment, waste management, use of clean energy, disease occurrence, etc. (Wu, 2020). Table 5.3 summarizes some common indicators of environmental benefits.

TABLE 5.3
Calculation of common indicators of environmental benefits

Indicators of environmental benefits	Calculation
Biodiversity	Species richness (number of different species present in a specific area), concentration ratio (proportion of dominant species)
Water quality	Percentage of achievement of water quality standards (see Table 4.2)
Discharge treatment	Percentage of discharge treatment
Waste management	Pond area with waste management
Use of clean energy	Clean energy generated/energy consumed
Disease occurrence	Frequency of disease

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PART II
Successful aquapark case studies

6. Chinese largemouth catfish (*Silurus meridionalis*) Aquaculture Industrial Park in Guangxi

The Guangxi largemouth catfish (*Silurus meridionalis*) Aquaculture Industrial Park is located in Guangxi Zhuang Autonomous Region, China. This park integrates an aquaculture hatchery and growout, feed production, fish processing, marketing, restaurants, smart fishery equipment, trade, etc. The aquapark covers fish farms in several cities, including Yulin, Nanning, Baise, Beihai, and Guigang, etc. The largemouth catfish (*S. meridionalis*) is the main species cultivated in the park, and includes polyculture with Chinese carps (*Mylopharyngodon piceus, Ctenopharyngodon idella, H. molitrix,* and *H. nobilis*). There are also other new, introduced species, such as the channel catfish (*Ictalurus punctatus*) and the largemouth bass (*Micropterus salmoides*).

In the last ten years, the aquapark has actively engaged in supporting small-scale farmers for "precise poverty alleviation", which is a national programme for poverty alleviation. The aquapark was led by the Xinjian Group and followed the organizational model of "enterprises + cooperatives + farmers". Xinjian Group is an "agricultural industrialization leading enterprise" in Guangxi and includes an aquaculture hatchery, growout and feed production. The aquapark has taken advantage of integrated management, technological innovation and upgrading, branding of Xinjian aquatic products, and unified marketing.

6.1 DEVELOPMENT BACKGROUND

6.1.1 Main challenges and constraints

Before 2010, the development of the Chinese largemouth catfish (*S. meridionalis*) industry in Guangxi was in its infancy, and there were many problems that constrained its development, such as a lack of professional organization, an incomplete industrial structure, a lack of local input supply and unavailability of aquaculture-related technological expertise (Guo *et al*., 2009).

Compared with capture fisheries, aquaculture was recognized as a sector with limited economic benefits with a long culture period with high risks. Although there is a strong market in large cities for Chinese largemouth catfish, its culture was not yet popular in China, and the supply of seed and feed were nonexistent in the area.

Lack of professional organization

Before 2010, the aquaculture sector in Guangxi was comprised of small-scale production and a decentralized operation, within a state of primitive, small-scale peasant economy (Figure 6.1). Although many farmers were carrying out aquaculture activities in the province, no typical farmed species with (distinct) geographical characteristics and advantages was raised, and there was a lack of professional organization in aquaculture sector.

Incomplete industrial chain structure

In general, the industrial chain structure was poor in Guangxi, in particular lacking a quality seed and feed supply. Similarly, the Chinese largemouth catfish aquaculture

FIGURE 6.1
Traditional fishing and farming practices in Guangxi

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industry was deficient, with an incomplete industrial structure and alack of industrial supporting facilities, such as hatcheries and feed factories. In addition, there was a non-existent value chain for aquaculture, i.e. the primary, secondary and tertiary industries (Figure 6.2). The aquaculture sector was an extensive development and was dominated by the traditional farming model, relying on natural food resources, and there was a strong demand for supporting industries, such as the hatchery and feed-mill, processing, and marketing facilities, etc.

FIGURE 6.2
Traditional market place for aquatic products in Guangxi

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Poor investment in infrastructure

Before 2010, the investment for aquaculture-related supporting infrastructure in Guangxi was very low. There were poor traffic conditions in the mountainous areas, and great difficulties in the transportation and marketing of aquaculture products (Ya, 2012). Due to a lack of investment in aquaculture sector, there was no production of fish fry and feed companies in the area. There was strong request to improve the infrastructure of roads, electricity and a local supply capacity of fish seed and feed, in order to facilitate the engagement of small-scale farmers within the aquaculture sector for a better livelihood.

6.1.2 Advantages and opportunities for industrial development

During the "12th Five-Year Plan", China's fishery policy was guided to develop aquaculture for providing aquatic food supplies, recognizing the decline/stagnation of capture fisheries (The Eleventh People's Congress of the Guangxi Zhuang Autonomous Region, 2011). The local government of the Guangxi Zhuang Autonomous Region has planned to establish and enhance the aquaculture of competent species, with potential sales exceeding USD 153.8 million (CNY 1 billion) and the associated businesses chain of USD 1.54 billion (CNY 10 billion).

Under this policy support, the Chinese largemouth catfish aquaculture industrial park was planned and developed with apilot in Fumian District of Yulin City, and then gradually expanded to Nanning, Qinzhou, Guigang, Baise, Wuzhou, Hezhou, and Beihai. At present, as Figure 6.3 shows, the park has six pond-based aquaculture bases, 25 reservoirs aquaculture bases and one demonstration farm (the Guishui Yuxiang Demonstration Area).

FIGURE 6.3
Distribution of ponds and reservoirs aquaculture bases in Guangxi (under the management of the aquapark)

Source: Prepared by Xinjian Group.

Location and resource advantages

The Chinese largemouth catfish aquaculture aquapark is located on the southeast edge of the Yunnan-Guizhou Plateau, adjacent to Viet Nam and Beibu Gulf in the south, and close to Southeast Asia; there are easy connections to Guangdong, Guizhou, Sichuan, Yunnan, Hong Kong, and Macao via railway, highway and airway. Guangxi is also a free trade centre between China and Association of Southeast Asian Nations (ASEAN). Guangxi has geographical advantages and the natural resources for aquaculture development.

With the support of the Ministry of Agriculture and Rural Affairs (MARA), it has favourable conditions for a free trade zone around the Beibu Gulf. Under the framework of World Trade Organization (WTO) rules, the implementation of the "Go Abroad" strategy is conducive to exporting aquatic products from the park to overseas markets such as Europe and the United States of America.

The park has a variety of land types, plenty of water resources, a wide range of commonly farmed species with high quality and market price, and highly trained/skilled farmers. The details are shown as follows:

- Land resources: the terrain of the region is generally high in the northwest and low in the southeast, with an inclination from northwest to southeast. Surrounded by mountains and plateaus, the region has generally a mountainous and hilly basin landscape, with a continuous range of huge mountains, and alternating embankments and valleys (Figure 6.4). There is a diversity of land types in the region with complex topography and geomorphology, and the difference in sunlight hours, heat, and water distribution determine the diversity of aquaculture

FIGURE 6.4
A picture showing the topography and natural environment of the aquapark in Guagnxi

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practices. This determines the rational layout of the park and the development of diversified operations, so as to make the best use of the land and rationally develop and utilize land resources.

- Water resources: the total water area in the aquapark is 473 000 ha, mainly comprised of rivers, reservoirs, lakes and ponds, which accounts for about 2 percent of the total area of the whole region. There are 937 rivers with an individual rainwater collection area of over 5 000 ha, 4 439 small, medium and large reservoirs and more than 74 000 ponds, which provide good and available water surface areas for aquaculture, agricultural irrigation, hydropower generation and water transportation in the park.
- Fish species: the aquapark has a variety of freshwater fishes, such as grass carp (*C. idella*), common carp (*Cyprinus carpio*), silver carp (*H. molitrix*), bighead carp (*H. nobilis*) and crucian carp (*Carassius auratus*) and introduced species, such as tilapia (*Oreochromis niloticus*), channel catfish (*I. punctatus*), largemouth bass (*M. salmoides*), yellow catfish (*Pelteobagrus fulvidraco*), etc. The natural environment of the aquapark is favourable for largemouth catfish aquaculture, which enables the farmer to stock and harvest two crops per year. Moreover, the largemouth catfish lives at temperature range from 0–38 °C, feeding on a wide range of food, has a strong disease resistance, low stress and high market demand.
- Human resources: there is a good availability of labour; aquaculture is a new sector and is attractive to local well-educated farmers, who are interested in aquaculture. Farmers in the aquaculture sector have a relatively high income, stable life, good nutritional status, sound health care and social security. In addition, the training in aquaculture knowledge and skills has helped the local farmers to work in the sector too.

Climate-related advantages

The Largemouth Catfish Aquatic Park ranges from 104°28' – 112°04' east longitude and 20°54' – 26°24' north latitude, with the Tropic of Cancer traversing through the aquapark (Guangxi Zhuang Autonomous Region People's Government, 2020.) It is located in the middle and south subtropical monsoon climate zone, with a warm climate, high precipitation and sufficient sunshine. The annual average temperature is between 16.5–23.1 °C. Horizontally distributed isotherms appear almost parallel to the latitudes, and the temperature decreases from south to north and from valley plain to hilly and mountainous areas. The annual average temperature is above 20 °C in about 65 percent of the whole region, which is suitable for two stockings and harvesting of farmed species per year.

The aquapark is located in one of the most precipitous regions in China, with annual precipitation ranging from 1 080–2 760 mm in most areas, which is beneficial to maintaining good water quality in the aquaculture ponds. In addition, sunshine hours in all areas of the aquapark is moderate, with fewer in the winter and more in the summer; annual sunshine hours are 1 169–2 219, which is conducive to maintaining optimal levels of photosynthesis and improved dissolved oxygen levels in the water.

Policy

There are several favoured policies for aquaculture development in the region. The *Law of the People's Republic of China on Professional Farmers Cooperatives* (Standing Committee of the Tenth National People's Congress of the People's Republic of China, 2006) has ensured voluntary entry into the cooperative, freedom of withdrawal from the cooperative, democratic management and self-service, and fully respects the demand and choices of farmers. The local government and authorities have increased their support for fishery economic cooperation organizations and have implemented various preferential policies on fiscal taxation, finance, science and technology innovations, etc.

The local government has also vigorously promoted the business model of "fishery economic cooperation organization + farmers" for the aquapark organization, and actively encourages other industrialized business partners to invest in the aquapark development.

There are policies encouraging the organization of training of individual farmers to engage in the aquapark operations and develop technological advantages, so that the farmers can follow the unified standards of aquaculture practices, procurement of inputs and market services and product branding, in order to enhance market competence and risk management.

6.2 AQUAPARK PLANNING AND CONSTRUCTION

6.2.1 Scientific planning and species selection

Organizational form and implementation plan

In 2008, the largemouth catfish aquaculture farm was built with an area of 3.3 ha in Shuiling Village, Fumian Town, Yulin City, Guangxi. Based on consultation, this farm was recommended as the pilot farm for a largemouth catfish aquapark, with the technical capacity for extension and training of farmers. In 2010, the aquaculture area of the park was expanded to 67 ha in Fumian Town, and the park management team was set up to undertake corporate operational management. In 2011, Xinjian Aquaculture Co., Ltd. was established as the leading company in the aquapark, and the aquaculture area was further expanded to 200 ha.

The aquapark adopted the development model of "enterprise + cooperative + farmers", and enhanced the organizational form, industrial chain structure and infrastructure construction. As the most important public function units of the aquapark, the hatchery and feed-mill were operated independently and provided support to all farmers in the aquapark, and the production of largemouth catfish adopted the united technical standard for procurement, as well as marketing. Through decades of development, largemouth catfish cultivation has become a distinctive industry in Yulin City, and the Xinjian Group has gradually become the largest aquaculture company in Guangxi.

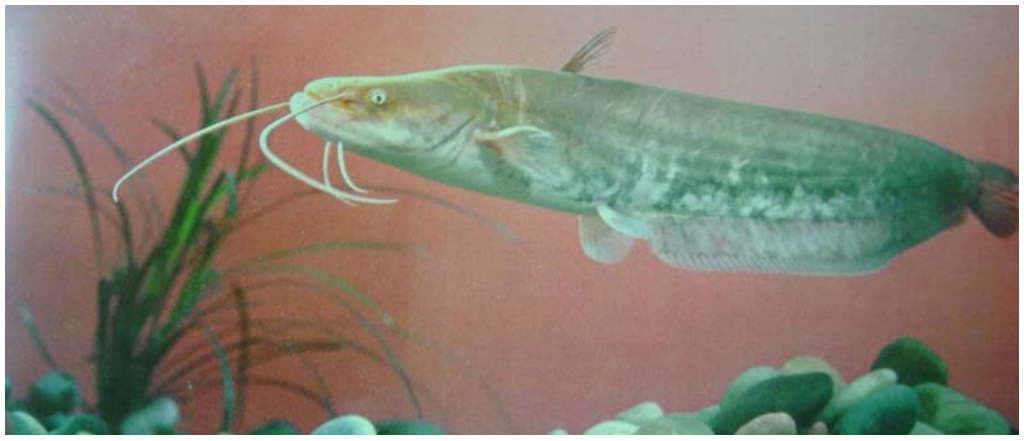
Selection of aquaculture species

The species selection mainly took into consideration the following: growth and productivity, market price, pond rent and production costs and technological

knowledge. After a comprehensive evaluation, based on the technical difficulty, cost and production cycle, finally the largemouth catfish was selected as the species for the aquaculture park.

The largemouth catfish (Figure 6.5), also known as South largemouth catfish (*S. meridionalis*), has the following characteristics: (i) fast growth with a short production cycle that lasts only 5–6 months; (ii) a strong ability to adapt to low temperatures with a survival temperature range of 0–38 °C; (iii) ease of feeding; after weaning from live food to formulated pellet feed, the fish still obtains satisfactory growth; (iv) good resistance to disease and stress with few diseases reported in the cultivation process; and (v) high consumption rate, market demand and economic benefits.

FIGURE 6.5
Largemouth catfish (*Silurus meridionalis*)



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6.2.2 Aquapark construction and implementation

Since 2008, the largemouth catfish aquaculture park has developed from a small-scale pilot farm into a model of "enterprise + cooperative + farmer". It includes the leading company, Xinjian Aquaculture Co., Ltd., with the involvement of professional cooperatives and farmers, and has greatly benefited the local small-scale farmers and sustainable economic development and livelihoods (Figure 6.6).

FIGURE 6.6
Harvesting largemouth catfish by local small-scale farmers in Guangxi

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The Xinjian Group has been the supporting the Largemouth Catfish Aquaculture Park and works with the cooperatives through contract farming. Under this business model, the cooperatives organize farmers to carry out aquaculture production, supervise technical guidance and coordinate input supply for farmers. The Group is also responsible for product marketing, by purchasing harvest products and providing market information, and ensuring that the Group is fully engaged in supplying fish fingerlings and technical service in growout farming, processing and sales. The Group applies strict aquaculture standards by united management. Under the contract aquaculture model, the Group collects harvested fish at a unified, insured price, when harvested fish meet the specified size and standards. In addition, the Xinjian Group regularly send professional technicians to supervise the aquaculture practices and assist cooperatives and farmers in solving problems encountered in the culturing process.

Ecological aquaculture pond model

The Aquapark has implemented national standards for ecological aquaculture, enhancing the effluent treatment from aquaculture ponds and reservoir cages. For cages in reservoir, the number of cages and total water surface area occupied by cages was limited to enable effluents to be purified within the natural carrying capacity of the ecosystem. Aquaculture ponds were constructed with effluent purifying areas, i.e. a water circulation system, called "three ponds and two dams" (which comprise of a sedimentation pond, an aeration pond an ecological purification pond and two filter dams located in between these three ponds) (Liu *et al.*, 2021), and treated water can be recycled within the system or discharged under the national treated water standard (Figure 6.7). By constructing effluent treatment and recirculating aquaculture systems (Figure 6.8), it is not only effectively improving the aquaculture water quality and growth of aquatic products, but also reducing and avoiding the occurrence of diseases and satisfies the discharge standard of wastewater from aquaculture. With these good practices, the aquapark was welcomed and requested to promote green and healthy aquaculture to other nearby towns, which greatly promoted healthy and sustainable aquaculture development.

FIGURE 6.7
Aquaculture effluent/wastewater treatment facilities in the aquapark in Guangxi

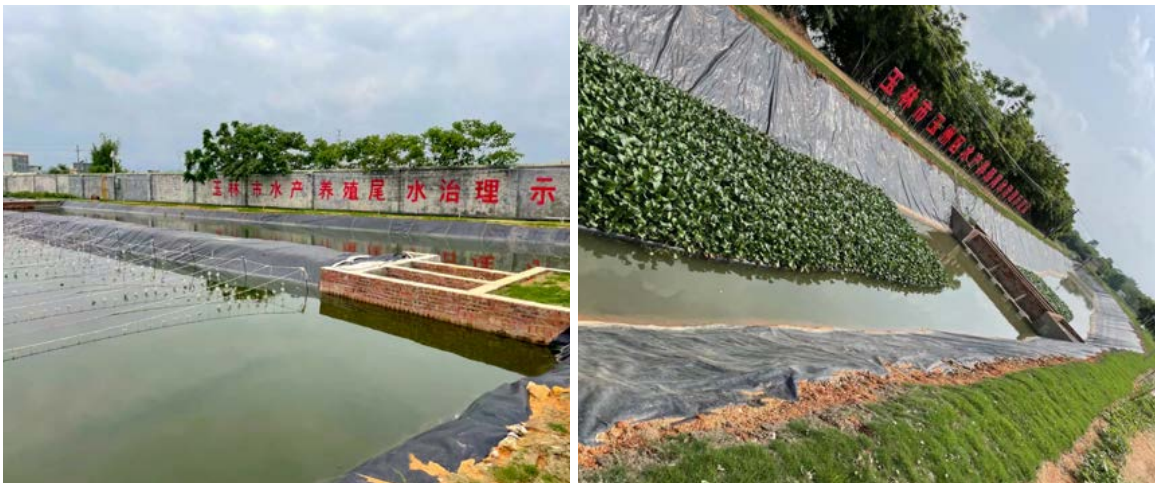

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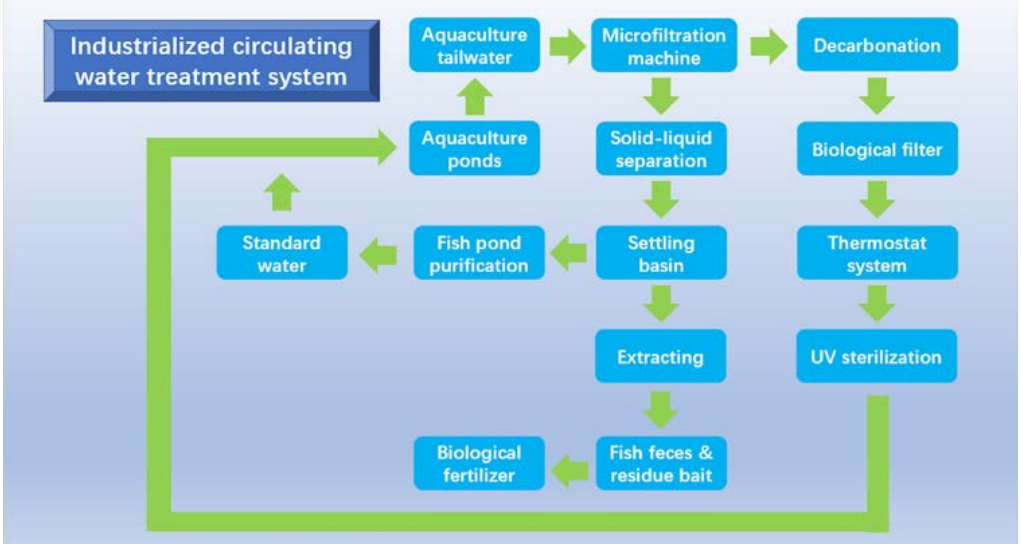
FIGURE 6.8
Industrial recirculating water treatment system in the aquapark



Source: Prepared by Shulun Jiang.

Hatchery and seed production

Largemouth catfish breeding

Ensuring a good quality seed supply is always the biggest challenge for aquaculture development. In 2011, the group decided to improve the hatchery and ensure a plentiful supply of largemouth catfish seed, in order to meet the quality seed demand, to support, in particular, the small-scale aquaculture farmers (Figure 6.9). There were three actions taken for the hatchery construction; first was to introduce an expert from Guangzhou, who is renowned in largemouth catfish breeding and who helped solve technical problems, such as the induced breeding and nursery techniques. Second was to improve the broodstock by purchasing 400 parent largemouth catfish to ensure high-quality seed production. Third was to introduce a water recirculating system for the fish hatchery, which greatly improved the success of induced breeding and hatching rates.

Following the technological improvements of the hatchery in the aquapark, two unique technical advantages were achieved: (1) the hatchery could start the breeding season one month earlier, hence earlier stocking enabled early marketing, which was welcomed by the farmers; and (2) the hatchery developed the slim strain; comparing the two types of fingerlings, i.e. the slim and the flat, the slim type is more active in feeding and grows faster.

FIGURE 6.9
Propagation of largemouth catfish fry in the aquapark

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Hatchery upgrading

With the technological innovations and high demand for quality largemouth catfish seed supply, the aquapark has gradually renovated the hatchery with the financial support from local government. Since 2011, the aquapark has progressively introduced and built an industrialized hatchery with a water recirculating system covering 1 200 m^2 and a national largemouth

catfish germplasm research laboratory of 160 m^2. The fry hatching workshop (Figure 6.10), including a water reservoir, a spawning pond, an egg-collecting pond, a hatching tank and a nursery pond, etc., has greatly improved the production efficiency, ensuring seed quality and cost-efficiency. The technological innovations have greatly improved the seed production capacity of largemouth catfish, and reduced the aquaculture cost of the industrial seed supply chain.

FIGURE 6.10
Construction of hatcheries with the water recirculating system in the aquapark

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Grow out fish culture

The aquapark model is designed to adapt to local conditions and market demand. Until now, there have been many types of aquaculture practiced in the aquapark, such as earthen pond aquaculture, ecological aquaculture in reservoirs, indoor industrialized aquaculture etc.

Earthen pond aquaculture

The earthen pond is a popular traditional aquaculture method (Figure 6.11), with the advantages of a high stocking density capacity, high yield, easy management and easy harvesting, but also some disadvantages, such as high rent and electricity costs, being labour intensive and requiring management skills. Therefore, it was recommended that fishes with regional characteristics and higher economic benefits were cultivated, and, at present, the major species grown in pond aquaculture are channel catfish and yellow catfish. The average yield of earthen ponds was around 30 000–37 500 kg/ha, which has good cost-benefit ratio.

FIGURE 6.11
Pond aquaculture in the aquapark

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Ecological aquaculture in reservoirs

The aquapark has developed ecological aquaculture in reservoirs (Figure 6.12) since 2016. Reservoir aquaculture has a culturing area exceeded 4 000 ha, with annual sales exceeding USD 15.4 million (CNY 100 million). Reservoir aquaculture has been continuously expanded in Yulin, Nanning, Qinzhou, Guigang, Baise, Wuzhou, Hezhou and Beihai since 2016. Up to now, the total area of reservoir ecological aquaculture has reached over 66 667 million ha and the cage culture area is about 17 333 ha.

FIGURE 6.12
Ecological aquaculture in reservoir in the aquapark

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Indoor industrialized aquaculture

The indoor industrialized aquaculture model (Figure 6.13) adopts highly mechanized, electrified and automatic computer-controlled technologies and culturing equipment, so that the cultured species can grow under optimal conditions (water temperature, water quality, dissolved oxygen, as well as light and feeding conditions). The advantages of this model include a high production of cultured aquatic products per unit water body, a high utilization rate of water and reduced feed conversion ratio (FCR) and no pollution or odour of aquatic products. This model is applicable to areas with convenient access to transportation, low land use cost, skilled human resources and low construction costs for aquapark facilities.

Industrialized feed supply

Quality aquafeed supply is essential for the success of aquaculture operations. Considering the disadvantage of common feed purchased from the market, the aquapark started to independently develop feed for of the largemouth catfish in 2011 (Figure 6.14). After more than two years of research and culturing experiments, the feed achieved good results and was ready to apply in large-scale production. In November 2013, the Xinjian Feed Company, with a total investment of USD 23 million (CNY 150 million), was established in Yulin City, which covers an area of 39 947.35 m^2 and a workshop area of 23 587 m^2. It is equipped with two domestically advanced, high-standard modern feed-mill production lines, with an annual production capacity of 200 000 tonnes of formulated feed (Figure 6.14). There are around 60 staff working in

FIGURE 6.13
Indoor industrialized aquaculture in the aquapark

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the feed company at present. The Xinjian Feed Company supply feed to all farmers in the aquapark. Based on the advanced production equipment and process technology, it has adopted an automatic production process, intelligent formulation, automatic measurement and zero waste discharge. As showed in Figure 6.15, Xinjian Feed Company obtained a quality management system certification (ISO9001) in 2021.

FIGURE 6.14
Various type of aquafeed produced in the aquapark

©Xinjian

FIGURE 6.15
Certificate of quality management system (ISO9001) in the aquapark

©Xinjian

Whole value chain quality system and smart platform

A quality system was established to monitor the aquaculture production industry chain in the aquapark, in order to ensure high quality and efficiency. A fishery big data platform was built to systematically control the production quality, integrating sales management, user management, product traceability, production base management, etc., forming a standardized and information-based quality management system, which closely connects enterprises, cooperatives, farmers and markets.

Based on the existing quality system of Xinjian Group, an online platform, through a dedicated mobile application was provided for the aquapark. When cooperatives and farmers encounter problems, they are able to consult and ask for help online and receive a reply from the Xinjian Group's professional technicians and other farmers. The platform also invited experts from research institutes, in cooperation with the aquapark, for technical assistance. Meanwhile, the data records of the platform help in monitoring the culturing process of cooperatives and farmers, and providing technical support to the production process, such as feeding, harvesting and application of medicine, etc.

In addition, the Xinjian Group's technicians use this platform for timely notification from farmers on technical actions, according to the season, weather and aquaculture stages through a mobile application, giving early warning to risks, diseases prevention, weather changes, etc., as well as input of record data. The smart platform development has greatly improved the digitalization of aquaculture management.

Technical and financing services

Under the business model of "enterprise + cooperatives + farmers", the aquapark frequently organizes aquaculture knowledge exchanges and training on technical and aquaculture management to employees, cooperatives and farmers, according to actual production needs. The aquapark has extended invitations to renowned professors specialized in aquaculture, aquaculture senior engineers and fishpond aquaculture management experts, to train, on demand, in topics in aquaculture innovation, fish disease prevention, management of reservoir cages and fishpond aquaculture. It was reported that more than 1 000 people have been trained since 2013. Meanwhile, the leading enterprise also encourages modern enterprise management and exchanges with other agricultural entrepreneurs in China.

In order to support the small-scale farmers in the aquapark, financing and fund support is crucial. As shown in Box 1, the Company can guarantee the farmers when applying for bank loans. The company also provides required feed and seed to cooperatives and farmers without payment in advance, and offers contracts to collect their harvest and cover the cost of payment.

BOX 1

Shengping largemouth catfish Farming Professional Cooperative (Enterprise + Cooperative + Farmer), Fumian District, Yulin City

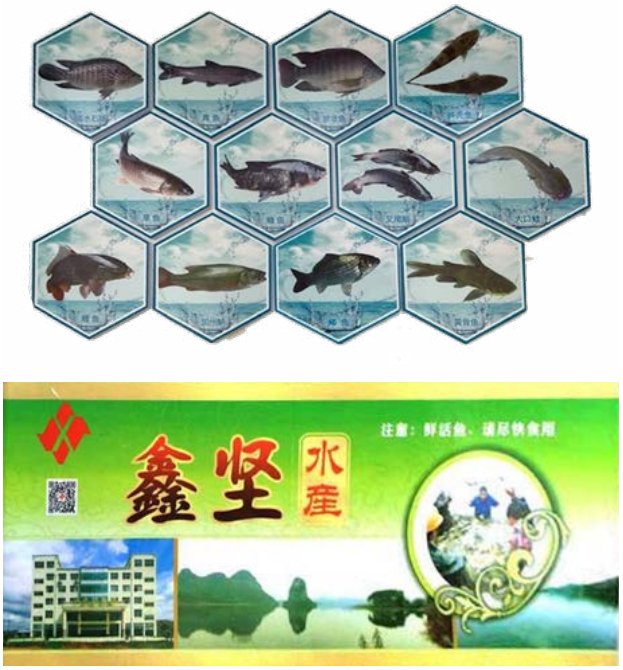
Shengping largemouth catfish Farming Professional Cooperative in Fumian District of Yulin City is located in Liangbiao Village, Fumian Town, Fumian District of Yulin City, and consists of 32 households. In the early stages, the head of the cooperative contracted more than 6.67 ha of fish ponds, but due to lack of skills, shortage of funds and other reasons, the benefits obtained were not ideal. Later, the Xinjian park led the cooperative in the farming and sale of freshwater fish, and assisted it in organizing information exchange, technical training and consulting services. Information exchange is mainly for the technical personnel of the park to analyze and discuss the existing production structure with fishers and employees, and give guidance, as well as listing the personnel composition and work contents to be coordinated from farmer/fish feed technician to field manager, production manager, general manager and then investor. The park's management team and junior employees receive high-quality technical training on the fundamentals of business management and the prospects of industrial development. Farmers and staff also receive training in knowledge and skills, covering areas such as the reservoir, the farmed species, the farming model, the farming equipment and the habits of the fish species, the main sales channels and the market trends for each species. The training also provides instructions on the functions and use of various types of nets, the benefits associated with and precautions related to various farming methods (e.g. cage culture), and some fish production techniques (e.g. fish harvesting practices, operation of automatic feeding machines). In addition, the standard of marketable fish in the park is explained in detail and the importance of production quality and safety is pointed out. The issue that all farms must pay close attention to production quality and safety is raised. For example, illegal drugs shall not be used, the requirements set for "Production Area of Pollution-free Agricultural Product" shall be strictly followed, and the input drugs must comply with national regulations and be traceable, i.e. the drugs shall be recorded to ensure the quality of the marketable fish. Consulting service mainly means that the park regularly sends professional technicians to the site to assist cooperatives and farmers in solving practical problems encountered in the farming process, observing the growth of farmed species and giving technical advice. When the cooperatives and farmers have problems in farming, they can contact park technicians directly by telephone or through internet, so as to get professional guidance and solutions. As a result, the quality and functional/operational capacities of all kinds of employees in the park are improved, and employees have a greater understanding of modern enterprise management, and there is a significant change in their mindset and attitude.

In terms of financial support, the park cooperates with Guilin Bank to provide guarantee services for the farmers through an innovative approach/pattern of supply chain finance to address financial issues faced by farmers. For example, the company can help the cooperative and farmers apply for bank loans, which are paid to the company's account, and the cooperative and farmers can get the required feed and other production materials from the company in advance. After the company buys and sells the aquatic products, the cooperative and farmers can repay the bank loans and production materials with the profits gained. In addition, with the assistance of the project team in the park, the cooperative has received more than USD 143 000 in government subsidies and has been awarded such honours as healthy aquaculture demonstration farm and pollution-free agricultural products certification.

Marketing and branding

The aquapark has the largest supply of cultured fish from the ecological reservoirs in Guangxi, and, in addition to largemouth catfish, it supplies many other species such as channel catfish, grass carp, largemouth bass, yellow catfish, tilapia and bighead carp. In addition, the aquapark not only supplies live fish to market, but also processed fish products, such as fish fillet and prepared fish food products. The products of the aquapark have been sold in many capital cities in China, such as Shanghai, Guangzhou, Chongqing, Guizhou, Sichuan, Yunnan and others, in addition to Guangxi Zhuang Autonomous Region, and processed products are also exported to Europe and the United States of America.

FIGURE 6.16
Aquatic products and processed aquatic food produced in the aquapark



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In 2014, the aquapark, supported by the leading Xinjian Group, registered the brand trademark of "Xinjian" (Figure 6.16), to promote its fully standardized production, and gradually establish a credit of safe aquatic food production in China. Finally, the aquapark has completed the construction of quality production and a traceability system of aquatic products "from pond to table", build the "first brand of reservoir fish in China".

After the brand products are registered, the farmers enjoy a higher market price and increased income. In the following years, the aquapark has acquired other quality inspection certificates (Figure 6.17), such as "Organic product certification", "Certification of environment friendly agricultural product", "Shenzhen standard certification", "Superior Agri-Products from Guangxi". In 2019, the Xinjian Group was listed as the Guangxi famous agricultural brand.

FIGURE 6.17
Various certification and prizes awarded to the aquapark

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6.3 BENEFIT EVALUATION OF PARK OPERATIONS

6.3.1 Economic benefits

The rapid development of the aquaculture park has brought huge economic benefits to the Xinjian Group and farmers. The park's "enterprise + cooperative + farmers" model has driven more than 3 000 farmers to increase their per capita income to more than USD 7 700 (CNY 50,000), and the farmers' pond culture has increased from the original yield of USD 2 310/ha (CNY 15 000/ha) to USD 11 535/ha (CNY 75 000/ha), and the intensive pond culture yield has increased from USD 4 620/ha (CNY 30 000/ha) to USD 34 620/ha (CNY 75 000/ha). The successful farming of largemouth catfish in Fumian Town, Yulin City has gradually promoted the expansion of the aquapark, whilst also driving the continuous expansion of the aquapark's farming areas and the increase of farmed species types. As of 2021, the water surface for ecological farming has expanded to more than 66 667 ha, and farming area for intensive farming has expanded to more than 17 333 ha.

6.3.2 Social benefits

The Park has also provided jobs for 3 200 people living in the nearby villages, boosting their per capita annual income to over USD 1 538 (CNY 10 000). In addition, the rapid growth of the aquapark has also promoted the gradual improvement of the road network system in the region. The power supply meets the production and living needs of local residents, and supporting facilities of the irrigation and drainage system have been installed.

In addition, the park fully mobilizes the motivation of the village collective, the cooperative and other organizations in the region, and provides poor households in the village collective with an opportunity of income from fish farming, firmly implementing poverty alleviation by developing industries. The park has established a reasonable interest connection mechanism, through which it advances money to supply seed/fry, feed, drugs for disease prevention and treatment to farmers in difficulty. It also provides free technical support, and solves all kinds of encountered problems, thus reducing risks for farmers, ensuring benefits and enhancing the farmers' confidence.

Further, the park stimulates rural development, improves the efficiency of integrated development and utilization of land resources, raises farmers' income, improves the image of rural areas, attracts young people returning to their hometowns, and further promotes the construction of new rural areas and harmonious social development. The park has helped more than 800 poor households, through measures such as "capital guarantee plus fixed return on investment", "capital and land shareholding", and "hiring poor households as labour", and has registered households confirmed as poor and created files in a system for them so as to distribute funds to them. Table 6.1 shows some cases of the support provided:

TABLE 6.1
Support cases

Year	Support Cases
2016	Industrial support agreements were signed with 600 poor households in 26 poor villages, including Shangpo Village in Fumian District in Fumian Town, Hehe Village in Chengjun Town, Taian Village in Zhangmu Town and Yongning Village in Xinqiao Town, and USD 1 076 000 (CNY 6 996 000) of dividends have been distributed to poor people through entrusted operation.
2017	According to the signed cooperative aquaculture agreement with the Zheyan Village, Gebu Town, Longlin Various Nationalities (Gezu) Autonomous County, the Xinjian Group was responsible for providing the main aquaculture materials, i.e. seed/fry, animal health-related vaccines, feed, aquaculture planning, technical guidance and sales management. The village collective was responsible for sending designated aquaculture personnel to feed the aquatic animals and maintain the main materials, and the Group provides technical guidance and regular training.

In addition, through employment assistance, the park actively employs migrant workers around the aquaculture base to increase farmers' income, give priority to employment in common aquaculture practices, such as fish pond dredging, fish catching, weeding, loading and unloading feed, etc., increasing the income of poverty-stricken households by USD 4 615–15 385 (CNY 30 000–100 000) per year. Since 2016, the park's public welfare assistance has established a "one-to-one" relationship with poverty-stricken students, and donated a total of USD 23 077 (CNY 150 000) for education. In 2020, USD 23 077 (CNY 150 000) were donated to Fumian District in the fight against the COVID-19 pandemic for prevention and treatment; in the same year, fish fillets worth USD 49 231 (CNY 320 000) were given for 3 200 poverty-stricken households in 16 villages in six towns in Fumian District as charitable gifts. From 2018–2021, the Park carried out charitable activities to poverty-stricken households living around Wanfeng Lake in Longlin County, Baise City, and in Nanyu Village, Beihai City and the money and materials donated were worth USD 20 000 (CNY 130 000). From 2018–2020, student funds and rural revitalization donations worth USD 80 462 (CNY 523 000) were given to Cenxi City.

6.3.3 Ecological benefits

During the establishment of the aquapark, scientific planning and technical support have been deployed to ensure environmentally friendly aquaculture is a top priority in achieving the sustainable development goals (SDGs). First, in the aquaculture park, a complete set of water treatment facilities, such as sedimentation tank, aeration tank, filtration dam and biological purification tank, were installed in pond culture farms, facility-based and indoor factory-based culture systems. The aquaculture effluent discharge was effectively reduced, and recycled to meet standards for discharge, thus realizing the green development of aquaculture. Second, good practices for farmers in the whole area was demanded to promote healthy and sustainable development of aquaculture and develop integrated circular agriculture. In particular, the agriculture farmers in surrounding areas were encouraged to follow the standard of environmentally friendly practices. Third, ecological aquaculture in large water bodies and cage aquaculture in reservoirs and rivers was promoted and good practices of precise feed feeding were adopted to effectively reduce the leftover feed, effectively reducing the nutrients of nitrogen and phosphorus in water during the aquaculture period. On the other hand, the limits of water surface area for aquaculture were strictly implemented, in order to maintain the aquatic ecosystem and protect the ecological environment.

6.4 POTENTIAL ADAPTION AND RECOMMENDATIONS

With the favoured policies for sustainable aquaculture industry development, the Guangxi largemouth catfish aquaculture park used the effective model of "enterprises + bases + farmers". Its development and construction can be seen as a successful example of inland aquaculture, composed of quality seed production and supply, aquafeed production, processing factories, marketing and branding, with strong technical guidance and services.

6.4.1 Carrying out a planning and feasibility study based on local natural resources

Guangxi largemouth catfish aquapark adopted the unique resource advantages of pond, reservoirs and rivers, and developed ecological aquaculture models based on market demand, enjoying also the established brand of fish produced by ecological aquaculture in reservoirs in China. Apart from the largemouth catfish, the aquapark has also developed production of other popular and high-priced fishes, such as channel

catfish, mandarin fish and yellow catfish and this diversity of farmed species increases income. At the same time, a culture model was developed, based on water bodies and cages suited to the size of reservoir and the shapes of river branches, in order to fully utilize the aquatic ecosystem based on the understanding the water bodies and its ecosystem characteristics.

6.4.2 Investment to ensure the supply of quality seed and feed

As a critical component of the modern aquaculture industry, the supply of quality seed and feed is the always the bottleneck, requiring a large capital investment and professional technology support, which most small-scale farmers cannot offer. The aquapark has been encouraged to introduce the Xinjian Group to invest in the hatchery and feedmill through the public–private partnership (PPP), greatly advancing the supply chain in the aquapark, as well as marketing and technical services (Figure 6.18). The quality seed and feed supply has guaranteed the standardized aquaculture production model and benefited the engagement of small-scale farmers in the whole aquapark.

FIGURE 6.18
Complete aquapark fishery industrial chain in the standardized aquaculture production model

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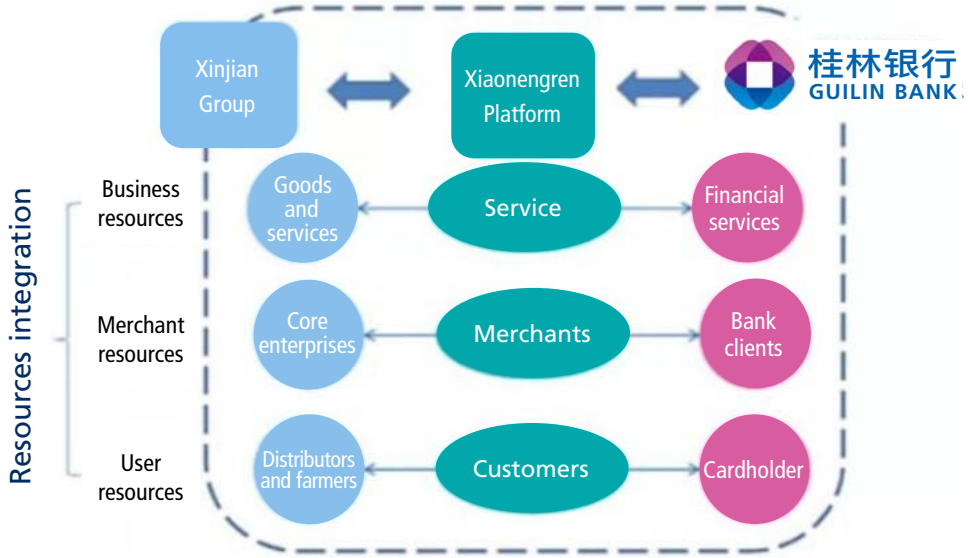
6.4.3 Digitalization of aquaculture and the quality management system

Digitalization in aquaculture has helped greatly to improve the management efficiency and quality management system. The aquapark has built a big data platform for production, transportation, warehousing and sales for aquaculture, which integrates sales management, user management, product traceability, base management, data management, cost management and enabled the realization of precision aquaculture. The feedback from customers, markets and logistics, based on record analysis, has helped to improve the farm practices and whole value chain management.

6.4.4 Access to financial services

Apart from the guarantee loan services supported by the leading company, the model of "enterprise + cooperative + farmer" has further enforced the supply chain finance systems (Figure 6.19). Cooperatives and farmers may contract the lead company for aquaculture production inputs supply, i.e. the fish seed and feed, and cooperatives and farmers payback with harvested aquatic products to enterprises. This model not only ensures the production of the cooperatives and farmers, but also the quality products supply to the market channels and processing units.

FIGURE 6.19
Rural financial services in the mode of "enterprise + cooperative + farmer"



Source: Prepared by Xinjian.

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7. Integrated rice-fish culture in the Hani Terraces, Yunnan

"Rice-fish culture" is seen as an important part of freshwater aquaculture (Cai, Dashu and Jianguo, 1995; Little, Surintaraseree and Innes-Taylor, 1996) and China is recognized as the first country in the world to start farming fish in paddy fields. Rice-fish culture technology is a production model with efficient integration and ecological benefits and its main principle is to make use of the shallow water environment of the paddy field, supplemented with aquatic products while planting rice, so that the water, aquatic weeds, plankton, insects and others in the paddy field can be fully utilized within the food chain. The interaction of aquatic animals and plants could contribute to biological pest control, enhance the soil fertility and improve production.

7.1 DEVELOPMENT BACKGROUND

Honghe County, located in Honghe Hani and Yi Autonomous Prefecture, Yunnan Province, is a national registered impoverished county integrating border areas, ethnic groups, mountainous areas and remote areas. There are Hani, Yi, Dai, Yao and other ethnic minorities living in the county. The ethnic minorities account for 94 percent of the total population of Honghe County, of which Hani accounts for 75 percent. Since the founding of the People's Republic of China, the county government has committed to improving people's livelihood and local residents' living standards. By the end of 2014, there were still more than 90 000 people living in poverty in the county, with a poverty rate of 33.15 percent.

In 2015, the Honghe County Government signed an agreement for technical support in poverty alleviation of the Hani Terrace rice paddy with the Freshwater Fisheries Research Center of Chinese Academy of Fishery Sciences (FFRC-CAFS) and Yunnan Zhonghai Fishery Co., Ltd., a leading enterprise in the freshwater aquaculture industry in Yunnan Province.

After the survey and interviews with local stakeholders, the aquapark of Rice-fish integration was proposed and a model of "leading enterprise + farmers" was initiated.

At the initial stage, 1 598 registered impoverished households (accounting for 22 percent of the total 7 200 population living in poverty) were invited to join the pilot project. The government organized training courses for farmers with technical support from the FFRC-CAFS, which helped the farmers understand the integrated rice-fish system and improve operational skills. The Yunnan Zhonghai Fishery Co., Ltd. invested and established a breeding base for superior loach in Menglong Village, Yisa Town, providing quality loach fingerlings to farmers. With both technical support and loach fingerling supply, the rice-loach culture in terraces was extended to an area of about 750 ha, which greatly improved the nutrition, income and livelihoods for the ethnic group of the Hani Terraces in Honghe County.

7.1.1 Main challenges and constraints

Lower yield and income

Traditionally the Hani Terraces adopted the most primitive farming method – the rice paddy. Each household was allocated a small terrace paddy to grow a crop of "red rice" every year, which provided the whole family with limited food. In some villages, the farmer randomly put a few wild common carp fingerlings in the terraces and harvested

them at the end of the year as a source of animal protein, providing complementary nutrients for the family members and improving health.

The ethnic group, living in this remote mountain area with limited food and income, remained in poverty for many years. Recently, with improved communications, many young people began to look for jobs in town and cities (Liu, 2014), and some terraces paddies were abandoned, and collapsed due to poor maintenance.

Ecosystem disruption

The terrace ecosystem was not effectively maintained and many terraces were replaced with dry land crops, due to the shortage of family labour. Traditionally the terraces were impounded by dykes to maintain water for rice planting after a crop of rice was harvested, however, broken dykes, due to the terraces not being impounded in time, led to some terrace paddy collapse when dry land crops, such as sugarcane, vegetables and traditional Chinese medicine herbs, were planted. This change of crops and farming method have brought devastating damage to the original landscape and ecosystem of the Hani Terraces.

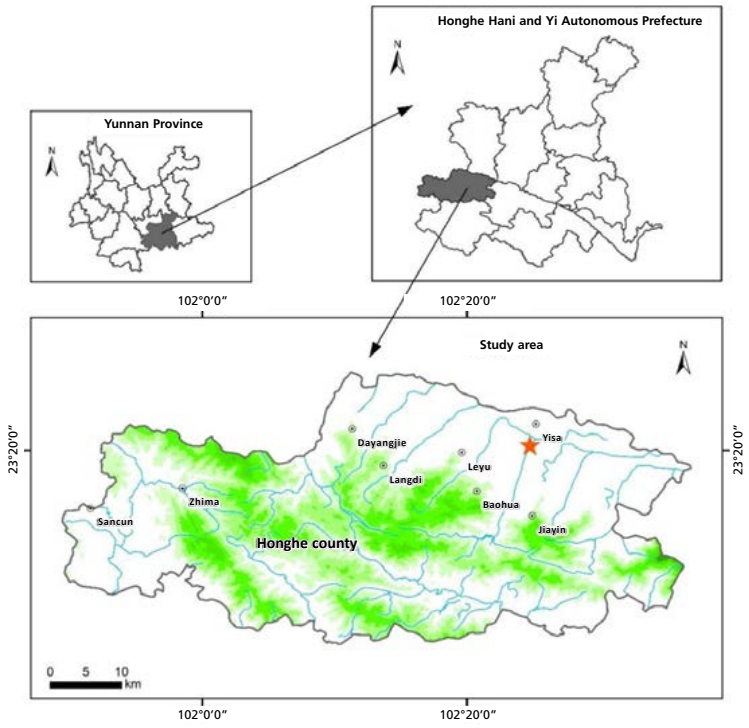
Although there was a traditional culture of Hani ethnic people living in the remote and mountainous areas eating fish as an additional dish with the staple food rice, this was not easy to achieve due to a limited supply of fish, and, as a result, the people have suffered from malnutrition and poor health conditions.

7.1.2 Advantages and opportunities of aquapark development

Location and natural resources

The aquapark is located in the southwest of Honghe Hani and Yi Autonomous Prefecture, at the core of the dry-hot valley (Mosha, Xinping-Hekou) on the south bank of the Red River Basin. The geographical coordinates are 23°05' – 23°07' N and 101°49' – 102°46' E (Figure 7.1). The undulating mountains (also called Ailao

FIGURE 7.1
The geographical location of the park



Red star ★ the location of good quality loach (*Misgurnus anguillicaudatus*) seed farm.

Source: Prepared by N. Shen.

Mountain) in this area are ranging from an altitude of 144–2 939 m, and the area has a typical south subtropical monsoon climate.

In the Ailao Mountain area, the annual precipitation reaches 2 200 mm when the altitude is around 2 800 m. At the northern foot of the Ailao Mountains, with an altitude below 900 m, the annual average precipitation is 800–900 mm. The water rises all year round and irrigates the rice paddy through small canals. Optimal light, climate, water source, water quality, soil, water temperature and humidity (hardness) provide good conditions for rice-fish co-culture. There is plenty of terrace acreage in Samaba, Baohua, which is known as the "World's Top Hani Terraces"; there are 17 640 ha of paddy fields in the county, of which more than 6 700 ha are suitable for rice-fish farming.

The Ailao Mountain is a complex ecosystem comprised of "forestry-rice paddy-village-river", which is a typical ecosystem for the terrace agriculture adopted by the Hani people. There are various niche ecosystems according to the mountain topography. Local diversity of rice varieties and integrated aquatic species are enriched by the long traditional practices.

Policy

In 2010, "Hani Rice Terrace System" was listed as one of the Globally Important Agricultural Heritage Systems (GIAHS) of the Food and Agriculture Organization of the United Nations (FAO) (FAO, 2006). In 2013, the Hani Terrace Cultural Landscape was listed as a United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage site. The recognition of "Dual World Heritage" not only brings new standards and requirements for the local government to protect the original landscape and agriculture practices of the Hani Terraces, but also brings new opportunity for development in the Honghe Hani Terraces. The local government has initiated a policy to solve both target poverty alleviation and terrace protection (ecological protection and inheritance of terraces paddy agriculture). The local government had been making every effort to develop eco-tourism and promote the development of agricultural industries based on local resources, focusing on enhanced agricultural production and the digitalization, branding and quality improvement of agricultural products.

In 2015, the local government called for proposals to take the advantage of the water resources and the terrace paddy. With the technical support from the FFRC-CAFS, the local government decided to carry out and promote standardized rice-fish culture in the Hani Terrace system in Honghe County, and introduced a new aquatic species, the loach (*Misgurnus anguillicaudatus*), into the rice ecosystem for standardized production. The local government has targeted the poor householders as the participants of the modern ecological integrated rice fish model, and free seed were provided at the trial stage, as well as technical training and services.

7.2 AQUAPARK PLANNING AND CONSTRUCTION

7.2.1 Scientific planning and species selection

In order to maintain the unique ecosystem of the Hani Terraces that cover forests, paddy fields, complex water and village ecosystems, and to take full advantage of its production capacity, the Honghe County government, under the guidance of Yunnan Provincial Aquatic Products Bureau, invited the scientific research team of the FFRC-CAFS to conduct a field investigate and survey on the Hani Terraces in Honghe County in 2015. The investigation undertook a complete study of the local natural and social environment, the major agricultural activities in terrace paddy, the rice varieties and their growth cycles, the hydrology of the water supply, the local aquatic species and seed supply, the consumption preference of local residents, etc.

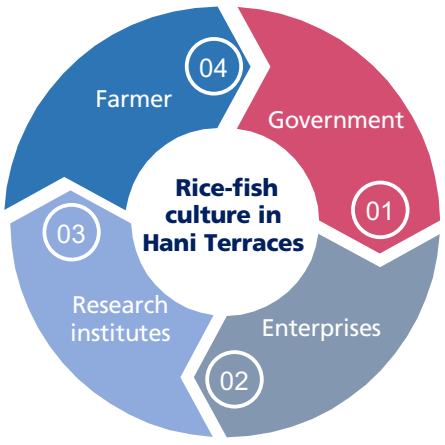
Based on the comprehensive investigation results, the Guideline for the sustainable development of agricultural in the Yunnan Province, and the relevant industrial development policies of Honghe County, the expert group has preliminarily proposed to promote the production and operation model of rice-loach culture in the selected area of the Hani Terraces in Honghe County. The proposal also included the establishment of a hatchery for the selected species loach (*M. anguillicaudatus*) to guarantee the seed supply. The rice variety suggested was the high price "red rice", which is welcomed by consumers and a traditional variety in the Hani Terraces.

Organizational form and implementation

Under the leadership of the government of Honghe County, with the technical support of the FFRC-CAFS and the Yunnan Zhonghai Fishery Co., Ltd., farmers were well organized to implement the rice-fish integration in the Hani Terraces.

The organizational and management model of "Government + Enterprises + Research Institutes + Farmers" in the park was established (Figure 7.2), and a new technical manual on rice-loach culture in Hani Terraces was developed. The protocol of green and sustainable agriculture development of the Hani Terraces in Honghe County was well adopted.

FIGURE 7.2
Organization and management mode of Rice-fish culture in Hani Terraces, Yunnan province



Source: Prepared by Hongxia Li.

Government

Government takes the lead in organization, with responsibility for the identification, planning, promotion, implementation and evaluation of the project and its activities, that include formulating a series of policies, providing land and funds to support industrial operation, encouraging farmers to cooperate with enterprises, and organizing management and technical training for relevant scientific and technical officials and farmers. For example, the Postdoctoral Research Station of the FFRC-CAFS and a workstation of the Academician Tang Qisheng were set up for research and demonstration of robust aquaculture practices, offering a strong scientific and technological support for the rice-fish culture innovation. The local government also support the leading enterprises in hatchery establishment and operation. Local farmers were strongly supported by the establishment of professional cooperatives, loans and financial support, and technical training on production, pest management, marketing, etc.

Leading enterprises

The Yunnan Zhonghai Fishery Co., Ltd. was invited to be a private investor to provide farmers with technical and input support. The company was responsible for organizing high-quality seed/fry production, distributing sufficient quality seed to households, and organizing rice and fishery production, finished product repurchase and subsequent processing and sales. It also received policy support and technical support from scientific research institutions.

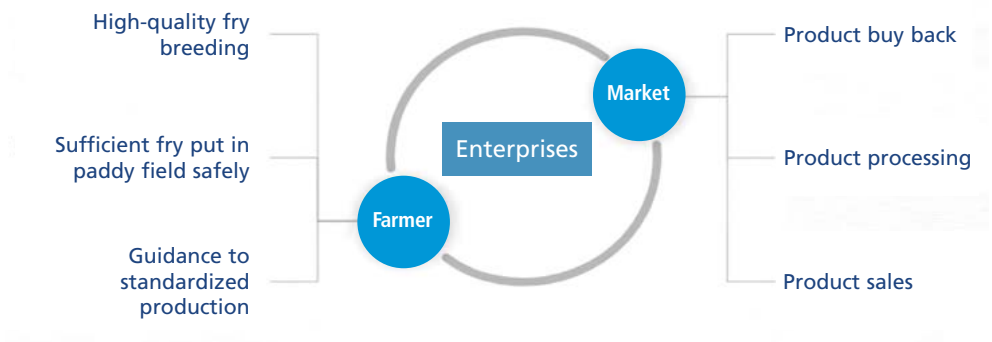
The company organized production and technical support through the professional cooperative to demonstrate the "rice-loach culture" model. It has established a loach hatchery in Menglong Village and Hekou Basa Seed Base. In recent years, the Yunnan Zhonghai Fishery Co., Ltd. has provided 4 million common carp seed and 65.06 million loach seed to registered households in total (Figure 7.3). The price of the quality seed

FIGURE 7.3
The hatchery established by the enterprises for the distribution of loach fingerlings to farmers

was 30 percent lower than the market price supported by the favoured policy in Yunnan. In addition, the company promised to purchase those harvested aquatic products at a guaranteed price of USD 3.69/kg (CNY 24/kg), and this measure strongly improved the confidence of farmers engaged in the pilot project. In the meantime, the company has trained farmers to manage production according to standards and technical guidance, to ensure the quality of products and good benefits.

The company constructed a hatchery for high-quality aquatic animal seed with the support of the government, carried out a breeding program with high-quality aquatic animal broodstock with the technical support of scientific research institutions, and provided high-quality seed to meet the demand of farmers participating in the rice-fish integration. Within the agreement, the enterprise was responsible for transporting fingerlings to the villages and distributing to households, and providing guidance to farmers on technical standards (such as stocking time and stocking density) and the daily management. On the marketing side, farmers have a choice whether to sell directly to the market or to the enterprises at the guaranteed price. The enterprise was able to build a brand for the live and diversified processing products. The enterprise operation model is shown in Figure 7.4.

FIGURE 7.4
Enterprise operation model of rice-fish culture in Hani Terraces, Yunnan Province



Source: Prepared by Hongxia Li.

Scientific research institutes
the technical department is mainly responsible for providing technical support for all aspects of industrial development. For example, the Postdoctoral Research Station of the FFRC-CAFS and the Academician Tang Qisheng Workstation of the Yellow Sea Fisheries Research Institute were established to study the aquaculture system engineering technology for keeping a "virtuous cycle" of ecological material flow and energy flow in Honghe Hani Terraces, the dynamics of rice nutrient salts and the income and expenditure mechanism of biogenic factors in the rice-fish culture system. These institutes strive to establish a rice-fish farming model with obvious characteristics and remarkable results in the Hani Terraces in Honghe, Yunnan Province, utilizing the winter fallow fields as well as promoting the structural adjustment, optimization and upgrading of the rice-fish culture industry, thus improving benefits and providing a strong technical guarantee for the development of the local rice-fish culture industry.

Farmers
in this pilot project, the farmers were the registered poor householders with terrace paddy. The farmers received support from government and the company to conduct the rice-fish integration farming in their own terrace paddy (Figure 7.5). They are trained to carry out standardized integrated rice planting and aquaculture to strictly align to the company's requirements, including pre-production field modification, seedlings and transplantation, stocking of fish fingerlings, aquaculture management, input management and preventing fish and fry from escaping and disease. Farmers are encouraged to conduct the agricultural innovations in a sustainable manner and received incentives for good performance.

FIGURE 7.5
Farmers receiving loach fingerlings and stocked loach fingerlings in the paddy

Selection of aquaculture species

Taking into consideration of the local climate and water quality in rice paddy, the rice planting duration and production cycle, as well as the preference of the local Hani people, two fish species were recommended, i.e. the common carp (*C. carpio*, FFRC strain) and loach (*M. anguillicaudatus)*, both suitable and productive in terrace paddy in Honghe. The economic value of loach is relatively higher than common carp, while common carp has high productivity. The comparison of production characteristics between common carp and loach is shown in Table 7.1.

TABLE 7.1
Comparison of production characteristics of common carp and loach

	Traditional species	Improved species
Common carp	The fingerlings are collected from the wild, with unstable supply, different specifications and slow growth	The seedlings are bred in the hatchery farm, with stable supply, unified specifications and rapid growth
Loach	Slow growth, small with variations in size, display burrowing behaviour	Fast growth, uniform size, no burrowing behaviour

7.2.2 Aquapark construction and implementation

Infrastructure and supporting facilities

Since 2016, the Honghe government has initiated a project of "expressway connecting all counties". The project planned to build 13 expressways, with a mileage of 826 km and a total investment of USD 18.46 billion (CNY 120 billion). Among them, there were six expressways connecting southern counties, with a total of 482 km and a total investment of USD 11.23 billion (CNY 73 billion), solving the bottleneck of market access and transportation and providing convenient transportation of products and procurement of inputs.

The People's Government of Honghe County approved and provided land and finance support to Yunnan Zhonghai Fishery Co., Ltd., which invested USD 1.46 million (CNY 9.5 million) (including USD 0.77 million (CNY 5 million) of government loans) to build the hatchery for local aquatic seed supply. The hatchery, including a 1 100 m² large-scale seed production workshop and outdoor nursery ponds of 3 965 m², mainly provides fingerlings for the rice-fish integration of the Hani Terraces. The FFRC-CAFS provided technical support to the local government and Zhonghai Fishery Co., Ltd., to build the national "rice-fish culture" pilot base (Figure 7.6). In terms of infrastructure

FIGURE 7.6
The loach hatchery (showing the hatching tanks) and brooder selection with an expert from FFRC-CAFS

©Y. Peng

within the hatchery, it includes 1 000 m of road hardening, 1 000 m of pipeline laying and 500 m of cable laying, ensuring the power and water supply required for seedling production. The annual operational cost of the base varies depending on the production plan, ranging from USD 95 846–116 153.

Seed production and supply

The loach hatchery kept 60 000 pairs of parental loach broodstock, 30 000 pairs of "GIFT (Genetically Improved Farmed Tilapia)" (*O. niloticus*) "Zhongwei No.1" broodstock and 1 400 pairs of common carp (*C. carpio*, FFRC strain) broodstock. The annual production capacity is about 25 million fish fingerlings and 3 billion loach fry, meeting the demands for loach and common carp fry for the high-yield, demonstration field project of tens of thousands of acres of terraces in Honghe County, ensuring the continuous and effective promotion of the culture model in the Hani Terraces. Since 2017, the breeding base of Yunnan Zhonghai Fishery Co., Ltd. has continuously provided high-quality fingerlings for the rice-fish culture project. The fingerlings produced by the company are shown in Table 7.2.

TABLE 7.2
Fingerlings production of Zhonghai Fishery Co. Ltd

	Fingerling production (millions)				
	2017	2018	2019	2020	2021
Loach (15 g)	31.7	19.3	16.9	12.5	n.a.
FFRC strain common carp (30 g)	n.a.	1.5	1.8	2.1	1.4
Tilapia (10 g)	n.a.	n.a.	n.a.	n.a.	n.a.

Aquaculture production management

Terrace paddy modifications

This mainly provides local farmers with technical guidance on how to improve the paddy dykes for prevention of water leakage and escape of aquaculture animals (Table 7.3).

TABLE 7.3
Terrace paddy modifications

Mode	Embankment	Water inlet and outlet	Fish trap
Rice-common carp	The embankment should be heightened by more than 0.5 m, the top width of the embankment should be 0.4–0.5 m, and the water layer should be kept above 0.2 m, so that the embankment will not leak or collapse. Digging ditches/channels for cultivating fish on terraces: the ditches account for 5–8 percent of the paddy field area. At the lower embankment of the paddy field, the I-shaped, cross-shaped and well-shaped ditches are excavated parallel to the terrace rows. The ditches are excavated 1.0 m away from the enbankment, with a width of 60 cm and a depth of 40 cm.	The water inlet and outlet should be located on the two diagonal corners of the paddy field for smooth water flow. The size of the water inlet and outlet should be determined according to the size of the field and the amount of water inflow during a rainstorm, to ensure that no fish escape.	Fish fences should be set up at the water inlet and outlet to prevent fish from escape and predators such as wild fish from entering the paddy field. Fish fences can be made of iron wire, bamboo strips and other materials. The length of the fish fence shall be twice that of the drainage outlet, arc-shaped, 20 cm higher than the enbankment, and the bottom should be buried into the hard soil for 30 cm.

TABLE 7.3 (CONTINUED)

Mode	Embankment	Water inlet and outlet	Fish trap
Rice-loach	The same as the rice field preparation method of the "rice-common carp" culture model.	Same as above	The difference is that loaches are vulnerable to predator attack, so anti-predator facilities need to be installed. 60–80 cm diameter meshes should be used around the embankment and should be 60 cm above the water surface to prevent sand snakes and rats, and bird-proof nets should also be installed.
Winter field	After the rice harvest is completed from October to November of the same year, the grass on the embankment should be removed and the embankment reinforced so that the height of the field is 30–40 cm, the width is 40–45 cm, the cross section is trapezoidal, the bottom width of the embankment is 60–80 cm, and the top width is 30–50 cm.	The water inlet and outlet pipes are installed at the enbankments on both sides of the middle of the terrace, generally pre-buried "L" polyvinyl chloride (PVC) pipes with a diameter of 20–30 cm. The long end of the pipes are buried near the embankment foundation and compacted with soil to keep the height of the enbankments consistent. The short end of the pipes are placed vertically, and its water inlet is installed inside the enbankment.	When catching fish, rotate the short end of the drainage pipe to be parallel to the field base, so as to ensure that the water of the field base is drained.

Fish stocking and management

There are two main fish species selected, i.e. common carp and loach. For the "rice-common carp" culture model, the "FFRC strain common carp No.1" and "FFRC strain common carp No.2" are the most popular species in the Hani Terraces, while the hybrid loach was also adopted by the local farmers. The fish stocking models are shown in Table 7.4.

TABLE 7.4
The main stocking model in "rice-fish" integration in the Hani Terrace paddy

Mode	Fish stocking	Water management	Escape-proof	Precautions
Rice-carp	Usually, stock around 150 kg of carp fingerlings (around 3 750 – 6 000 individuals) of 25–40 g fingerlings per ha. The time for stocking fish is 7–10 days after the rice seedlings take root and become green.	During the growth period of rice, the water depth of paddy fields should be kept at 5–10 cm. While the rice and the fry are growing, the water can be deepened to 15 cm. After the rice ears are harvested, the water in the paddy fields should be kept fresh, and the water depth should be more than 50 cm.	Regularly check whether there are holes in the fish fences and enbankments, step up inspections during rainstorms, discharge floods in time and remove a variety of debris.	Disease-resistant and insect-resistant varieties should be selected to reduce the use of pesticides. Select pesticide formulations with high-efficiency, low-toxicity and low-residue to prevent and control rice diseases and pests. Before spraying the pesticide, first dredge the fish ditch and fish pit and deepen the rice field water to more than 10 cm. Spray the powder with a sprayer when the rice is with dew in the morning. If aqueous solution is used, it should be sprayed in a mist form after the dew is dry on a sunny day.
Rice-loach	Stock 12 000–150 000 loach fingerlings of 2–5 cm at 10–15 days after the rice seedlings take root (generally in mid-May). Put the loach fingerlings into 3–5 percent salt water for a 5–10 min bath before stocking to kill surface bacteria and parasites.	The daily feeding rate of formulated feed is 2–4 percent of the fish body weight, and the roughage is 5–8 percent of the fish body weight.	Regularly check whether there are loopholes in fish fences and enbankments, step up inspectionduring rainstorms, discharge floods in time and remove a variety of debris.	Ground cage trapping could be used, or release water and even dry water to catch fish.

TABLE 7.4 (CONTINUED)

Mode	Fish stocking	Water management	Escape-proof	Precautions
Winter fallow field	After 7–14 days of water storage and farming in October, select healthy, active, and disease-free fish in similar specifications/sizes and put them on winter terraces in the morning of sunny days. The common carp fingerlings are 40–50 g, up to 3 500 individuals may be stocked.	The terrace in winter can store deep water for fish aquaculture, which is equivalent to the pond aquaculture environment. The water level should remain above 40 cm from November to next March. During the aquaculture production cycle, a small amount of rice bran, wheat bran, soybean cake, etc. can be fed once in the morning and once in the evening, with a daily feeding rate of 3–5 percent of the bodyweight of fish, ensuring feed is consumed within half an hour.	Excavate 0.5 m wide areas at both ends of the near-field enbankment, with a depth of 30–40 cm, install a 4.75 mm (4 mesh) white polyethylene mesh and make an arc fish fences with iron wires, bamboo strips and other materials. Compact the bottom and sides of the mesh with soil, keep the bottom of the mesh inserted with hard soil by 20 cm, and the height shall exceed the embankment by 10–20 cm, with the convex side facing outward.	When catching a large number of fishes, water can be discharged to the level just enough to catch fish, so as to reduce the scope of the activity of terrace fish, catch them in a standardized manner, and avoid death due to water shortage. When catching a small number of fishes, feed or fermented cow manure is usually placed near the embankment as bait, and bigger fishes are caught with a net after they gather together, leaving smaller ones in the water.

Fish stocking during the winter season

To fully utilize the terrace paddy field for fish farming, the stocked fish should be introduced during the winter season when the rice is harvested. The rice paddy should be filled with water and large-size common carp fingerlings stocked in November.

This farming model helps to maintain water in the terrace fields, and improve productivity with an additional fish harvest.

Product sales

The company is responsible for brand building, packaging and sales of products, including trademark registration, application for "well-known trademark", "local famous trademark", "China national well-known trademark", environmentally friendly aquatic products, green aquatic products, organic aquatic products, national geographical origin, etc. This brand building improves the economic benefits of product sales and ensures that the farmers in Honghe County, participating in integrated rice-fish farming, receive a better income.

Technical support

The Freshwater Fisheries Research Center of the Chinese Academy of Fishery Sciences (FFRC-CAFS) has an in-depth cooperation with local governments and enterprises, and, in order to effectively protect the Hani Terrace ecosystem, has carried out research on comprehensive solutions to improve the yield and protect terraces as a world cultural heritage with its important global agricultural cultural heritage. The FFRC-CAFS and Yunnan Zhonghai Fishery Co., Ltd. were responsible for providing technical training and guidance for local farmers, and, up until now, farmers from 13 villages and towns have received technical training and on-site guidance, 36 technical training courses have been conducted, more than 80 on-site technical guidance and consultation have been carried out, 1 800 training materials distributed, and more than 4 000 aquaculture technicians and registered farmers have been trained.

7.3 MAJOR IMPACT AND INDICATORS

The implementation of the integrated rice-fish farming project of the Hani Terrace Fields plays a positive role in many areas, such as increased rice yield, the total output, quality and efficiency, and income of farmer householders. It has achieved the goal of the "use water for multiple purpose, utilize farmland for multiple crops, and created sustainable agriculture industrial value chain" and has reconciled economic, social and ecological benefits/values.

7.3.1 Economic benefits

The county has implemented the high-yield integrated "rice-fish" farming model in a total of 6 700 ha terrace paddy, with a total output value of USD 185 million (CNY 1.2 billion), and the average income in terrace paddy reached USD 1 1540/ha. With the guaranteed purchase price policy, the average annual income of participating poor households has reached around USD 1 540 (CNY 10 000) and helped 22 900 farmers in the county to increase their income and improve their livelihood.

According to the results of a survey of 12 households, the average yield in terrace paddy was 5 700 kg/ha of rice and 525 kg/ha of common carp. In 2021, there was a total area of 1 350 ha in Honghe County that had adopted the rice-fish integration, the total revenue was around USD 8.4 million (CNY 54.63 million) (market price for common carp was USD 7.7/kg (CNY 50/kg) and USD 0.38/kg (CNY 2.5/kg) for rice), of which: the sales revenue of common carp was USD 5.47 million (CNY 35.57 million), and USD 2.95 million (CNY 19.22 million) of rice. The net profit was USD 4.96 million (CNY 32.26 million), and the average net profit was USD 3 565/ha (CNY 23 172/ha), the household income increased by USD 216 (CNY 1 408), and the per capita income increased by USD 54.8 (CNY 352). The comparison of the economic benefits of different models is shown in Table 7.5.

TABLE 7.5
Comparison of the economic benefits of the different farming models

Model	Output	Output value and profit
Rice monoculture	The yield of rice is 6 000 kg/ha	The unit price is USD 0.38/kg (CNY 2.5/kg), and the output value is USD 2 307.69/ha (CNY 15 000/ha), net profit of USD 92.31 (CNY 600) (deducting USD 33.85 (CNY 220) for seedlings, USD 27.69 (CNY 180) for fertilizers, and pesticides).
Rice-common carp	Increase aquatic product yield by 570 kg/ha without reducing rice yield (400 kg)	Based on the market price of USD 7.69/kg (CNY 50/kg) (common carp), the output value is USD 292.31 (CNY 1 900). After deducting the cost of USD 138.46 (CNY 900) (costs for purchasing fish fingerlings: USD 346.15/ha, excavation of fish ditches and pools: USD 692.31/ha (CNY 4 500/ha), complementary feed: USD 230.77/ha (CNY 1 500/ha), and labour cost: USD 807.69/ha (CNY 5 250/ha)), the income per ha increases by around USD 2 808 (CNY 15 000). At the same time, the cost of fertilization and pesticides for rice production can be reduced by USD 230.77/ha (CNY 1 500/ha).
Rice-loach	The yield of rice is 5 700 kg/ha The yield of loach is 1 500 kg/ha	The unit price of rice is USD 0.92/kg (CNY 6/kg), and the output value is USD 5 261.54/ha (CNY 34 200/ha), while the output of loach is 1500 kg/ha, the unit price is USD 7.69/kg (CNY 50/kg), and the output value is USD 11 538.46/ha (CNY 75 000/ha). After deducting the cost of USD 276.92 (CNY 1 800) (including USD 33.85 (CNY 220) for seedlings, USD 27.69 (CNY 180) for fertilizers, USD 153.85 (CNY 1 000) for loach fingerlings and USD 61.54 (CNY 400) for feed, the net income is USD 11 423.08/ha (CNY 74 250/ha).
Winter rice field	The yield of fish is 750 kg/ha	Based on the market price of fish of USD 9.23/kg (CNY 60/kg) during the Spring Festival, the output value is USD 6 923.08/ha (CNY 45 000/ha). After deducting the cost of USD 138.46 (CNY 900) (fingerling purchase fee of USD 346.15/ha (CNY 2250/ha), excavation of fish ditches and pools of USD 692.31/ha (CNY 4 500/ha), coarse feed of USD 230.77/ha (CNY 1 500/ha), and labour cost of USD 807.69/ha (CNY 5 250/ha), the income increases by around USD 4 846.15 (CNY 31 500).

Data provided by the FFRC from the survey results in Honghe County in 2022.

7.3.2 Ecological benefits

With a long history and unique culture system, the Hani Terraces in Honghe are known as the typical ecosystem of forestry-terrace-village-people in China. Integrated rice-fish farming in the Hani Terraces is of great significance to their ecological environment protection and sustainable, and stable economic and social development. "Rice-fish farming" has realized the sustainable use of agricultural resources, created a comprehensive rice field ecosystem and implemented the combination of crop production and aquaculture, while the ecological production model of integrated rice-fish farming allows for the production of excellent, green and pollution-free agricultural and aquatic products.

In addition, due to the interaction of rice and aquaculture, the use of chemical fertilizers and pesticides in rice fields is generally reduced by more than 30 percent (the cost of fertilization and pesticides for paddy production is reduced by about USD 230.77/ha (CNY 1 500/ha). Diseases, such as schistosomiasis and Culicidae larvae in rice fields are successfully biologically controlled, and the pathogen biomass greatly reduced, thus decreasing the application of pesticides and herbicides. The greenhouse gas emissions in the integrated rice-fish farming model have also been reduced, with methane emissions reduced by 7.3–27.2 percent and carbon dioxide reduced by 5.9–12.5 percent, dropping environmental discharge and improving the ecological performance of agriculture.

7.3.3 Social benefits

Through the development of integrated rice-fish farming parks, farmers have been encouraged to adopt the innovative production models, safeguard terrace rice-fish production and ethnic culture, maintain traditional agricultural system technologies and achieve poverty alleviation through effective rural revitalization. At the same time, it has further promoted the passing down of traditional farming skills, terrace protection and sustainable development of natural resources. In addition, it has improved the status of women and improved the family livelihood and social stability. Table 7.6 showed social benefits analysis results.

TABLE 7.6
Analysis of social benefit of rice-fish integrated farming

Poverty alleviation and rural revitalization	Through the development of the agriculture industry and the advancement of rural revitalization, the successful implementation of rice-fish farming in the Hani terraces has introduced a new way to boost the industries of registered poor households in mountainous areas and the border and minority-nationality regions; by 2021, the Project had lifted 12 800 households (51 200 poor people) out of poverty, making outstanding contributions to poverty alleviation in Honghe County, Honghe Prefecture, Yunnan Province.
Promotion of women's and children's status and balanced diet	The construction of terrace facilities for "rice-fish farming" has improved the output value of the terraces, thus increasing the farmers' income, improving the status of women striving for more opportunities for children to receive education, retaining rural labour force, and even attracting some migrant workers to return to their villages for agriculture. It has also contributed to building a balanced diet for the Hani people, with the increase in animal protein fulfilling their nutritional needs and enhancing their physical fitness.
Inheritance of traditional farming culture and terrace protection	"Rice-fish farming" is an indispensable and important traditional production model for ethnic minorities in China. This culture method permeates all aspects of their life, from eating habits to customs and etiquette and has promoted the "World heritage" protection status of the Hani terraced rice farming culture and terraced landscape and developed ecological agriculture.
Promote the integration of three industries and the development of terraces	Relying on the Hani terrace red rice industry, products related to the Hani terrace farming experience will be developed and other farming cultural experience activities will be carried out. For example, tourists can participate in rice transplanting, millet threshing, feeding, catching and eating fish from rice fields, in order to experience the farming life. Traditional festivals of the Hani ethnic people, such as the "Changlong Banquet" and "Kaiyangmen" will be held to augment and pass on the rice farming system and farming culture of Hani terraces, and rural cultural products, mainly based on "Hani Ancient Songs" and "Hani Four Seasons Production Tunes", will be developed. Terrace rice-fish farming will be promoted,while developing the tourism industry, designing "fishes' home" leisure tour, giving new content to the rice-fish farming and increasing its added value. Therefore, with effective publicity, "rice-fish farming" terraces can become a resort for leisure fishing.

7.4 POTENTIAL ADOPTION AND RECOMMENDATIONS

7.4.1 Favoured policy and infrastructure support

There is always a need to provide the necessary favoured policy and infrastructure support for industry development in remote areas. It is difficult to attract private investments in mountainous areas, when the infrastructure is lacking, such as enabling access to water, roads and electricity. During the negotiations for private investment, especially in the construction of hatcheries and the provision of technical support, there was a strong request that the government should formulate corresponding and stable policies for land and financial support. Marketing facilities of products should also be considered, not only as a support measure to the farmers, but also as a marketplace for exchange and promotion. It should be mentioned that government should invest in the training of farmers for capacity building of knowledge and skills, in order to implement the scientific guidance and innovations in the terrace rice-fish integration.

7.4.2 Holistic approach to planning and design

A holistic approach was adopted in this aquapark development. First, a comprehensive investigation and survey was conducted to better understand the real situation, including the disadvantages and advantages, natural resources and social considerations. Second, technical support from academia and universities played a key role in finding scientific and practical solutions. It was approved that the integrated terrace rice-fish farming was a simple and easy-to-learn technical model based on the capacity of farmers in mountainous areas. Third, the cooperation among government, farmers and private sector is crucial for success. For local governments to achieve the poverty alleviation, integrated rice-fish farming can stimulate the enthusiasm of farmers to grow grain, especially in some southern areas of low-lying fields and flooding fields. Integrated rice-fish farming can effectively avoid the abandonment of farmlands and protect the terrace ecosystem. Farmers expect the obvious benefit of increased income, and they are more motivated to participate in innovative practices for better production.

7.4.3 International exchange and knowledge sharing

In June 2017, the training workshop on "Integrated rice-fish farming", supported by the Food and Agriculture Organization (FAO) and Ministry of Agriculture and Rural Affairs (MARA), was successfully conducted. The training workshop was attended by extension officers and farmers from China, Viet Nam, Myanmar, Cambodia, Lao People's Democratic Republic and other countries. The Hani Terrace "Rice-fish Farming" aquapark in Honghe County, Yunnan Province, was proposed as a field study tour and a technical exchange with local fishery officials, lead enterprise and farmers (Figure 7.7).

The integrated rice-fish farming in the Hani Terraces in Yunnan has had a profound impact on the local economy, ecology and society, due to its unique social and geographical characteristics, as well as its ecological and replicable farming methods. It is also of important reference value for other countries and regions with terrace fields; terraces are widely distributed globally, in areas and countries such as North Africa, the Mediterranean coast, France, Central America, China, Japan, India, Philippines, Republic of Korea and Southeast Asia, for example Myanmar. However, due to the difficulties in farming operations and maintenance of terraces, many have been abandoned. This aquapark for integrated rice-fish provides a good reference and example for countries with terrace paddy.

FIGURE 7.7
FAO workshop on Integrated rice-fish farming and study tour in the Hani Terrace paddy

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8. Guangdong Tilapia farming aquapark

The Tilapia Industrial Park, located in Maonan District, Guangdong Province, China, is comprised of four towns, i.e. Jintang Town, Gongguan Town, Shan'ge Town, and Xinpo Town, with a total area of around 30 100 ha, including 68 administrative villages and a total of 3 983 fishery households. It is associated with a fishery population of 12 617 people, accounting for 73.45 percent of the total fishery population in Maonan District. The Tilapia Industrial Park has a core area in Maoming City and main farmed tilapia strains are the Genetic Improved Farmed Tilapia (GIFT) (*O. niloticus*), hybrid Tilapia (*O. aureus* × *O. niloticus*), red tilapia (*O. aureus* × *O. mossambicus)*, etc., with an annual production of nearly 220 000 tonnes.

The Tilapia farming aquapark implements the "One Fish" development strategy, establishing a tilapia "Golden triangle" industrial base in Guangdong province. The total investment of the Tilapia Industrial Park is around USD 31 million (CNY 202.66 million), including USD 7.6 million (CNY 50 million) from provincial government, USD 4.8 million (CNY 31.4 million) from local government and USD 18 million (CNY 121 million) from private (social capital), and has supported more than 100 000 people engaging in tilapia aquaculture and related industries.

8.1 DEVELOPMENT BACKGROUND

8.1.1 Main challenges and constraints

Small aquaculture farmers showed low efficiency, poor training and ability in terms of production and a lack of resilience to natural and market risks (Leyva and Engle, 2008). After the reform policy in China in the 1980s, householder farms attained the majority in both the agriculture sector and the aquaculture sector. With limited technical knowledge and investment, the individual small farmers faced big gaps in contract aquaculture and commercial marketing, and their inability to access quality seeds, feed, diseases prevention and control methods, etc., resulted in failure and poor economic return. There was a high demand for united and technical support for the small-scale aquaculture farmers, as well as a connection to the market, which is conducive to the sustainable development of the aquaculture industry.

Seed supply

In China there were several challenges in tilapia breeding and hatchery development. First, the small and medium-sized breeding farms, usually family owned, could not supply large quantity and high-quality tilapia seed, due to limited knowledge and skills (Bhujel, 2000). Second, there were few large-scale breeding and hatchery farms with their own brands to meet the demand. Third, there was increasing awareness and demand for hybrid all-male tilapia seed with strong disease resistance, requiring professional technologies. Fourth, the market price of high-quality tilapia seed was relatively high, while the all-male tilapia ratio was not stable and generally low. Fifth, farmers sometimes bought tilapia seed from counterfeit brands, and suffered of low-quality tilapia seed.

In order to protect the local tilapia farmers, the local competent authority tried to strengthen the quality inspection and quarantine of tilapia seed supply and encourage the local lead tilapia farms to support quality tilapia breeding, aiming to produce hybrid all-male tilapia with resistance to diseases and stress.

Food safety

Although there are tilapia aquaculture standards published at national and provincial level, there were reports of detection of antibiotic residues by different inspection and testing entities (Haygood and Jha, 2018). Due to production methods or improper operation by farmers, there were incidents where water-retaining agents and ozone residues in tilapia exceeded the standard.

In the processing of tilapia, the control of the sanitation process of food contact surfaces is a key control point. Improper control can easily lead to contamination from surfaces and excess microorganisms in tilapia products. In the self-inspection on semi-finished and finished products in the processing plant, if the total number of bacteria, i.e. total coliform, *Vibrio parahaemolyticus* and other microorganisms, are found to exceed the standard, the products will generally be returned for disinfection, and repackaged and shipped after passing the inspection, instead being destroyed (Ortega, Wang and Widmar, 2014), which was not good practice.

Aquaculture diseases

The Maonan District has a humid climate with consistently high temperatures throughout the year. These environmental conditions facilitate the proliferation of harmful pathogens in water environments. The interplay between the environment, pathogens and fish compromises the immunity of tilapia, making them susceptible to infections during periods of pathogen prevalence. Furthermore, inadequate regulatory systems in the area have led to below standard management practices in fishponds, including increased stocking density, deteriorating water quality, poor feed quality, improper feeding strategies and drug misuse. There were also reported large-scale outbreak of streptococcus infection among tilapia in South China, which caused high rate of failure of tilapia aquaculture (Ke *et al.,* 2012).

8.1.2 Development advantages and opportunities

In order to mitigate the difficulties and problems in the development of tilapia aquaculture, it was proposed that the Maoming Tilapia Aquaculture Park explored a new development pathway, based on the advantages and opportunities of regional geography, climate and policies.

Location and natural resource

There are five rivers, i.e. Meihua River, Meijiang River, Baisha River, Xiaodongjiang River and Dakeng River (the longest river in Shange Town) in Maonan District, with a total length of 80 km. There are 24 reservoirs in Maonan District, including one medium-sized reservoir, five small type I reservoirs, and 18 small type II reservoirs. There are 141 sluices, including two large sluices (Dongjiangkou sluice and Wushi sluice) and18 state-managed water supply channels. Through the construction of division channels, the water network systems of Gaozhou Reservoir, Jianjiang River, Mine Lake and Xiaodongjiang River are connected, and the regional water source and the urban water source are integrated for interchange (Zhao *et al.*, 2023). The sewage treatment plant in Maonan District and the sewage treatment station in Jintang Town in the Maonan District have been completed and put into operation, which provides sufficient and fresh water for the standardized aquaculture of tilapia and is conducive to the growth of tilapia.

The Industrial Park is 16 km away from the downtown, 19.5 km from Maoming Railway Station, around 30 km from Shuidong Port, 100 km from Zhanjiang Airport, and only 40 minutes' drive from West Guangdong International Airport, the third largest international airport of Guangdong. The Shantou-Zhanjiang Expressway, Maozhou-Gaozhou Expressway, Maozhou-Huahua Expressway, Hefei-Maozhou Railway, Jiangmen-Zhanjiang Railway and "Provincial Highway 291" run through the

aquapark. It is located in a 3 hours economic circle of Guangzhou, Shenzhen, Zhuhai and associated cities. Maonan District also has the advantage of the comprehensive construction of "Roads to Village" and rural road network projects, with convenient roads connecting of cities and towns, and complete road networks from administrative villages to natural villages. These infrastructures provide a convenient connection to the aquapark, easy logistics, free up the flow of people, capital flow and information flow, which also aids tilapia transportation, marketing and professional technical services.

Climate

Guangdong Province has favourable climatic conditions throughout the year, and the average annual temperature is optimal for tilapia farming. The annual water temperature is above 22 °C from April to October. In addition, Guangdong Province has abundant precipitation conducive to water exchange of farming ponds, and sufficient sunshine beneficial to maintaining the dissolved oxygen in the water (Li *et al.,* 2022). The optimal temperature for tilapia aquaculture is 23 °C. Maoming has favourable climatic conditions; the annual average temperature is above 22 °C and the annual average rainfall is between 1 530–1 770 mm. The annual sunshine duration is 1 560–2 160 h and the sunshine rate is above 35.6 percent which is suitable for the rapid growth of tilapia.

Policy

In order to promote the tilapia industry, Maonan District Government adhered to the high-quality development blueprint of the tilapia industry, and implemented the "One fish" strategy. In recent years, Maoming has focused on the construction of the Maonan Tilapia Farming Industrial Park and cultivated leading tilapia enterprises to make the zone more competitive, based on scientific and technological support. It has built up the tilapia industry as one of the agricultural pillar industries of Maoming, to enhance the development of tilapia farming and the production base, to meet the needs of processing companies. In May 2004, the Maoming Municipal Party Committee and Municipal Government officially approved the implementation Plan for Building the Tilapia "Golden Triangle" Industrial Base in Maoming City, which aimed to build a tilapia "Golden Triangle" industrial base, covering a total of 23 towns (with sub-district offices) in the Southwest of Gaozhou, the Southeast of Huazhou and the east and west of Maonan District. This initiative has been fully affirmed and strongly supported by national and provincial authorities.

For a standardized process, Maoming City has published two local standards, i.e. "Technical specifications for hybrid tilapia (*O. aureus* × *O. niloticus)* aquaculture" and the "Technical specifications for healthy tilapia aquaculture". It has also enhanced implementation of more than 20 national, provincial and municipal scientific and technological projects, such as "Research on tilapia selective breeding and large-scale breeding of GiAo Tilapia" and "Research on New Methods of large-scale breeding of *O. aureus* × *O. niloticus* with high male rate". It has effectively solved the problems concerning the key technologies of tilapia breeding and aquaculture and promotes the sustainable development of tilapia aquaculture in Maoming City.

8.2 AQUAPARK PLANNING AND CONSTRUCTION

The Tilapia Modern Agricultural Industrial Park is committed to building a provincial modern agricultural industrial park for tilapia production and has achieved great results. After more than 30 years of development, the operational modalities of the industrial park have changed from the initial contract aquaculture with multiple farmers to the current centralized cooperation model, which has been developed to promote the sustainable and healthy development of the Maoming tilapia industry.

8.2.1 Scientific planning and feasibility study

The Maonan Tilapia Modern Aquaculture Industrial Park is a provincial-level, modern agricultural industrial park mainly led by the Maoming City government. It is aimed to develop the modern agricultural industry and establish an export-oriented industry aquapark, encompassing tilapia seed/fry production, growout and processing. With the strong support of the Maonan District Government, the District Government has issued preferential policies for the development of agricultural industries in terms of land use, tax exemption and reduction, financing and insurance, etc., and planned for the park to become an industrial zone with primary, secondary and tertiary industries. The aquapark has two core development dimensions (industrial development and industrial cultural tourism), three functional zones (standardization demonstration zone, brand incubation and promotion zone, and sightseeing, leisure and cultural tourism zone), and six thematic demonstration and promotion projects (standardized tilapia hatchery and nursery, standardized processing, standardized growout aquaculture, standardized cold chain storage, standardized epidemic prevention and diagnostic facilities and healthy aquaculture).

Organizational modality and implementation planning

For the purpose of improving the tilapia industry in Maonan city, the government has been working hard to find the most efficient organization modality. There were two main targets: one to introduce competent enterprises to enhance the core technology, input supply and whole value chain; two to engage the predominantly small-scale farmers in the aquapark.

There were three main models of organization modality for the tilapia industrial park:

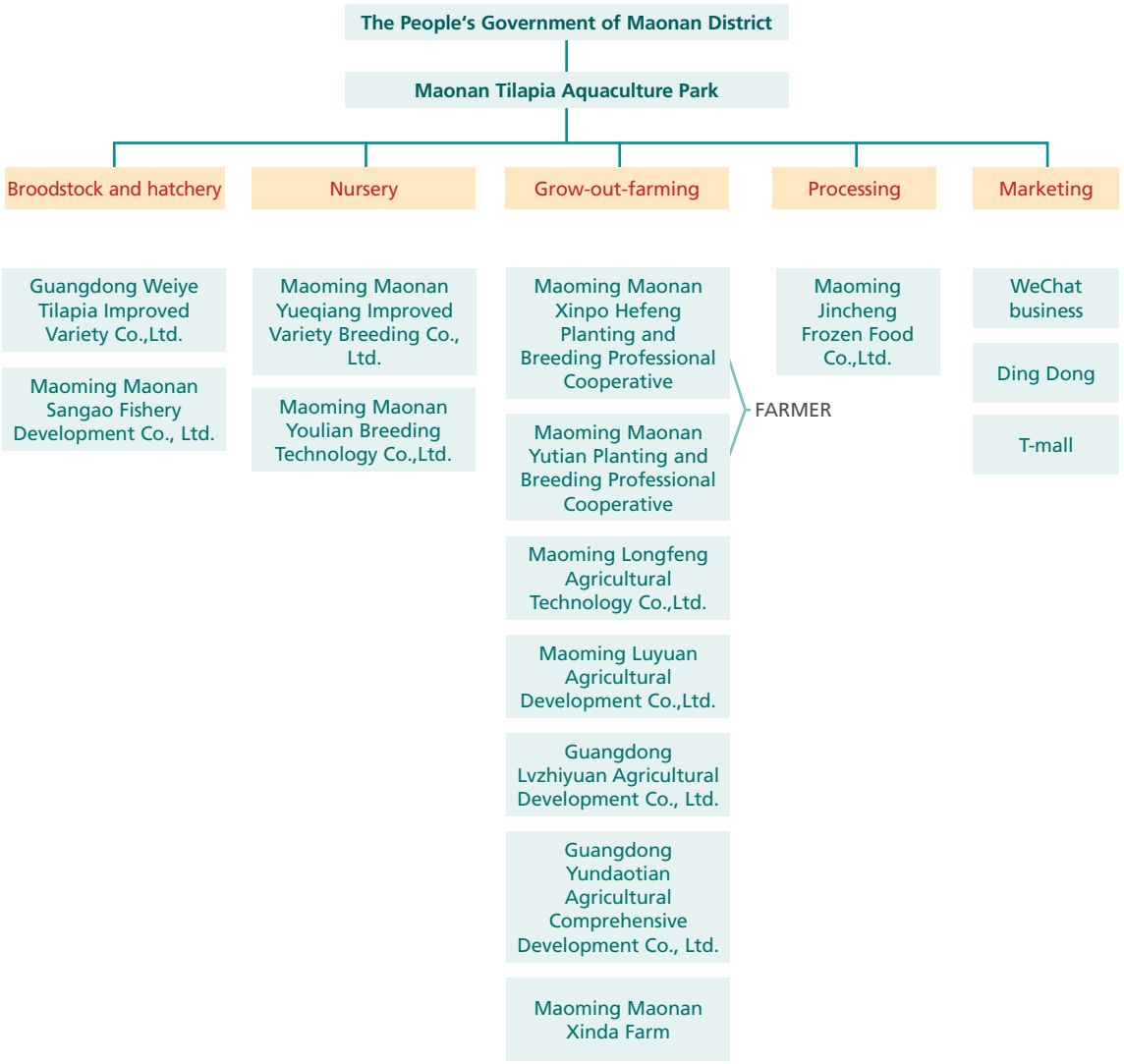
- **the development model of "company + base + farmer + standard"** (Figure 8.1). Maonan District People's Government of Maoming City worked with several leading companies in the district: the Maoming Maonan Sangao Fishery Co., Ltd., Guangdong Weiye Tilapia Improved Farmed Species Co., Ltd., Maoming Maonan Yueqiang Improved Farmed Species Breeding Co., Ltd., and Maoming Maonan Youlian Farming Technology Co., Ltd. Each company led 10–20 demonstration sites. The company provides fingerlings, feeds, technical training and services for the contracted farmer households, and carries out growout production. Tilapia farmer households were trained in pond renovation, feeding, and a unified stocking model and standard management was conducted, so that the bases met the requirements for certified tilapia aquaculture.

- **the modern industrialization development model of "company + cooperative + farmer"**. A community of shared interests is formed among cooperatives, comprised of large-sized farming households and farmers, where cooperatives are responsible for high-risk nodes such as pre-production investment, in-production technology and post-production sales, and farmers are responsible for production management, ensuring that farmers engaged in the industry get rich with "zero risk" to encourage more to participate in increasing their incomes. The cooperative regularly holds aquaculture technology exchange meetings and cooperates with representatives from multiple nodes to achieve low-cost, safe and efficient aquaculture for farming households.

- **the model of "industrial technology innovation partnership".** Maoming has established the "Guangdong Tilapia (Maoming) Industrial Technology Innovation partnership" and designed a technological innovation system focused on tilapia that effectively brings together industry, university and research institutes. The partnership is jointly established by Maoming Maonan Sangao Fishery Co., Ltd.,

with scientific research institutes including Sun Yat-sen University, Guangdong Ocean University and the FFRC-CAFS, six leading companies and the agricultural promotion center, and aims to give full play to the integrated innovation advantages of the partnership and effectively connect enterprises, universities and scientific research institutions at the strategic level. The partnership transmits the technical demands of market-oriented farms, improved hatcheries and growout farms and processing plants to the technology research and development departments of universities and scientific research institutes, improving the efficiency of the whole industrial chain, while continuously accelerating the development of tilapia industry (Figure 8.1).

FIGURE 8.1
Operation model of a tilapia aquapark in Maonan district



Source: Prepared by J. Qiang.

8.2.2 Aquapark construction and operation

In order to establish a whole tilapia industry value chain, the Maonan District Government has planned an upstream, middle and downstream industrial chain system, which includes tilapia seed supply, growout production and processing, a storage warehouse, marketing, promotion and associated business nodes. The Maonan

Modern Tilapia Industrial Park has promoted industrial and technological integration, built an entrepreneurial service platform and encouraged the participation of local aquaculture farmers. Guided by the requirements for establishing the whole industrial chain, and in line with standard of the provincial modern agricultural industrial park, the aquapark encompasses a modality of "tilapia production + processing + technology service + marketing brand". At present, the aquapark has set up a business model highlighting the complete tilapia production chain and attracted public and private partnership in resource mobilization.

In order to speed up the efficient and high-quality construction of the industrial park, a leading group and a coordination office was set up during the construction period. The district government assigned a senior officer to join the leading group, and a coordination office as monitor and supervisor. In 2018, the management office for the industrial park was established in order to coordinate the aquapark operation. At present, the government has committed USD 7.69 million (CNY 50 million) for 16 entities in the aquapark, to support the field construction and infrastructure.

Effluent treatment

Maonan District Tilapia Industrial Park has a high requirement for environmentally friendly aquaculture. The ecological tilapia aquaculture demonstration base was promoted with effluent treatment and an industrialized recirculating aquaculture system (Du *et al.,* 2020). In order to achieve high standard of pond tilapia aquaculture practices, precise feeding was adopted to reduce excessive nutrients, usually leading to a relatively high concentrations of nitrogen and phosphorus entering the natural environment through pond water exchange and sediment discharge. There were "six aspects" in effluent collection and treatment in the park; namely, full connection of the pipeline network, full collection of effluent, full treatment of effluent, discharge fully meeting standards, networking of monitoring stations and around the clock supervision.

According to the characteristics of the effluent from the aquapark and environmental protection inspection standard, the sewage treatment plant in the tilapia industrial park was technically renovated up-to-standard, ensuring that its discharge reaches the standard of Grade A and has the capacity to receive all upstream and downstream water. An automatic alert and early warning systems was equipped for real-time monitoring.

Recirculating aquaculture, using a water regulating system, was applied in the tilapia industrial park for efficiency and reuse of water in tilapia aquaculture (Schrader, 2023). With technical support, the aquaculture environmental factors (including water flow, water quality, light) and feeding are manually regulated to provide a favoured growing environment for tilapia, so as to achieve high quality, high yield and high efficiency. Therefore, the recirculating aquaculture system in the modern aquapark and the peripheral purification area were effectively used to improve production efficiency and control of aquaculture effluent from the aquapark.

Construction of a seed production base

In order to build a high-level tilapia production base, a quality seed supply base was urgently needed and cooperation with scientific research institutes was recommended as the most convenient approach. The local aquaculture leader in Maoming City, Mr. Li Ruiwei, visited the FFRC-CAFS and received full support from Professor Xia Dequan, an academician famous for tilapia breeding (Figure 8.2). The broodstock of *O. aureus* and *O. niloticus* were introduced for hybrid tilapia breeding (Abaho *et al.,* 2022) guaranteeing a high-quality, all-male tilapia seed supply. Later, the base was designated as a technical demonstration station for the national tilapia industry technology system, and dedicated to promoting high-quality tilapia seed supply and as a pilot trial station for tilapia research and development in China.

FIGURE 8.2
Technicians from FFRC giving on-site technical assistance

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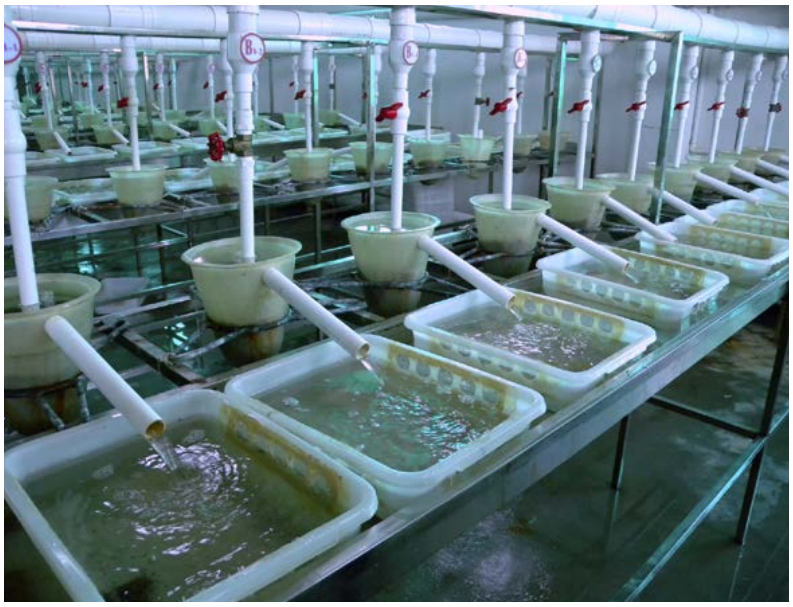
In 2002, the Sangao Breeding Base in Maonan District was accredited as a provincial tilapia breeding farm and rated as the "Guangdong Tilapia Science and Technology Innovation Center". In 2003, it won the "First prize for science and technology progress for the development and application of improved tilapia germplasm resource" for its success in breeding and aquaculture of hybrid all-male tilapia. In 2004, the "Sangao Aoxiong" (brand name) (hybrid *O. aureus* × *O. niloticus* all-male fingerling) won the "Guangdong Province (agricultural) famous brand product". In 2005, The "Sangao tilapia breeding base" was registered as a high-tech enterprise in Guangdong Province and a national tilapia breeding farm. In 2006, Sangao Company was praised by experts from the WorldFish Center for the success of its tilapia breeding programme. In 2007, Sangao Base made a breakthrough in the research on "all-male tilapia", which increased the male rate of tilapia fingerling from 95 percent to over 99 percent.

In 2009, the "Constant-temperature (28–30°C) tilapia seed incubation workshop" was developed at the Maoming Tilapia Industrial Park (Figure 8.3). The constant-temperature incubation system has greatly improved production capacity and resilience during the unstable weather, and the male ratio of tilapia.

FIGURE 8.3
Constant temperature incubation hatcheries unit



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The Industrial Park in the Maonan District has strong technical strength in tilapia seed production and aquaculture. The industrial park has built a tilapia genebank, which maintains more than 50 families of high-quality broodstock. In addition, it also owns independent intellectual property rights for the breeding of "GiAo Tilapia". In 2015, this strain was certified as a "new aquaculture strain" by the Ministry of Agriculture and Rural Affairs of the People's Republic of China.

The aquapark also owns a national-level tilapia hatchery farm, Maoming Weiye Tilapia genetically improved tilapia farm, and a provincial-level tilapia hatchery farm, Maoming Maonan Sangao genetically improved tilapia hatchery farm. The two tilapia seed farms are accredited as nationa,l modern aquatic seed production bases. Currently 800 million high-quality tilapia fingerlings are produced in the district, accounting for 51 percent of the total production of tilapia fingerling in Maoming City.

Construction of a commercial tilapia production base

Maonan District of Maoming is the core area of tilapia aquaculture and is also named as the "Town of Tilapia in China". The Maonan District Tilapia Industrial Park has a large aquaculture area of 3 386 ha, with an annual output of 38 000 tonnes of high-quality tilapia. The tilapia enjoyed the brand name of "Sangao Aoxiong" tilapia, which is a famous tilapia brand in Guangdong Province. Maonan tilapia Industrial Park has 12 professional cooperatives and 26 demonstration farms for healthy tilapia aquaculture accredited by the Ministry of Agriculture and Rural Affairs.

In the aquapark, 13 farms have been listed as provincial quality and safety aquaculture demonstration sites, and 17 breeding enterprises have been listed as a Production Demonstration Base participating in the "Safe Food and Famous Brand" Project in Maoming, "Guangdong Water-saving, Land-saving, High-quality, Efficient and Healthy Aquaculture Demonstration Base", "Guangdong Fishery Mechanization Demonstration Count" and "Maonan District Tilapia Provincial Modern Agricultural Industrial Park". There are more than 100 000 employees in the whole chain, with annual income of more than USD 4 615 (CNY 30 000) per capita.

Construction of a tilapia export base

To improve the marketing and economic return, the aquapark has been contracted to supply tilapia to processing and export enterprises in Zhanjiang. With its large size and excellent quality, tilapia from the aquapark have successfully passed the inspection and examination by the provincial fishery quality monitoring department. The aquapark has subsequently established its own processing company. At present, there are more than ten tilapia export enterprises in the aquapark, such as the Maoming Changxing Food Co., Ltd, Maoming Jincheng, Maonan Haimingwei, Guangdong Yujia Aquatic Products Co., Ltd., Maoming Shengxing Food Co., Ltd., Maoming Xinzhou Seafood Co., Ltd., Huazhou Xinhai Seafood Co., Ltd. and Maoming Haiyi Food Co., Ltd. The annual processing capacity is around 170 000 tonnes. The farmers and processing companies are enjoying the locally produced seed and short transportation distance, and the high-quality tilapia products with excellent food safety were welcomed at domestic and abroad markets.

According to customs statistics, in 2019, the total export of Maoming tilapia products was 98 000 tonnes, with a value of USD 323 million (CNY 2.11 billion), mainly exported to Mexico, the United States of America, Africa and other countries, ranking as one of the top cities of tilapia exportation in China (Zhang *et al.*, 2017). In the first half of 2020, Mexico became the largest importer of tilapia products from Maoming, with an import value of USD 47 million (CNY 310 million), exports to the United States of America were about USD 41 million (CNY 270 million), and exports to African countries were about USD 9.23 million (CNY 60 million).

Construction of a tilapia processing base

The tilapia aquapark has developed processing companies and a cold chain processing logistics demonstration base, optimized the production and equipment and facilities for processing, storage, cold chain distribution and transportation, and supported facilities for new industries emerging in the industrial park.

At present, the Industrial Park has a daily processing capacity of ten tonnes of tilapia, which is equal to the aquaculture output from 233 ha of tilapia growout ponds. At present, the processing plant has three advanced tilapia fillet production lines, with an annual production capacity of 10 000 tonnes, two frozen tilapia production lines, with an annual production capacity of 5 000 tonnes, three supported processing lines for fish meal using tilapia offcuts, with an annual production capacity of 30 000 tonnes and three fish oil production lines, with an annual production capacity of 7 000 tonnes. In addition to plain fish fillets, more flavoured products have been developed, including shallow skinned tilapia fillets, deep skinned tilapia fillets, super deep skinned tilapia fillets, unskinned tilapia fillets, frozen tilapia, fish oil, and fully defatted fish meal (Figure 8.4). All these products are certified/approved by the American Hazard Analysis Critical Control Point (HACCP), British global standard for food safety of British Retail Consortium (BRC), Aquaculture Certification Council (ACC) and Wal-Mart Ethical Standards (ES), and meet the quality standards for export. All companies offer a reliable guarantee for food safety and health, environmental protection, social responsibility and animal welfare involved in the entire tilapia industrial chain as well as the whole-process traceability system.

The Industrial Park has also introduced processing plants for tilapia filleting, such as Guangdong Yujia Co., Ltd, Guangdong Xinhai, Guangdong Universal, and Maoming Hongye. Currently, the annual tilapia filleting processing capacity is 70 000 tonnes, generating an output value of USD 98 million (CNY 640 million). Gelatin and collagen were also produced using tilapia skins and scales.

FIGURE 8.4
Tilapia processed products from the park

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Branding tilapia products

After the tilapia industry became a leading industry in Maoming, the local government developed the "One City, One Product" strategy and supported the creation of a well-known brand for the popularity of tilapia products to accelerate the development of the industry in the whole region. The government has provided special funds to organize activities to build the tilapia brand, such as publicity and promotion events, the construction of a tilapia culture exhibition hall, an ecotourism of fish–lotus culture trip in Heshui, Xinpo village, etc.

As the largest tilapia aquaculture and export processing base in China, Maoming City has implemented the strategies of "one town, one industry" and "one town, one product", strengthened branding and brand awareness and made full use of radio, television and exhibition for the publicity. In 2018, 12 tilapia products in Maoming City were awarded as famous brand products in Guangdong Province, and Maoming Tilapia was awarded a national-level brand.

At present, in order to cultivate a local, high-end brand, the Maoming tilapia industry has developed a unified trademark for tilapia products and simplified the registration of new tilapia products, so as to further improve the competitiveness in domestic and foreign markets. It has also established its own offline brand retail store, and tried to improve customers' brand loyalty.

8.3 MAJOR IMPACT AND INDICATORS

8.3.1 Economic benefits

In 2019, the tilapia aquaculture area in Maoming City was nearly 17 000 ha, with an output of 224 500 tonnes, accounting for around one third of the total output of tilapia aquaculture in Guangdong Province, and one eight of the total output of tilapia aquaculture in China, with an export volume of 108 000 tonnes and a value of USD 320 million (Gu *et al.*, 2019).

There is a new strain for aquaculture called "crispy tilapia" with firmer meat, commanding the higher price of USD 3.4–4.3 (CNY 22–28)/kg, as compared to USD 1.2–1.4 (CNY 8–9)/kg for normal tilapia. A deep pond aquaculture model has also been developed, with ponds around 3–3.5 meters deep, to rear large size tilapia, increasing stocking density from 30 000–60 000 fish/ha to 120 000–150 000 fish/ha, and the profit by USD 13 800/ha. Thus, if a farmer has 0.66 ha tilapia pond, his annual total output value could reach around USD 61 500 (CNY 400 000), and the annual net income to around USD 7 690–15 380 (CNY 50 000–100 000).

8.3.2 Social benefits

The Maonan District Tilapia Farming Park has promoted aquaculture in an area of more than 667 ha, engaging 13 000 people in the tilapia production chain, with around 1 800 farmers receiving training in tilapia farming technology, becoming the key players at the tilapia aquaculture base. The aquapark has extended tilapia farming to 520 poor households by providing free tilapia fingerlings, worth around USD 76 900 (CNY 500 000), and marketing service to the households selling more than 8 000 tonnes of tilapia with an output value of more than USD 9.2 million (CNY 60 million). The community service was greatly recognized as a social contribution to poverty reduction.

8.3.3 Ecological benefits

As a modern aquapark, the ecological benefits have been a high priority. First, the aquapark was well-planned, according to the local natural resources; a water purification area, accounting for 8–10 percent of the total aquaculture area, is provided, and, in addition, there are various aquatic plants and filtering species stocked in the surrounding areas, water exchange is regularly carried out, and the purification area and the aquaculture ponds have a well-arranged landscape. Second, the park promotes high-quality tilapia species, such as "Zhongwei No.1" (*O. niloticus*), "Sangao" hybrid all-male tilapia and GiAo tilapia, which has improved the pond production efficiency and health conditions and it is reported that the area of high-quality tilapia account for more than 90 percent of the aquapark zone. Third, improved pond management skills, such as increasing dissolved oxygen in the water to reduce the concentration of ammonia, nitrogen and nitrite, has also reduced the occurrence of diseases, thus lessening the use of antibiotics and other chemicals. It was recorded that the usage of fish medicine was less than one third of the previous practices.

8.3.4 Knowledge sharing and technical exchange

Since its establishment, the Tilapia Industrial Park has conducted more than 60 training sessions on tilapia aquaculture technology for more than 3 000 aquaculture technicians, both locally and from abroad, providing a good opportunity for knowledge sharing

and technology exchange among researchers, extension officers, farmers and brokers; the involvement of participants from more than 30 countries has greatly helped to extend the advancement of tilapia farming and management technologies worldwide (Figure 8.5 and Figure 8.6).

FIGURE 8.5
Participants of the 2019 "Belt and Road" developing country training course on tilapia breeding and high-yield technology visiting the tilapia aquapark

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FIGURE 8.6
Technical exchange with international participants

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8.4 POTENTIAL ADOPTION AND RECOMMENDATIONS

The tilapia aquaculture park has great advantage in promoting tilapia aquaculture with small-scale farmers; through its establishment, the organization work together to enhance the production efficiency and management, significantly improving the capacity of small-scale farmers in the supply of inputs, farm operation, marketing, and information exchange, etc.

8.4.1 Input from academia

The Industrial Park has strengthened cooperation with scientific research institutes, introducing technical support and farmed species selection, quality seed production, processing and ecological pond renovation, etc. Academia has carried out research programs in the aquapark and solved problems arising from zonation, production system and business model to cover the whole value chain.

In order to satisfy the younger generation as potential consumers, the development of instant food products was adopted and has achieved great success in marketing development, and e-commerce was also introduced in the tilapia aquaculture park, such as, the JD.COM, T-mall and other e-commerce platforms.

8.4.2 Building public–private partnerships

Public–private partnerships (PPPs) have been promoted for the tilapia aquapark establishment and business operation. The combination of the government guiding process and attracted private capital has greatly increased the investment in the aquapark; due to the limited government funding, private enterprises are an important force in agricultural industrialization. When the government has formulated the development plan, the private enterprises are encouraged to engage in the agricultural modernization programme and build partnerships between government, social capital and farmer households.

Based on the local conditions, the tilapia aquaculture park adopted the "company + base + farmer" model; the rights and obligations of companies and farmers in production, sales, service, benefit distribution and risk sharing are stipulated in the form of a contract, forming a relatively stable trading relationship and partnership, balancing the interests of companies and farmers. Farmers can obtain technical guidance for production, and solve problems encountered in aquatic product sales, while companies can organize farmers to carry out specialized production, allowing them to benefit from advantages in both scale and regional specialization.

8.4.3 Brand construction

Branded products can greatly enhance the market recognition and consumers' purchase preferences. A famous local brand adds value to the products and also improves the popularity and assurance of quality products. The tilapia aquaculture industrial park has played a key role in implementing the "one town, one product" strategy, actively coordinating the development of related upstream and downstream industries and creating a more dynamic and vigorous industry. This branding process is particularly beneficial not only for the domestic market but also the international market. In recent years, the aquapark has won the famous brand of tilapia in Guangdong province, as well as recognition of international market, for its quality and competent production standard.

8.4.4 Strengthening quality and safety control

Quality is essential to strengthen enterprise reputation and sustain its market share. The aquapark was firmly committed to meet the requirements for "quality", and actively guides enterprises to improve the awareness and capacity of quality control, establishing a self-inspection and self-control mechanism and testing centre for aquaculture product quality and safety.

A standardized protocol ensures the quality and safety of aquaculture products in the aquapark. Maoming Customs has set up strict control standards for tilapia products to meet the exportation requirements, and regularly examines the factories to ensure they are registered for exportation (Yang *et al.*, 2009). The inspection process includes video supervision, daily record supervision, an annual audit, certificate renewal review, and introduces a "withdrawal" mechanism for factories that cannot continuously meet the registration requirements.

There are also standards for the supply chain, which covers the supply of inputs, the farm production process, post-harvest and transportation. Each farm has a responsibility for quality and safety standard control in production, harvesting, product packaging and transportation. Inspection was introduced throughout the whole supply chain, and, in particular, the inspection was extended to seed and feed supply, and the certification and standard have to comply with the standard of the aquapark, as well as the national and international certification scheme.

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9. Guangdong Zhanjiang Shrimp Comprehensive Industrial Park

The Guangdong Zhanjiang Shrimp Industrial Park is located in Zhanjiang City, Guangdong Province, China. Since 1997, Zhanjiang City, Guangdong Province has vigorously supported the "One Shrimp" (*Penaeus vannamei*) project, relying on its unique marine resources and subtropical marine climatic conditions. Since 2002, it has focused on building a national shrimp industrial park according to the plans in the national "High innovative technology research program (plan "863 project" "Southern Base for Mariculture Seed Project"), and has developed and established a seed base as the core (Long, 2023). It is a comprehensive shrimp industrial park, focused on shrimp processing and export, covering key industrial nodes such as aquaculture bases, processing bases and trading centres. With the development of the industrial park, Zhanjiang has achieved "the first in China" in seven consecutive years, in areas such as aquaculture, shrimp feed, shrimp seed, shrimp output, processing capacity, shrimp export and 110 specialized markets, and has occupied an important share in the global shrimp supply market (Li, 2018). In 2019, the aquaculture volume of shrimp in Zhanjiang reached 250 000 tonnes, with an output value of nearly USD 1 billion and an annual processed capacity of shrimp of one million tonnes. Zhanjiang has the largest specialized shrimp trading market in China and 33 shrimp processing enterprises registered for export by China Inspection and Quarantine (CIQ). The export of shrimp products earned USD 460 million, accounting for nearly 30 percent of the China shrimp export share and 15.4 percent of the global share. It has created more than 1.8 million jobs, accounting for around 20 percent of the city's total population. Therefore, Zhanjiang City has been certified as a National Professional Demonstration Base for Foreign Trade Transformation and Upgrading by the Ministry of Commerce of the People's Republic of China and a "Global Aquatic Products Supply Chain Base" by the Société Générale de Surveillance (SGS), an international certification body.

9.1 DEVELOPMENT OF THE SHRIMP AQUAPARK

9.1.1 Main problems

Seed-related issues

Seed supply remains a constraint to the sustainable development of Zhanjiang shrimp industry. Due to the high cost of introduction of shrimp broodstock from abroad, most of the shrimp seed farms choose to independently cultivate shrimp broodstock with excellent traits. However, as a result of the limited number of originally introduced parental populations, in-breeding occurs, and the quality and stress resistance of the cultivated shrimp is poor and there are frequent outbreaks of whitespot disease. Consequently, the shrimp farming industry has suffered a heavy loss caused by poor shrimp seed, and the production and quality are also low, resulting in serious stagnation of the development of shrimp-related processing, export and associated industries. In order to achieve the healthy and sustainable development of the shrimp industry in Zhanjiang, it is necessary to prioritize solving the problem of seed supply, implement the protection, preservation, development and utilization of germplasm resources, introduce and develop excellent new strains through selectively breeding, and support the research on breeding of new shrimp strains (Luan and Kong, 2020).

Disease problems

The shrimp aquaculture model in Zhanjiang City is mainly pond aquaculture, and the production model is mostly in the form of subcontracting to households. In this process, most aquaculture farmers have limited knowledge and skills in shrimp farming, and poor management results in frequent disease occurrences. The main reasons are: first, the aquaculture method is inappropriate as most of the entities involved in shrimp aquaculture in China are blindly pursuing economic benefits; with an increase in stocking density, with the aim for higher production, the deterioration of the water quality and shrimp mortality usually results, leading to production losses. Second, the problem of overfeeding, causing high nutrient loading and eutrophication in the shrimp pond, resulting in pathogen proliferation and shrimp disease outbreaks. Third, the transfer of pathogens from imported shrimp seed also has been reported, resulting in the occurrence of large-scale outbreaks of shrimp disease (Sheng and Jie, 2020).

Environmental issues

In the past, the traditional shrimp aquaculture production was relatively extensive. During the rapid expansion of shrimp aquaculture, water exchange is accelerated due to large requirement for discharge irrigation. After years of aquaculture effluent being directly discharged into the surrounding water body without treatment, problems, such as poor water quality, pathogen spread and excessive use of antibiotics, has resulted. Sometimes the discharged water is pumped directly back to the pond, bringing greater risks to the sustainable development of the entire shrimp aquaculture industry.

9.1.2 Advantages and opportunities of aquapark development

Location

The aquapark is located on Donghai Island, Zhanjiang City, Guangdong Province, China. Donghai Island lies in the east of Leizhou Peninsula, with latitude 20°55'–21°55'N and longitude 110°11'–110°21'E. It is an important seaport and is also the import and export hub of the Golden Triangle Economic Zone in Southwest China. The island is relatively remote and far away from industrial and agricultural production areas and towns, and enjoys an environment free of pollution and transmitted pathogens from the mainland. At the same time, it is easy and safe to extract seawater and freshwater, which is convenient for the cultivation of shrimp broodstock and conducting breeding research, etc.

Climate

The aquapark has a tropical northern monsoon climate, which is regulated by the marine climate all year round; it is not severely cold in winter nor intensely hot in summer. The annual average temperature is 22.7–23.5 °C, the annual average rainfall is 1 395 – 1 723 mm, and the annual average sunshine hours are 1 714 – 2 038 hrs. The rainy season is from April to September, with the most rainfall in August and least rainfall from October to March. The climate conditions are suitable for growing and breeding shrimps.

Policy

The Zhanjiang Municipal Government attached great importance to the development of the shrimp industry, actively promoting the infrastructure development of an aquaculture base, processing base and trading centre. The aquapark takes advantage of the national high-tech innovative project (Plan 863) "Southern Base for Mariculture Seed Development", focusing on building the entire industrial chain of the shrimp industry, making every effort to build a high-standard industrial shrimp park. The construction of the shrimp seed production base was the core component and aimed

to create a world-famous brand for shrimp processing and exportation. In order to promote the sustainable and high-quality development of the shrimp industry in Zhanjiang, the Zhanjiang Municipal Government has supported a special promotion project on the Cultivation Plan of Zhanjiang National Demonstration Base for Foreign Trade Transformation and Upgrading of Aquatic and Marine Products (2012–2020), which has included several shrimp aquaparks on the east and west coasts of the Leizhou Peninsula, such as Zhanjiang National Aquatic Products Processing Demonstration Base, Zhanjiang South International Aquatic Products Trading Center, Xiashan Aquatic Products Wholesale Market, etc.

Capital investment

There are more than 300 companies in the shrimp industrial chain in Zhanjiang City, including shrimp seed production, feed, chemicals and medicines, growout aquaculture, processing and exportation. As of today, the aquapark has attracted more than USD 21.5 billion (CNY 140 billion) investment of social capital, making this a significant success story. It has developed into the largest shrimp industrial base in China and has gradually become a shrimp trading centre in China and Southeast Asia. The advantages of industrial clusters are becoming more and more clear; with the products of the park being exported to the United States of America, Japan, Russian Federation, Australia, Mexico, Canada, Republic of Korea, Malaysia, European Union (EU) and other countries and regions, this export-oriented industry has brought huge international market opportunities for the aquapark.

9.2 PARK PLANNING AND CONSTRUCTION

9.2.1 Scientific planning and feasibility study

Organizational form and implementation planning

The Guangdong Zhanjiang Shrimp Industrial Park is a national, modern agricultural industrial park, mainly built in Zhanjiang City. In order to address the main difficulties and problems faced in the development of the shrimp industry, the local government has promoted the aquapark with advantages and opportunities to attract investment into feed production, aquaculture equipment, aquatic animal veterinary products, logistics and service agents, which support shrimp aquaculture and processing in Zhanjiang. The main goal is to build an aquapark that adapts to the development of a modern agricultural industry zone, integrating export-oriented shrimp seed production, shrimp growout, processing and exportation. With the strong support of the Zhanjiang Municipal Government, preferential policies for the development of agricultural industries, such as land use, tax exemption and reduction have been introduced, and the aquapark has been designed as a comprehensive industrial park integrated with primary, secondary and tertiary industries. In the initial stage, the aquapark included shrimp seed production, growout aquaculture and processing bases, and a trading centre.

In 2002, the lead company of the shrimp aquapark, Guangdong Hengxing Group, received a grant from the Ministry of Science and Technology to implement the "Southern Base for Mariculture Seed Project" under the "National High-tech Research and Development Plan (Plan 863)". The "Shrimp seed production base" in the aquapark covers an area of 3 313 ha, with a total area of 8 000 m^2 of laboratory facilities, training and expert's villa buildings, 166 500 m^2 of shrimp selective breeding ponds, 3 000 m^2 of shrimp seed production workshop and 1 500 m^2 of nutrition experiment workshop, and it is equipped with advanced test instruments and equipment (Figure 9.1).

As one of the three seed production bases under the Hengxing Group, the seed base mainly focuses on the breeding of high-quality aquatic products, broodstock cultivation and larval production. It is also designated as one of the comprehensive experimental

FIGURE 9.1
Shrimp seed production base in the Guangdong aquapark

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stations of the National Shrimp and Crab Aquaculture Industry Technology System. The seed base has multiple departments such as breeding, feed, microbial testing facilities, growout aquaculture and disease prevention. Each department has full-time technician, and 3–5 technical assistants. The seed base was supporting the research and development of special formulated feeds and microbial agents for shrimps, focusing on the selective breeding of new specific pathogens free (SPF) and improved disease resistance strains. Capacity building for the seed base staff was carried out through technical training to meet the demand for the supply of production inputs, such as shrimp seed, feed and microbial agents.

To achieve greater advances in science and technology, the aquapark introduced industry-university-research cooperation agreements with scientific research institutions. The famous institutes included Sun Yat-sen University, Ocean University of China, Guangdong Ocean University, South China Sea Institute of Oceanology, the Chinese Academy of Sciences, South Aquatic Products Research Institute and the Chinese Academy of Water Sciences.

In order to speed up the efficient and high-quality construction of the industrial park, the government has taken responsibility for overall planning, coordination and monitoring. A special aquapark management committee and work team were established with the representatives of relevant enterprises in seed production, growout aquaculture, processing and trading (Figure 9.2).

The management and operation of the aquapark is coordinated by the government through the Management Committee. In order for new enterprises to enter the aquapark, a vote for the decision will be introduced at the Management Committee meeting. In the meantime, the government has been highly responsible for coordinating the allocation of land and approval of permits and subsidy funds. Enterprises were encouraged to be responsible for the field construction and business management. To attract more investment, government has distributed subsidies which are equivalent to 30 percent of the total investment of enterprise construction capital.

FIGURE 9.2
Processing enterprises in the aquapark (Guolian Aquatic Processing workshop)

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9.2.2 Aquapark construction and implementation

Seed production and supply

Since 2002, the aquapark has cooperated with Sun Yat-sen University under "The shrimp seedling base" (Plan 863) to conduct selective breeding of shrimp, focusing on disease resistance and growth. Through multi-generation population selection and family breeding, it has obtained a new strain of *P. vannamei* called "Zhongxing No.1" (Figure 9.3). The aquapark can cultivate specific pathogen free (SPF) broodstock of *P. vannamei* and breed SPF nauplii and shrimp larvae, through selectively breeding programmes (Figure 9.4). The project implementation in the aquapark has not only promoted the shrimp

FIGURE 9.3
"Zhongxing No.1" Shrimp strain with high disease resistance

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FIGURE 9.4
Hengxing "Zhongxing No.1" Shrimp post larvae

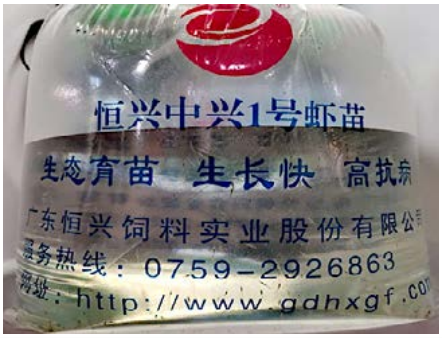

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FIGURE 9.5
An award showing the popularity of shrimp feed Kangxia peptides

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industry development in Zhanjiang City, but also made significant contributions to the shrimp industry in Guangdong Province and even the whole country.

Feed production and supply

Beside the high-quality shrimp seed supply, the aquapark has also established a long-term university-enterprise cooperation model on nutrition and disease prevention. The research teams of Sun Yat-sen University, Guangdong Ocean University and other universities have conducted research to tackle digestive system diseases which often occur in the shrimp aquaculture. With the promising scientific research results, the aquapark provided necessary facilities for a trial test. Following research and development, the aquapark have developed a series of functional feeds targeted at reducing the incidence of digestive system diseases, i.e. the Yixia peptides and Kangxia peptides (Figure 9.5). Compared with the general shrimp feed, the functional shrimp series feed has a higher nutritional value and an FCR, with an average of 0.9–1.1, while that of the general high-grade shrimp feed is at the level of 1.2–1.4, effectively shortening the growout cycle by 10–20 days, thus reducing the risk of infection in the long shrimp culture cycle, and also feed costs. In addition, with the improved feed, it has been shown that the liver and pancreas of shrimps were healthy, the intestines were obviously thickened, the survival rate of shrimp was improved, the growth rate increased, the vitality was enhanced, the muscle was firm and transparent and the body color was fresh. The results have also shown an improved pH in the intestines of shrimps, which inhibits the development of pathogens in the intestinal tract.

Water quality improvement

In order to improve the water quality in shrimp ponds, the aquapark has also attached importance to research on and the development of water quality improvers, including water treatment, pond sludge, decomposition products (to reduce organic contents and improve nutrient recycle), anti-stress products, premix products, alternatives to antibiotics, the prevention and control of early mortality syndrome (EMS), and other products. Based on the micro-ecosystem at the pond bottom, the biological bottom improvement approach was developed for the first time, and a series of products were developed, such as algin, effective fertilizer and effective microbials (EM), calcium and magnesium compounds, etc. There are also biological products for anti-stress, diseases and other stresses, such as Yuxia'an, three yellow powder and garlicin for medicated feed.

To improve the technical knowledge of the farmers, training and exchange were organized. The guidance of the core technical concept of "disease prevention, water treatment and pond bottom improvement", various technical service guide schemes have been developed for different models.

Growout shrimp aquaculture and supply

In order to achieve complete export-oriented businesses operations, the aquapark is dedicated to developing a replicable and promotable growout aquaculture model, which was guided with "good seeds, good feeds and good method". The core growout aquaculture base is located on the east and west coasts of Leizhou Peninsula, with a

FIGURE 9.6
Shrimp growout ponds in the Hengxing aquapark

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total area of about 1 400 ha (Figure 9.6 and Figure 9.7). The shrimp ponds are high-level coastal ponds with standardized modification and equipped with modern aquaculture facilities, such as irrigation, aeration, automatic feeding, etc. The annual production was about 10 000 tonnes of high-quality shrimps.

The growout aquaculture was extended to an area of about 200 kilometers around the shrimp seed base. The park integrates resources and has coordinated planning, aiming for high-value industry through processing and export-oriented operations. To guarantee the quality and sustainability, the aquapark has applied a monitoring mechanism, such as an invited third-party testing agency for audit and testing. The Rules for the Inspection of Frozen Shrimp for Export (SN/T 0384-1995) and the corresponding food export standards of the United States of America, EU and other recipient countries were adopted and certified with commercial business requirements, and the shrimp were welcomed by the buyers and consumers worldwide.

FIGURE 9.7
A shrimp growout pond

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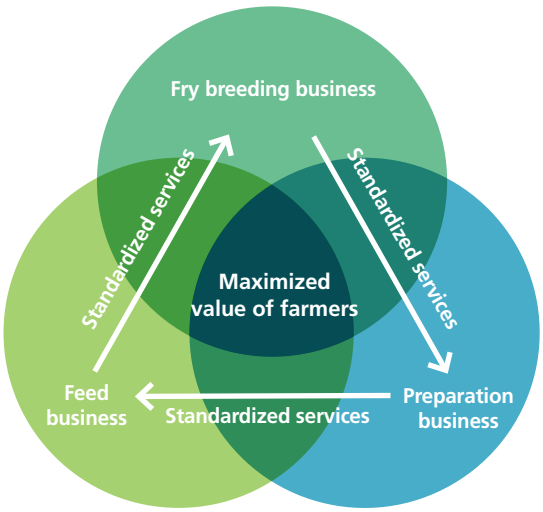
FIGURE 9.8
Breeding Standardization Service



Source: Prepared by J. Qiang.

Aquaculture standardization service

In 2014, the aquapark formulated and issued the national seed raising standard "*Technical Regulations for Larval Rearing of Whiteleg Shrimp/Pacific White Shrimp* (Litopenaeus vannamei)", and established a standardized service management platform system. The technical regulation covers 396 items and operation procedures in five major aspects, including "shrimp rearing, shrimp hatching, feed processing and nutrition, biosecurity and welfare, water treatment, and disease prevention and control", providing farmers with standardized services and comprehensive solutions (Figure 9.8).

The Seed Production Base in the aquapark mainly focuses on seed supply, supplemented by feed business, develops bio-products and premix, implements the operation model of "company + base + farmer + standard + service" and provides an integrated aquaculture service platform of "feed + seed + bio-products and premix + aquaculture technical service". The operation model of the "company + base + farmer + standard + service" is as follows: supported by the Seed Production Base in the aquapark, individual farmers are contracted to receive high-quality seed by the shrimp breeding base, feed by the feed enterprises affiliated to Hengxing Group, and bio-products and premix by the enterprises affiliated to the group. The farmers would also receive technical guidance on standardized operating procedures and access to the quality management platform. In a complete cycle, an integrated technical service and input supply were formed to ensure the sustainability of the business.

Shrimp processing

The aquapark has world-class shrimp processing enterprises, which serve as the national aquatic product processing demonstration base. The processing enterprises have established a highly developed quality and safety control system to carry out comprehensive and effective quality and safety control on aquatic product processing, and have successively been accredited by the US HACCP, Codex Alimentarius Commission (CAC), ISO/DIS:22000 food safety management system, Aquaculture Certification Council (ACC) and Best Aquaculture Practice (BAP).

The processing enterprise collects shrimp from contracted shrimp farmers in the aquapark. The contracted farmers receive high-quality shrimp seed from the shrimp seed base, ensuring that the cultivated growout shrimps are collected and processed within the aquapark, to guarantee the benefits of the farmers.

The processing enterprises have developed a series of products, such as whole shrimp, headless shrimp, peeled shrimp, butterfly shrimp, fantail shrimp, bread shrimp, shrimp for sushi, instant shrimp food, etc. (Figure 9.9). It is reported that the processing capacity and cold-chain storage was ranked as a top industry in China.

Product marketing

Quality product is the top consideration in marketing. The aquapark has supported the processing enterprises, actively establishing the whole product chain traceability system, which covers the whole supply chain from the pond to the dining table (Figure 9.10). A fully mechanized independent, contact-free production line minimizes the risk of

contamination, ensuring a completely controlled production procedure.

The aquapark takes advantage of market centres in Zhanjiang city, such as the South International Aquatic Products Trading Center and Xiashan Aquatic Products Wholesale Market (Figure 9.11). All shrimp products were welcomed by domestic and international consumers, including large- and medium-sized cities in China and are exported to the United States of America, EU, Canada, Africa, Russian Federation, Australia, Japan, Republic of Korea and Southeast Asia.

Knowledge sharing and technical exchange

After 30 years of development, the aquapark has become the most highly developed complete shrimp industry cluster in China, and also a base for integrated aquaculture, scientific research, demonstration and training. In the past five years, it has received more than 1 600 guests, experts, professors and aquaculture technicians from home and abroad, and trained more than 10 000 shrimp aquaculture farmers. It has provided farmers with high-quality seed, supporting technical services and relevant information, and achieved popularity in the shrimp industry at home and abroad, which not only promotes the healthy and sustainable development of shrimp aquaculture, but also the experience of the development and management of a modern shrimp industry cluster. It could serve as an example for small-scale farmers and shrimp-producing countries and regions in Africa, Asia and Southeast Asia.

9.3 MAJOR IMPACT AND INDICATORS

9.3.1 Economic benefits

The aquapark has annual capacity to cultivate 100 000 pairs of *P. vannamei* SPF broodstock, 30 billion SPF nauplii and 2 billion SPF shrimp seeds. Every year, 20 000 pairs of SPF shrimp broodstock are selected and bred,

FIGURE 9.9
An example of a frozen shrimp product for export

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FIGURE 9.10
Major shrimp marketing partners in China

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FIGURE 9.11
South China International Aquatic Trade Centre in the Aquapark

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producing 5 billion specific pathogen free (SPF) nauplii and 1 billion shrimp post-larvae, with an output value of about USD 30 million (CNY 200 million). The total shrimp farm area reached 100 000 ha, and the total growout production value reached USD 780 million (CNY 5.1 billion).

With the technical service of the aquapark, a new feeding model "1121" for winter shrimp was introduced, which implies using Zhongxing No.1, mixed 10 barrels of Yixiabao peptide in 100 bags of conventional feed and 200 bags of functional feed, the farmer could achieve a harvest of 7500 kg/ha, and an average output of USD 46 000/ha (CNY 20 000/ha).

9.3.2 Social benefits

The major benefits to society are the job opportunities and income generated from the whole value chain. The seed and feed production, bio-products, processing and sales operations of the shrimp value chain have greatly contributed to local society. As of 2021, it has provided job opportunities to a total of 370 000 people, including direct employees in the aquapark and those in its associated supply chain. For the local small-scale farmers, the "1121" feeding model has been adopted by more than 1 100 farmers, which helps the farmers increase their income by more than 50 percent. As a result of the comprehensive aquapark establishment, Zhanjiang has achieved success in increasing local employment and the income of small-scale fishers and developed the sustainable development of Zhanjian's "comprehensive shrimp industry zone" and "export-oriented shrimp industry".

9.3.3 Ecological benefits

Environmental protection and restoration were a top consideration in the aquapark development in Zhanjiang. Several aspects were highlighted in the eco-system approach of the aquapark design and operation: first, the ecological aquaculture model was adopted for shrimp aquaculture, and the environment friendly inputs and discharge are well monitored and controlled. Second, aquaculture effluent treatment and water recycling facilities were provided, such as aeration, sedimentation collection, nitrification and denitrification balance, in order to meet the standard and regulations (set for discharge). Third, the aquaculture effluent discharge is tracked and monitored, with the help of real-time water quality monitoring equipment and systems. Fourth, there are government supported sewage water networks connected to the aquapark to separate the sewage water treatment. The environmental protection department of the government regularly supervises the discharge of effluent and waste in the aquapark and overhauls the drainage pipe network system, thus maintaining the ecological landscape of the entire aquapark (Figure 9.12).

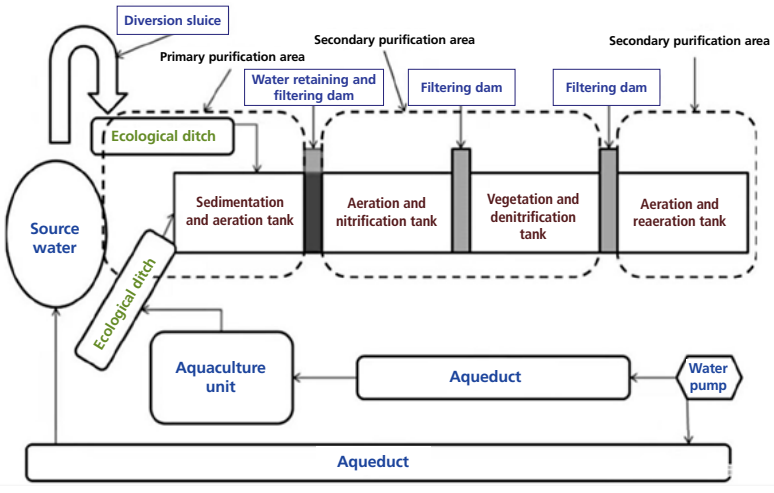

FIGURE 9.12
Shrimp aquaculture effluent treatment and recycling network

Source: Prepared by B. Li.

9.4 POTENTIAL ADOPTION AND RECOMMENDATION

9.4.1 Worldwide applicability

During the development of the shrimp aquapark, there has been exchange and cooperation with 14 international institutions such as the University of Hawaii, the University of Oslo, and International Business Machines Corporation (IBM) in Research and Development projects. There is also positive discussion on the promotion of the aquapark model in other countries abroad. There are pilot and demonstration centres in Viet Nam, Malaysia, Indonesia and other countries, and the Hengxing Group has provided technical support in planning and design services for the construction of aquaparks. The Group has successfully supported Egypt to build an aquapark, with a total investment of USD 90 million (Box 2). It is reported to be the largest aquaculture project of China's sustainable aquaculture industry abroad.

9.4.2 Public–private partnership investment and technical support

The construction of the shrimp industrial park requires advanced technology and high investment, so high-level enterprise investments are key to the success of the industrial park. The Guangdong Hengxing Group Co., Ltd. is a leading private enterprise group, integrating seed production, feed production, aquaculture, processing of aquatic products and import and export trade. It has established a complete industrial chain, using abundant funds, adopting a long-established management model that focuses on in–depth cooperation with universities and institutes in industrial technology with strong technical strength. The standardized service management platform system provides integrated aquaculture services including "feed supply + seed supply + supply

BOX 2

Hengxing, China – Egypt National Aquaculture Industrial Park

The Hengxing, China – Egypt National Aquaculture Industrial Park Project is located in the estuary area of the Nile River that flows into the Mediterranean Sea (Figure 9.13). The aquapark covers an area of 900 ha and is comprised of tilapia and shrimp aquaculture ponds. The project is funded by the Egyptian government.

The Hengxing Group is responsible for the planning, design, supply and installation of equipment, technical training and operational guidance, as well as the transfer of technology and application of the standards of Hengxing aquaculture industry chain as a whole. The aquaculture industrial park includes fish and shrimp hatcheries, feed mills, land-based growout farms, deep-water cage farms, aquatic products processing plants, ice production plants, foam box production plants, central laboratories, effluent treatment plants, fish meal production plants and woven bag production plants. The aquapark became operational in November 2017, when the first phase of the project was completed. The Egyptian President El-Sisi attended the opening ceremony and met with Hengxing Chairman Mr Chen Dan and his team. The project has become the largest aquaculture industrial park in Egypt, and even in the Middle East, creating more than 3 000 jobs. The feed mill produces 120 000 tonnes of fish feed and 60 000 tonnes of shrimp feed annually, and the daily processing capacity of the processing plant is 100 tonnes (tilapia and shrimp). The aquapark enables the production of processed products which not only meet local needs, but also could be exported to neighbouring countries.

The Hengxing Group has established in Egypt a complete aquaculture industrial chain from scratch, and which has now become a world leader in its field. The successful operation of the industrial park has greatly improved the supply capacity of Egypt's domestic aquatic products, improved the technical level of aquaculture and processing in Egypt, and laid a foundation for the development of Egypt's aquaculture industry.

FIGURE 9.13
Egypt National Fishery Industrial Park

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of bio-products and agents + aquaculture technical services". At the same time, with three seed production bases + three aquaculture bases + eleven feed enterprises + four processing enterprises under the Group, it has been integrated into an aquaculture park with comprehensive capacity, covering the whole industrial chain, and its products such as *P. vannamei, P. monodon, Macrobrachium rosenbergii* and tilapia are qualified for exportation to the United States of America, Canada, the European Union, Japan, Southeast Asia and other countries and regions.

9.4.3 Government policy support and science-based decision-making processes

A strong political enabling environment is essential for the success of the establishment and operation of the aquapark, providing a guarantee for the public private partnership in aquaculture development. The strong will of the government to achieve food security and improve livelihoods is critical when taking into consideration the local

circumstances and environmentally-friendly supply chain. It is also important for local government to provide investment for infrastructure, such as use of land, roads, irrigation, and favoured policy support. It is also important to use a science-based decision-making process, involving academia, universities, and adopt a participatory approach when formulating science-based planning, construction and implementation, and to make full use of government policies and enabling conditions, and make corresponding reserves in terms of funds, technology, talents and management.

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This manual seeks to facilitate the exchange of knowledge and successful practices in aquapark planning, establishment, operation and management, providing references and technical support for the effective organization of small-scale farmers to contribute to sustainable aquaculture development. By sharing the insights gained from the development of the aquapark system in China, this manual is designed to strengthen the capacity of small-scale aquaculture farmers operating within an aquapark. The information presented in this manual are intended to support informed decision-making in the public and private sectors, including policymakers, small-scale aquaculture farmers and private enterprises. It provides a comprehensive, objective, and applicable guide for the effective implementation of this model to advance sustainable aquaculture development.

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