Development of Smart Food Value Chain Intervention Models for the Milkfish Industry in Region 1, Philippines

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ABSTRACT

Milkfish production is an important sector of the Philippine aquaculture industry. The Ilocos Region (Region 1), particularly the province of Pangasinan, is the country's largest producer of milkfish. However, production and environmental constraints confront the milkfish industry, such as insufficient egg supply, degradation of water quality, limited processing facilities and technology, and noncompliance of small-scale processors to food safety standards. To achieve sustainability and resilience, the Department of Science and Technology-Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (DOST-PCAARRD) commissioned a value chain study to examine the current and "new normal" threats posed to Region 1's milkfish industry. The study aims to develop intervention models to create a "smart" milkfish value chain. In a smart value chain, the industry players access quality information better, and there are technological innovations along the chain. Various milkfish industry players, such as hatchery operators, growout operators, market intermediaries, retailers, and processors, were interviewed for the study. Furthermore, consultations with various stakeholders, such as relevant government agencies and industry practitioners, determined the most suitable solutions to address the value chain's core issues. The value chain analysis surfaced a need for an effective strategy to help farmers adopt technological solutions. In addition, the efforts of various support institutions should be harmonized and rationalized. We are proposing these interventions: (1) create a regional milkfish seedstock command center; (2) implement a science and technology community-based farm; and (3) establish a *bangus* processing enterprise development hub.

Keywords: sustainability, aquaculture, hatchery, technology

JEL codes: O13, O38, Q16

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INTRODUCTION

Milkfish (*Chanos chanos*) is the most popular fish species cultured in the Philippines (Santos, Basiao, and Quilang 2019; Su, Lee, and Liao 2002; Tan et al. 2017; Yap et al. 2007). With an average per capita consumption of 3.6 kg/year, milkfish (commonly called *bangus* in Filipino) is the most consumed food fish in the country (Salayo et al. 2021). It is farmed in fresh, brackish, and marine waters throughout the archipelago, although Region 1[1] is the largest producer. The industry began as early as the 15th century (Yap et al. 2007), but production and processing technologies are continuously evolving. The Department of Agriculture (DA)-Bureau of Fisheries and Aquatic Resources (BFAR) has been at the forefront of developing the Philippine milkfish industry. On the other hand, value chain actors composed of seedstock producers, growout operators, market intermediaries, and processors provide employment opportunities and facilitate food security by supplying affordable protein sources.

Nevertheless, the Coronavirus disease of 2019 (COVID-19) affected various stakeholders' efforts in developing the milkfish industry. The pandemic amplified supply chain inefficiencies, value creation restrictions, and inclusivity issues. The Department of Science and Technology (DOST) responded to the challenge through a broad program developing smart food value chains. A smart food value chain is characterized by technology adoption and better access to high-quality information along the chain. However, operationalization of the program is not yet clear; and interventions identified in the earlier stages of proposal packaging need to be revisited. This study commissioned by the DOST-Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD) analyzed milkfish value chain and developed intervention models to build a smart food value chain.

1 One of the administrative regions of the Philippines composed of four provinces—Ilocos Norte, Ilocos Sur, La Union, and Pangasinan

REVIEW OF LITERATURE

The aquaculture industry is an important economic sector in many Asian countries including China, Indonesia, Thailand, Vietnam, and the Philippines. Hence, several scholarly articles on the aquaculture value chain have been written in recent years.

Value chain is defined by Ponte et al. (2014, 52) as the "full range of value-adding activities that firms, farmers, and workers carry out to bring a product from its conception to its end use and beyond." Social relationships and norms within the chain influence the participation of poor households (Rosales et al. 2017). This insight allows researchers to understand the potential impact of value chain upgrading on poverty alleviation.

Milkfish production is prevalent in Indonesia, the Philippines, and Taiwan (Su, Lee, and Liao 2002). Various culture methods are practiced depending on the natural resources available. For example, Jaspe, Caipang, and Elle (2011) showed how the polyculture of white shrimp (*Litopenaeus vannamei*) and milkfish in the Philippines could be a strategy for efficient utilization of natural food production in ponds. On the other hand, Holmer et al. (2002) revealed that fish pen culture in Bolinao, Pangasinan, Philippines leads to greater impacts on benthic carbon and nutrient cycling compared with suspended cage culture. Several studies were later conducted to investigate sustainable solutions to the negative impacts of milkfish production on marine biodiversity and coastal health. For example, Sugimoto et al. (2016) explored co-management in the governance of the aquaculture industry in two municipalities of Pangasinan, Philippines.

Saraswati and Suadi (2020) investigated the milkfish supply chain model in the Beringharjo market in Yogyakarta, Indonesia. They identified four actors in the milkfish supply chain model in the study area: suppliers, fish processors, sellers/traders, and ultimate consumers. The information in the milkfish supply chain comes primarily from the processor. In another study, Silalahi et al. (2018) utilized the interpretive structural modeling (ISM) to analyze the milkfish supply chain of an enterprise in the district of Sidoarjo, Indonesia. The study recommended some managerial strategies, which include relationship management with stakeholders, capital infusion, and market development.

The state of the Philippine milkfish aquaculture industry presented by Marte (2010) noted that milkfish farming since 1990 had an average annual value of PHP[2] 10 billion. In another study, Tan et al. (2017) investigated the milkfish attributes that consumers value in the province of Iloilo, Philippines. The attributes that affected price are colors of eyes and gills and fish size. The results of the study could serve as a vital source of information in upgrading the milkfish production processes. German and Catabay (2018), using data gathered from local producers in the province of Pangasinan, showed that the type of food, size of egg/fry, frequency of feeding per day, schedule of water replacement per week, volume of eggs, and water level affect productivity.

Ahmed et al. (2001) comprehensively assessed the milkfish fry resource in the Philippines. A survey of 194 fry gatherers in five provinces across the country showed their strong perception of a declining supply of wild fry because of pollution, degradation of coastal habitats, overexploitation of fishery resources, and decline in the number of sexually mature milkfish.

Salayo et al. (2021) conducted the most recent value chain analysis of the Philippine milkfish industry. The study presented the value chain of the clustered milkfish production system in the Philippines. Unlike previous studies, the paper focused on the primary production segment, which comprised breeding, hatchery, nursery, and grow-out operations. Salayo et al. outlined several recommendations on how to sustain the industry through investments in breeding and hatchery operations.

Existing literature presented a number of key challenges in the aquaculture industry in Asia and the Philippines:

a. Stringent import regulations, food safety standards, and third-party certification of key markets such as the US and EU have led aquaculture producers to seek new markets (Jespersen et al. 2014).
b. The "realization that aquaculture activities are not high on the [government's] agenda…" is a common obstacle to value chain upgrading (Lim 2016, 196).
c. Disruptive digital platforms and technologies in aquaculture trade and logistics have been dramatically changing the performance, structure, and conduct of value chains (Bush et al. 2019).
d. The limited demand for quality from customers and weak national regulatory capacity (e.g., poor enforcement of food safety standards) leads to a lack of upgrading in the value chain (Ponte et al. 2014).
e. Milkfish seedstock production in the Philippines cannot meet the domestic demand for eggs, fry, and fingerlings (Ahmed et al. 2021; Salayo et al. 2021; Santos, Basiao, and Quilang 2019).
f. Importation of milkfish fry may become limited due to a possible milkfish fry export ban by Indonesia (Santos, Basiao, and Quilang 2019).
g. The technological development in milkfish production is not always integrated effectively into actual industry practice (Su, Lee, and Liao 2002).

Past studies in the aquaculture value chain observed and/or recommended the following courses of action to address the issues that the industry faces:

a. Establish a lobby group to enhance the value chain players' ability to bargain support from the government (Lim 2016).
b. Improve product, process, volume, and/or variety through technological intervention (Ponte et al. 2014).
c. Create a robust legal framework and effective legal basis of quality control to improve products and processes (Ponte et al. 2014).

[2] Philippine peso; USD 1.00 = PHP 55.62 (2023) (https://www.forbes.com/advisor/money-transfer/currency-converter/php-usd/)

d. Implement strict regulations on size limits of harvest, certification processes, seasonal closures for selected species, and habitat protection among small-scale fisherfolk (Rosales et al. 2017).
e. Provide small-scale fisherfolk with postharvest and credit facilities (Rosales et al. 2017).
f. Engage in vertical integration to gain more control in the value chain (Kaminski et al. 2018).
g. Integrate small-scale producers in the value chain through the development of cold chains and logistics (Kaminski et al. 2018; Saraswati and Suadi 2020).
h. Develop value-added products from excess milkfish production to improve their marketability to the younger generations and the export market (Marte 2010).
i. Invest in integrated breeding and hatchery facilities through public-private partnerships to secure seedstocks for a sustainable and self-reliant milkfish aquaculture industry (Ahmed et al. 2001; Salayo et al. 2021).
j. Ensure favorable investment climate in the upstream stages of the milkfish value chain to foster the establishment of more breeding and hatchery facilities (Salayo et al. 2021).
k. Implement strict regulations on the catching of sexually mature milkfish (locally called *sabalo*), destructive fishing, fry gathering, and fry smuggling (Ahmed et al. 2001).

Despite considerable studies on the aquaculture, fisheries, and milkfish value chains, research on the development of a smart food value chain for milkfish does not exist. According to Ryciuk (2018), a smart supply chain, characterized by better access to high-quality information, is essential in today's uncertain and turbulent environments. A smart supply chain is one that makes full use of new technologies, thus making it "interconnected, automated, intelligent, instrumented, integrated, innovative, and concentrated on an individual client's needs." Bush et al. (2019) implied the importance of smart value chain studies when they recommended that research on value chain should focus on sector-wide innovations, among others. This type of research will contribute to the design and implementation of public and private interventions, expanding and regulating the aquaculture sector. Furthermore, Zhang, Yang, and Yang (2023) asserted that smart supply chain management has become an important research topic under Industry 4.0. Their paper highlighted the need for more research on the different strategies for adoption of new technologies in supply chains. Hence, this study attempts to contribute to existing literature by analyzing the milkfish value chain and formulating intervention models to facilitate access to information and technology adoption.

METHODOLOGY

Analytical Framework

Porter (2001, 50) introduced the value chain as a systematic way to examine how the activities of a firm are performed. The approach involves disaggregating a firm into "its strategically relevant activities in order to understand the behavior of costs and the existing and potential sources of differentiation." The value chain of a firm is just one component of the value system, which represents a larger stream of interconnected activities in the economy. The value chain of suppliers, also called the upstream value, creates and delivers the inputs to the primary producers. On the other hand, the channel value, also called downstream value, is the chain that ensures the delivery of the product to the final user. All the activities in the chain are supported by other activities such as technology development and procurement. This paper used the value chain framework of Porter to develop intervention models for milkfish in Region 1. Figure 1 shows the generic value chain mode.

Operationalizing the framework of Porter (2001), this study developed a general approach composed of two phases (Figure 2). This approach aims to systematically analyze the root cause of the problems in the milkfish value chain and formulate models to address the challenges.

Phase 1

The first phase of this study involved conducting industry assessment through the following steps (Salayo et al. 2021):

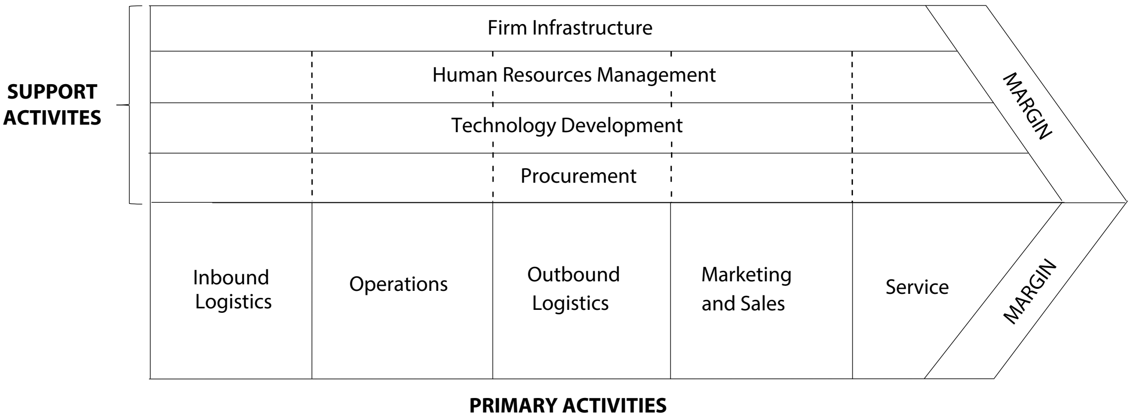
Step 1: Map the chain. Determine the flow of inputs and outputs in each segment of the value chain.

Step 2: Analyze the chain. Describe the production capacity and profitability of enterprises along the chain.

Step 3: Understand value. Determine the value addition at each stage of the value chain.

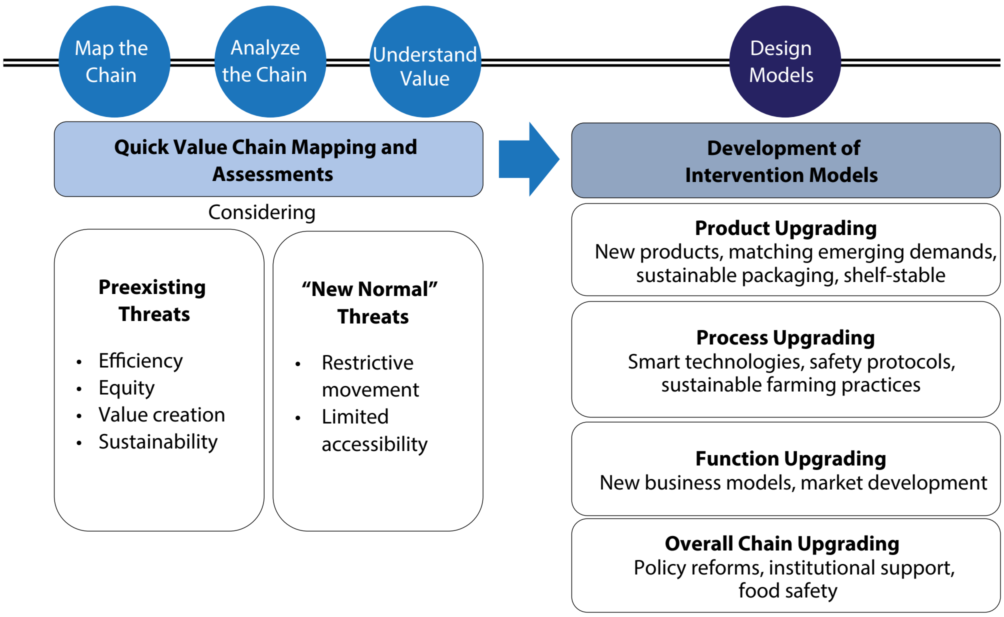
The first step in the framework is value chain mapping, accomplished by investigating the

Figure 1. Generic value chain framework



Source: Porter (2001)

Figure 2. Analytical framework to develop value chain intervention models



answers to the six questions outlined by Brown et al. (2010):

a. Who are the customers and what are their product requirements in terms of volume, quality, packaging, delivery schedules, as well as grades and standards?
b. Who are the key players in the chains and what are their respective roles?
c. What are the activities and processes along the chain?
d. What is the flow of product, information, and payment along the chain?
e. What are the logistical issues?
f. What are the external influences?

Phase 2

The second phase of the study involved identifying opportunities for upgrading the segments of the value chain based on the result of the first phase. Kaplinsky and Morris (2012) identified the following strategies for value chain improvement:

a. Process upgrading – reducing cost by enhancing efficiency of the process
b. Product upgrading – developing new products or improving existing ones
c. Function upgrading – changing the mix of activities
d. Overall chain upgrading – shifting the whole chain to new and higher value products

The research team coordinated with relevant DOST agencies to provide feedback from industry stakeholders about the factors that facilitate or hinder technology adoption.

Data Collection and Analysis

The phase 1 of the study conducted from May to November 2021 utilized both primary and secondary data. Primary data were gathered through semistructured key informant interviews (KIIs) with personnel and staff of relevant institutions and agencies including DOST Regional Office 1, BFAR Regional Office 1, the Southeast Asian Fisheries Development Center-Aquaculture Division (SEAFDEC-AQD), and the Provincial Agriculture Office of Pangasinan. The interviews were done online because of the COVID-19 restrictions. Relevant data were collected through database search and document reviews, such as key issues confronting the milkfish industry, the impact of the pandemic on industry players, and technological interventions or programs planned or deployed to solve industry issues.

The study included in-depth phone interviews with milkfish value chain players preidentified by the municipal and provincial agricultural offices. Primary data on milkfish producers were collected using a structured questionnaire.

The phase 2 of the study was conducted from January to May 2022. Focus group discussions (FGDs) through online Zoom meetings validated the technological solutions and interventions needed to respond to the problems that milkfish industry players encountered. The project team, accompanied by BFAR Regional Office 1 representatives, visited and documented hatcheries, growout farms, processing facilities, and agencies, such as BFAR Regional Office 1, DOST Regional Office 1, and the Don Mariano Marcos Memorial State University (DMMMSU) College of Fisheries.

Pangasinan and La Union were chosen as sampling sites for Region 1 because both provinces are known as the highest producers of milkfish in the region. Pangasinan is the top producer, harvesting and marketing a substantial volume of milkfish that generates employment and provides subsistence.

Milkfish operators/farmers were chosen randomly from master lists provided by the Pangasinan municipal offices and the provincial agricultural office of La Union. Many of the operators listed were either unavailable for interview or could not be contacted due to weak mobile phone signal. In place of unavailable owners, caretakers were interviewed because they were directly involved in most of the farm operations. A total of 29 milkfish operators/farmers were interviewed, with one respondent for each type of market intermediary, except for processors since most players in this sector were not available for interview during the data collection period. Since no respondent was interviewed for wholesalers, the insights of the key personnel from various agencies and institutions were taken into account.

For the industry assessment and value chain mapping, a comprehensive literature review was conducted to synthesize the key findings of past value chain studies in the milkfish industry. Interviews of officials and personnel from the BFAR Regional Office 1, DOST Regional Office 1, SEAFDEC-AQD, DOST-PCAARRD, DMMMSU, and the Provincial Agriculture Office of Pangasinan provided further insights. Stakeholders and industry practitioners in the region were also interviewed to understand better the milkfish value chain. Meanwhile, stakeholder analysis was undertaken through FGDs with representatives from government agencies and the milkfish industry, namely, hatchery operators, growout operators, and processors. Additionally, reviewed documents identified and described the milkfish industry technologies and innovations developed by DOST-PCAARRD, BFAR, and SEAFDEC-AQD.

RESULTS AND DISCUSSION

Phase 1a: Value Chain Mapping

Key customers and product requirements

The most essential product requirements for milkfish are its size and freshness, which influence marketability and price. Yap et al. (2007) described fresh milkfish as those that have bright eyes, bright red gills, undamaged abdomen, white muscle tissues, and firm flesh. End consumers purchase both fresh and processed milkfish products. Most of the consumers buy milkfish products from vendors in public markets. Table 1 presents the farmgate, wholesale, and retail prices of fresh milkfish produced in Region 1. As shown in the table, a kilogram of milkfish costs PHP 120 at the farm level in Pangasinan, while retail price is higher by PHP 50 to PHP 80.

The president of the Raois Fish Vendors' Association in La Union said that vendors prefer to be supplied with milkfish size 5:2 (i.e., five pieces in 2 kg) and 2:1 (i.e., two pieces in 1 kg). Milkfish growers in La Union usually bring their produce directly to public markets such as in San Fernando, Balaoan, Damortis, and Santo Tomas. According to a BFAR survey, auxiliary wet market vendors in La Union sell small-, medium-, and large-sized milkfish for PHP 140, PHP 180, and PHP 200/kg in retail. The price of milkfish increases in accordance with its size.

Institutional buyers, such as supermarkets, food chains, and restaurants, require product consistency in terms of quality, size, volume, and delivery schedule. They purchase milkfish products through *consignacion*, wholesalers, *viajeros*, or processors, depending on their preferred product forms.

Table 2 suggests that most processors (19) in Region 1 are registered in Pangasinan. Most of the processors in the province are small scale, processing milkfish into various forms: deboned, smoked, marinated, steamed boneless, smoked boneless, marinated boneless, *longganisa* (sausage), *chicharon* (crackling), and *lumpia* (spring rolls). Only two processors were operating at medium- and large-scale, and both are based in Lingayen.

Key players and their roles

The key players in the milkfish value chain are the seedstock producers, milkfish operators/farmers, market intermediaries, processors, and the end consumers (Figure 3).

a. Seedstock producers

The seedstock producers, in general, include the players involved in the production of fingerlings. The most basic participants are the milkfish breeders who raise and maintain broodstock or sexually mature milkfish (*sabalo*) for spawning eggs. Hatchery operators rear eggs that produce milkfish fry, which are then raised by nursery operators for one to two months until they become fingerlings. Participants at this stage

Table 1. Farmgate, wholesale, and retail prices of milkfish in Region 1, 2021

Province	Name of Major Public Market	Farmgate		Wholesale		Retail	
		Average price per kilo (PHP)	Size (no. of pcs/kg)	Average price/kg (PHP)	Size (no. of pcs/kg)	Average price/kg (PHP)	Size (no. of pcs/kg)
Pangasinan	Magsaysay Public Market	120	L (1–2)	135	L (1–2)	200	L (1–2)
	Urdaneta City Public Market	120	L (1–2)			200	L (1–2)
	Bolinao Public Market	150	L (1–2)			200	L (1–2)
La Union	Auxillary Wet Market	100	S (6 and >)	120	S (6 and >)	140	S (6 and >)
		130	M (3–5)	150	M (3–5)	180	M (3–5)
		160	L (1–2)	180	L (1–2)	200	L (1–2)
Ilocos Norte	Laoag City Commercial Complex	90	L (2)	110	L (2)	140	L (2)
		115	M (5)	130	M (5)	180	M (5)
Ilocos Sur	Vigan City Public Market	150	2	180	2	200	2
		120	3	150	3	180	3
		110	4	130	4	150	4

Source: BFAR (2021)
Notes: L - large; M - medium; S - small

Table 2. Types of milkfish products processed in the Ilocos Region, 2021

Province	Number of Processors	Type of Milkfish Products Processed
Pangasinan	19	Frozen whole, smoked, marinated, steamed boneless, smoked boneless, boneless, marinated boneless, *longganisa*, *tinapa*, *chicharon*, *shanghai*, *lumpia*, and fresh frozen deboned (plain, different cuts, and relleno kit)
La Union	2	Fresh frozen deboned (plain and marinated)
Ilocos Norte	3	Deboned, *shanghai*, and smoked
Ilocos Sur	4	In oil, deboned, and smoked

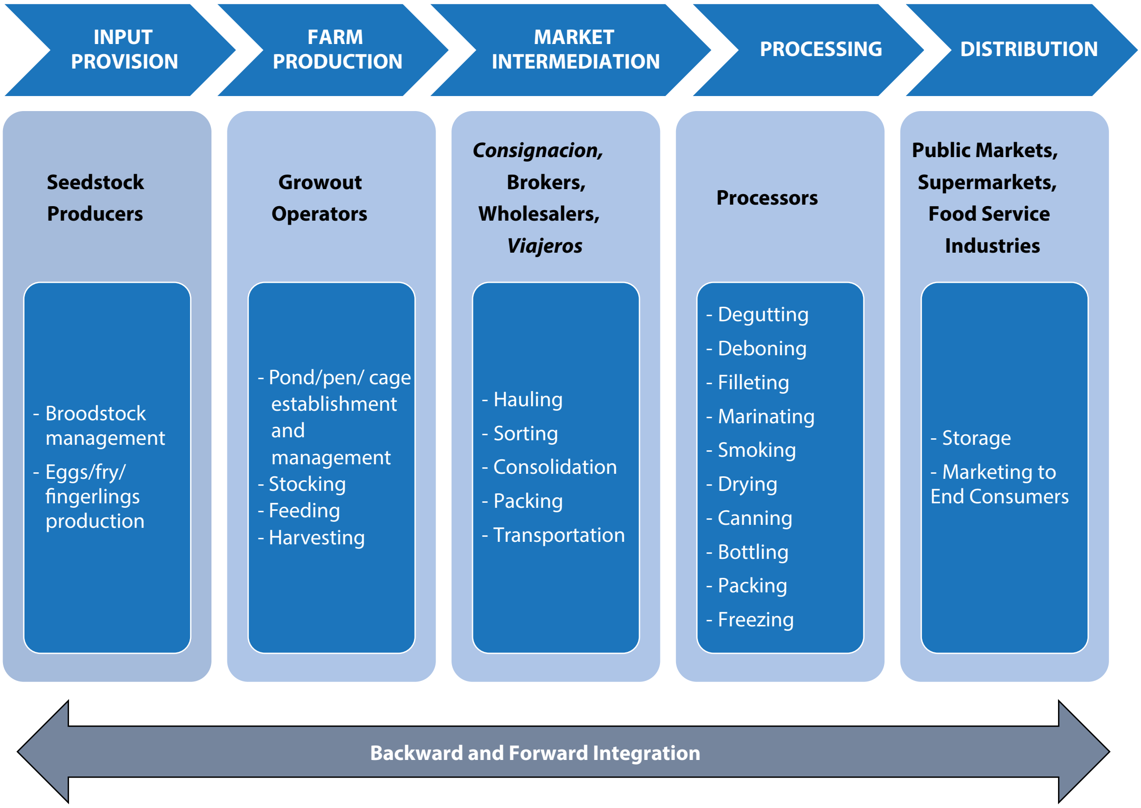
Source: BFAR (2021)

of the value chain may perform one or more of the functions. It is important to note that some players gather fry from the wild that they sell to nursery operators.

Hatcheries play a significant role in the milkfish industry since there is scarcity in the supply of fry in the country. The major hatchery operators, such as Feedmix Specialist, Inc. and the BFAR-National Integrated Fisheries Technology Development Center (NIFTDC), are located in Pangasinan. Hatcheries in Region 1 produce an estimated 147 million fry annually. Fishing grounds in Agno, Dasol, Bolinao, Infanta, Lingayen, San Fabian, and Dagupan City can also provide 28 million pieces fry in a year. Wild fry from the Lingayen Gulf is distributed to Aringay, Agoo, Bacnotan, Bangar, and San Juan. Meanwhile, Ilocos Coast and Bangui Bay are the sources of fry for farmers in Binmaley, Dagupan, San Vicente, Sta. Maria, Pagudpod, and Laoag City. Table 3 shows the sources and destinations of wild fry in Region 1 for the period January–June 2021.

Another alternative source of fry is Indonesia. Imported fry from Indonesia costs PHP 0.10 to PHP 0.13/piece, while hatchery-bred fry in the country costs PHP 0.30 to PHP 0.35/piece.

Figure 3. Milkfish value chain in Region 1



The fry requirement of nursery operators in Pangasinan is 53.4 million annually; on average, each nursery operator needs 1.1 million pieces of fry.

Seedstock producers are mainly concerned with production losses. Inappropriate handling of fry causes stress and low survival rate. The seedstocks should have enough oxygen supply and nutrition to develop optimally. The productivity of seedstock producers is also limited by the low *sabalo* population in the country. Private sector investment on *sabalo* raising is limited due to its long payback period—it takes five years for milkfish to be ready for spawning. Spawning of *sabalo* is still seasonal except for Feedmix Specialist, Inc., which was able to develop a technology for year-round spawning.

b. Growout operators

Fingerlings can be cultured by nursery and growout operators either in cages, pens, or ponds until they have reached the marketable size and ready for harvest. An operator may either be the owner or a hired caretaker. Cage and pen operators assemble and repair frames and nets as well as monitor and maintain cages and pens. Pond operators excavate ponds, drain, and apply lime, fertilizer, and pesticide. On the other hand, all operators adopting the different culture systems perform stocking, feeding, harvesting, packing, and hauling of produce. Most of them call the *consignacion* for a hauling schedule before harvesting their produce to ask about the prevailing market price of milkfish. Harvesters usually pack the milkfish in styropor boxes or *banyeras* (tubs) with ice. The milkfish-filled containers are then hauled

Table 3. Sources and destinations of wild fry in Region 1 (January–June 2021)

Source		No. of Fry Collected (in millions)	Total No. of Fry Gatherers	Area of Distribution
Fishing ground	Province			
Ilocos Coast and Bangui Bay	Ilocos Norte	11.98	68	Binmaley, Dagupan, San Vicente, Sta. Maria, Pagudpod, Laoag City
Ilocos Coast	Ilocos Sur	8.15	377	Vigan City, Sta. Catalina, Candon City, Sta. Cruz, Sta. Lucia, Santiago, Sinait, Dagupan, San Juan, Sta. Catalina, Narvacan
Lingayen Gulf	La Union	1.84	161	Aringay, Agoo, Bacnotan, Bangar, San Juan
	Pangasinan	0.44	3	Dasol

Source: BFAR (2021)

to a vehicle, which will transport the harvested produce to fishports, trading centers, or public markets.

c. Consignacion/*brokers*

The growout operators sell their harvested milkfish through market intermediaries such as *consignacion* or brokers. When the milkfish harvest arrives, the *consignacion* hires classifiers to sort the milkfish by sizes. The *consignacion* and brokers sell the fresh milkfish by bidding or negotiating the price with wholesalers in the fish port, public market, and trading centers. After sorting, *consignacion* laborers would weigh the fish according to the buyer's volume of order. Immediately after the end of the broker's and buyer's transaction, the broker would pay the milkfish producer in cash.

d. Wholesalers

Wholesalers purchase milkfish in bulk from farmers, through the *consignacion,* and resell them. The wholesaler's primary function is to transact with the *consignacion* in fishports. Typically, wholesalers' market outlets are commercial processors and supermarkets as they demand enormous amounts of milkfish for local or international markets.

e. Viajeros

Viajeros transport the milkfish and distribute them to the *consignacion* in fishports for price negotiation or to retailers in wet markets. The *viajero* interviewed mentions that his/her key role is to assist with distribution. Likewise, *viajeros* are entrusted with overseeing/monitoring the condition of the milkfish while in transit and in observing fish port transactions. Together with the driver and the laborer (*pahinante*) who unload the milkfish produce, *viajeros* bring the milkfish to fishports usually located in Navotas and Malabon in Metro Manila.

f. Processors

Processors could be small-scale operators in a public market or large-scale operators who own processing plants. These plants process fresh milkfish into various products such as marinated, smoked, deboned, *longganisa, shanghai*, and *relleno*. Small-scale processors often source fresh milkfish from small vendors, while large-scale processors typically buy them from a *consignacion* and wholesalers who can supply in large volumes. Large-scale processors supply supermarkets as well as restaurants.

g. Distributors/retailers

Distributors pertain to retailers occupying stalls in supermarkets and public markets who sell the product to end consumers. The retailers unpack the milkfish from the containers and display these in stalls. In some cases, they would also remove the fish scales and slice the fish; they weigh the milkfish that customers wish to purchase to provide them an accurate price. The COVID-19 quarantine protocols at the height of the pandemic prompted market closures that affected retailers. They resorted to selling to their neighbors to avoid wastage and the deterioration of milkfish quality. Retailers also struggled to follow food safety regulations at the time because of the inadequate storage and marketing facilities, such as the availability of ice, which is key to keeping their products fresh.

Activities and processes in the value chain

a. Broodstock management

Broodstock management refers to the raising of *sabalo* (i.e., sexually mature milkfish) for egg spawning and reproduction. Adult milkfish weighs between 5 and 6 kilograms and measures 68–70 centimeters in length. For the first five years, the broodstock can be reared in cages, tanks, and ponds. After five years, the broodstock is transferred to breeding facilities using plastic tube bags and styropor bags or tanks in trucks. Eggs produced by the broodstock are collected; after 14–18 hours, the eggs hatch into larvae.

b. Larval rearing

The larvae are nourished upon hatching. Their natural foods, such as rotifers, are developed in semi-intensive hatcheries. When rotifers are in short supply however, the larvae consume plankton. Green algae and rotifers are added into the tank on the second day of larval development (The Milkfish Technical Committee 2016).

c. Nursery and growout

The larvae are reared into fry, which are then distributed to nursery and growout operators. Cages, pens, and ponds are the most common structures used in raising milkfish in Region 1. For pond operations, the farmer prepares the pond by applying lime, fertilizer, and pesticide. On the other hand, cages and pens are repaired and cleaned prior to stocking. Fishpond operators rely mainly on natural feeds such as *lablab*[3] and *lumot* (green algae), while cage and pen operators use commercially available feeds.

d. Marketing and transportation

Growout operators sort the marketable milkfish they produced according to size. Buyers negotiate the volume and price based on the quality of the milkfish. Institutional buyers have better bargaining power compared with individual customers. As earlier mentioned, the *viajeros* transport the products primarily to fishports in Metro Manila.

e. Processing

The smallholder processors produce only deboned and marinated milkfish and sell them in public markets. Commercial processors also engage in value adding activities, such as bottling and canning. They sell the products in local distribution channels and export markets.

Flow of product, information, and payment

BFAR estimates that growout operators bring around 80 percent of the total milkfish production from Pangasinan province to the trading centers in Bolinao, Dagupan, and Alaminos towns. Only around 20 percent of the province's

[3] "Biological complex of cyanobacteria, diatoms, filamentous algae, and associated invertebrates that occur initially on the pond bottom as a brownish, greenish, or yellowish film." (https://www.fao.org/fishery/affris/species-profiles/milkfish/production/en/)

production is brought directly to Metro Manila. In contrast, La Union province's minimal milkfish produce is sold primarily within the province only. The primary buyers are retailers in the province's public markets.

Vital pieces of information, such as prices, delivery schedules, and sources of inputs, are shared among the industry players. Usually, other farmers and family members who are also engaged in milkfish farming share information on the possible sources of inputs. Seedstocks and fingerlings are often sourced from hatcheries, agents, and wholesalers while agricultural inputs, such as herbicides and fertilizers, are available at agricultural input suppliers in public markets.

Consignacion and brokers are the sources of information on the prevailing prices of milkfish. However, those who do not transact with *consignacion* obtain the information from other farmers or the public market vendors. Payments are usually in cash. However, other producers who lack the needed cash to start their farming activity make a deal with financiers who provide them with inputs or funds to be paid during the harvest. Credit arrangements between *consignacion* and buyers (*viajeros*/wholesalers) are quite prevalent. In this type of arrangement, the buyers request a payment term of two to three days after delivery, but the *consignacion* pays milkfish growers upon delivery.

Logistics issues

Fingerlings and fry are transported from hatcheries to nurseries and growout ponds. The fingerlings and fry must then be acclimatized prior to their release into the primary culture systems to minimize temperature shock that may result in mortality. Heavy rainfall or typhoons usually bring about massive fish kills, reducing harvests significantly. Fish kills also happen in April or May due to high water salinity.

The COVID-19 pandemic also created some challenges in milkfish marketing. The abrupt implementation of travel restrictions forced farmers to harvest their milkfish simultaneously, resulting in oversupply that reduced selling prices by PHP 50–80/kg. Furthermore, producers who usually sell in Dagupan City were unable to do so due to the city's stringent entry restrictions. Similarly, those who had established regular market outlets in Navotas and Malabon in Metro Manila could not distribute the products to their regular customers due to travel restrictions. As mentioned earlier, the scarcity of ice during the pandemic was another logistical challenge; milkfish cannot be harvested if ice is unavailable.

External influences

The milkfish industry in Region 1 is supported by government and nongovernmental organizations (NGOs) that develop technologies and policies for the aquaculture sector. These organizations are as follows:

a. SEAFDEC-AQD

SEAFDEC-AQD is an NGO hosted by the Philippine government. The first successful induced spawning and larval rearing of milkfish took place between 1976 and 1978 at SEAFDEC-AQD. Since then, milkfish has been cultivated and reproduced in concrete tanks, ponds, and floating cages in the country. Larval rearing techniques were successfully implemented in 1984, increasing fry production substantially and giving milkfish growers a plentiful supply while also generating a market for milkfish exports. SEAFDEC-AQD continues to support the milkfish sector through research, development, and extension (RDE) activities.

b. BFAR

BFAR is an agency under the DA that provides technical assistance to fisherfolks through seminars and trainings on production, marketing, and business management. BFAR also distributes fry, fingerlings, processing equipment, and related supplies and services to growout operators.

c. DOST-PCAARRD

PCAARRD is a council under DOST that develops strategies and projects for research and development (R&D) in the country's agricultural, aquatic, and natural resource sectors. Among other things, it secures government and external funding for the development of technologies and innovations for the milkfish industry. PCAARRD fosters collaborative R&D, human resource development and training, and technical assistance and facilitates the exchange of information and innovations with international and regional institutions.

d. Academe

Various state universities and colleges support the milkfish sector in Region 1 such as the DMMMSU in La Union. Its RDE program supports smallholder milkfish growout operators and processors. DMMMSU also collaborates with other government agencies for the delivery of trainings and other support services.

Phase 1b: Production Capacity

Pangasinan province is the largest producer of milkfish in Region 1, contributing 95.2 percent of the total milkfish production in the region as of 2020 (Table 4). The Office of the Provincial Agriculturist named Bolinao, Anda, and Sual as the major milkfish producing municipalities. The production methods used vary depending on the location of the farm and the available natural resources. For example, producers in Sual typically use fish cages for growing milkfish at the Lingayen Gulf. On the other hand, fishponds are primarily used in Binmaley, Dagupan, and Lingayen where water can be accessed from the surrounding rivers.

La Union follows Pangasinan in terms of the volume of milkfish production in Region 1. The total production in La Union represents 4.6 percent of the total milkfish produced in the region. On the other hand, the provinces of Ilocos Sur and Ilocos Norte contribute 0.2 percent and 0.01 percent, respectively, to total production. The milkfish industry in Region 1 is valued at PHP 14.2 billion as of 2020 (Table 5).

Phase 1c: Understanding Value

As shown in Figure 3, each actor in the milkfish industry contributes to value creation. The growout operators bear the production risk in rearing milkfish until it reaches the market weight. Hence, as shown in Table 6, growout operators have the highest profit margin at PHP 17.1/kg of milkfish sold.

On the other hand, the risks of losses during transport and price fluctuations are borne by market intermediaries such as the *consignacion*, wholesalers, and *viajeros*. These players are the ones who search for potential buyers and who facilitate the transportation of fresh milkfish. As shown in Table 6, they have a profit margin of approximately PHP 7/kg of milkfish sold.

Table 4. Volume of milkfish aquaculture production (in tons) by province in Region 1, 2016 to 2020

Province	Volume of Milkfish Aquaculture Production (in Tons)				
	2016	2017	2018	2019	2020
Philippines	398,088.17	411,103.47	395,130.31	409,906.56	414,488.93
Region I (Ilocos Region)	112,026.18	112,478.05	105,867.60	116,796.79	125,913.08
Ilocos Norte	19.21	20.27	33.97	15.52	10.36
Ilocos Sur	219.61	236.37	214.05	233.76	254.61
La Union	5,073.93	6,697.57	7,299.06	6,654.01	5,748.69
Pangasinan	106,713.43	105,523.84	98,320.53	109,893.50	119,899.42

Source: PSA (2021)

Table 5. Value of milkfish aquaculture production (in thousand PHP) by province in Region 1, 2016 to 2020

Province	Value of Milkfish Aquaculture Production (PHP '000)				
	2016	2017	2018	2019	2020
Philippines	35,042,257.39	37,623,623.34	40,767,835.02	42,879,624.07	43,379,111.83
Ilocos Region	11,325,023.86	11,779,513.63	11,849,710.30	13,560,732.38	14,185,627.85
Ilocos Norte	2,301.53	2,345.93	4,168.82	2,059.64	1,500.67
Ilocos Sur	23,187.48	26,033.25	23,708.64	28,158.30	36,462.86
La Union	537,161.71	703,043.14	838,641.55	839,756.21	747,806.33
Pangasinan	10,762,373.14	11,048,091.31	10,983,191.29	12,690,758.23	13,399,857.99

Source: PSA (2021)

Table 6. Profit margins of various players in the milkfish value chain in Region 1

Value	Value Chain Players				
	Growout	Consignacion	Wholesaler	Viajero	Retailer
Selling price (PHP)/kg	130.93	137.48	147.89	158.82	167.94
Total cost (PHP)/kg	113.86	130.93	140.85	151.26	159.94
Margin (PHP)/ kg	17.07	6.55	7.04	7.56	8.00

Source: BFAR (2021)
Note: These values are estimated for fishponds with area of 1 ha and milkfish with size 2:1.

Finally, the retailers facilitate the access of final consumers to fresh milkfish. They also provide consumers with diverse services such as degutting, cutting, and washing. The retailers also bear marketing risks especially during periods when consumers shift to other protein sources due to an increase in the price of milkfish. The profit margin of retailers is PHP 8.00/kg of milkfish sold.

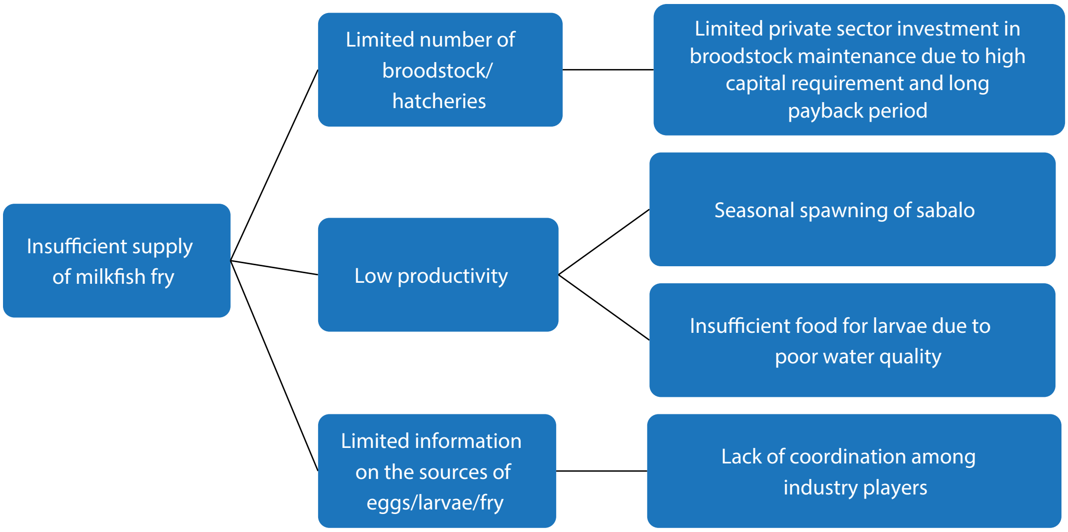
CONSTRAINTS IN THE VALUE CHAIN

Shortage in the Supply of Milkfish Eggs and Fry

Stakeholders consulted from BFAR, SEAFDEC, DOST-PCAARRD, and private hatchery and nursery operators unanimously identified "the inability to produce sufficient volume of milkfish eggs" as the primary constraint in the hatchery sector. Figure 4 presents the problem analysis in the seedstock node. BFAR estimated that the demand for milkfish fry in Region 1 in 2020 was 269 million, but the total supply of fry from the wild and the private and government hatcheries in Region 1 is only 109 million, leaving a deficit of 160 million. As a result of the shortage in the supply of eggs, operators in Region 1 rely on one functional government-owned hatchery in the region, the BFAR-National Fisheries Development Center (NFDC) in Dagupan City. According to BFAR, the regional and main satellite hatcheries were established to produce milkfish eggs for distribution to other satellite hatcheries. However, BFAR-NFDC could not supply eggs to satellite hatcheries because the eggs produced are only sufficient for the needs of the core hatchery[4] itself. Despite this perceived insufficiency, it was found in a stakeholders' consultation that some hatcheries released milkfish fry to the wild because they produced more than what they required. At the same time,

[4] Maintains broodstock and produces milkfish eggs and fry as source of steady supply for satellite hatcheries

Figure 4. Problem analysis for the seedstock node of the milkfish value chain in Region 1



other hatchery and nursery operators could not find a source of fry to meet their requirements. With efficient coordination among hatchery and nursery operators, the oversupply in one hatchery could be absorbed by another that is in need.

Aside from the few legislated hatcheries,[5] only a few private entities are willing to invest in broodstock development, aggravating the shortage in egg supply. SEAFDEC mentions that the capital cost for broodstock development is quite high. Moreover, since milkfish becomes sexually mature only after four to five years, the private sector opts to buy the eggs and/or larvae rather than raise its own broodstock.

Environmental Degradation

The main environmental issue in Pangasinan is the obstruction of canal and river systems because of installed fish pens that are fixed structures. The pens are anchored on the lake floor, which is why they cause more pollution compared with cages that are usually floating. The pens' poles accumulate sediment that further obstructs water flow. Unsustainable feeding practices also add to the problem such as what happened in Anda and Bolinao towns. Overstocking and overfeeding resulted in fish kill. While Bolinao town prohibits such practices, it cannot regulate through zoning, which is difficult to monitor. As a result, various local government units (LGUs) implemented a moratorium on fish pen operations in selected areas in Pangasinan. Figure 5 shows the problem analysis for the growout node of the value chain.

Noncompliance of Small-Scale Milkfish Processors to Food Safety Standards

An ocular inspection of small-scale milkfish processors in selected public markets in Pangasinan revealed their noncompliance to food safety standards. These small-scale processors lack the facility to enhance food safety such as a vacuum sealer and a stainless table. They pack deboned milkfish products into nonfood-grade plastics that are sealed with staple wires. Moreover, the disposal of the fish entrails and other wastes from milkfish processing is not regulated.

A stakeholder consultation showed that many small-scale processors in Pangasinan have limited product lines brought about by limited facility and skills. Most of them are producing marinated milkfish products because the process is simple and requires readily available input, such as vinegar.

[5] Facilities constructed based on government law/ mandate

Figure 5. Problem analysis for the growout node of the milkfish value chain in Region 1

One of the root causes of these problems in the processing node of the value chain is the lack of market incentive. The primary customers of the small-scale fish processors, the consumers in the public market, do not demand compliance to food safety standards. Figure 6 shows the root causes of the problem in the milkfish processing sector.

PHASE 2: OPPORTUNITIES FOR UPGRADING THE VALUE CHAIN

Technological Innovations

R&D agencies such as DA-BFAR, DOST-PCAARRD, DMMMSU, and SEAFDEC-AQD are in the forefront of developing technologies for the milkfish sector in the Philippines. Document reviews and KIIs showed that a substantial number of technological innovations are available for various players in the milkfish industry. Table 7 summarizes the technologies for process, product, and function upgrading.

The insufficient supply of milkfish eggs and fry can be addressed by the core satellite hatcheries program that BFAR and DOST-PCAARRD implement. The program aims to establish core hatcheries in strategic locations in the Philippines, which will then supply milkfish eggs to satellite hatcheries owned by private investors. With this arrangement, the long payback period and high production risk involved in raising and maintaining a broodstock or *sabalo* will be taken care of by the government-owned core hatcheries.

To address the problem of environmental degradation due to unsustainable feeding practices of growout operators, the mechanized top- and bottom feeders and plant-based milkfish diets could be introduced. In a stakeholders' FGD,

Figure 6. Problem analysis for the processing node of the milkfish value chain in Region 1

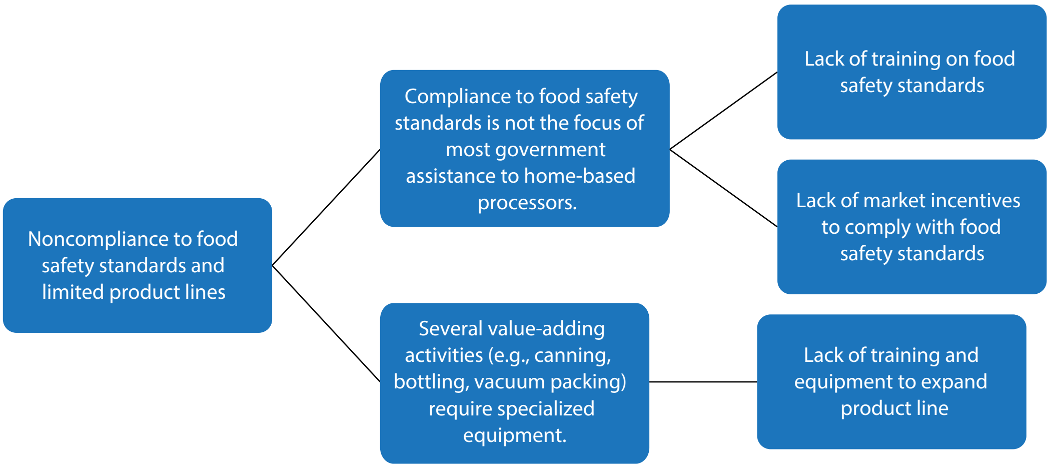


Table 7. Technological innovations for the upgrading of the milkfish value chain in Region 1

R&D Institution	Process Upgrading	Product Upgrading	Function Upgrading
Seedstock producers			
DOST-PCAARRD	Automated fry counter Core satellite hatcheries	Milkfish broodstock management and hatchery practices DNA probe kits Synbiotic feeds	
SEAFDEC-AQD	Induced spawning and larval rearing Broodstock management, breeding, and hatchery	Formula for milkfish broodstock diet High quality seeds	
BFAR	Core satellite hatcheries	Satellite community-based larval rearing facility	
Growout operators			
DOST-PCAARRD	Mechanized top- and bottom feeders Plant-based milkfish diets Paddlewheel aerator *Lablab* drying and feeding management	Diagnostic kits to detect off-flavor	
SEAFDEC-AQD	Cost-effective feeds		
BFAR	Various culture system Liming, fertilizer, and pesticide application Ad-libitum system		
Milkfish processors			
DOST Region 1		Provision of food safety-related tests such as nutritional analysis, heat penetration test, microbial test, shelf-life test, commercial, and sterility test	Provision of production equipment such as drier, freezer, retort machine, and pressure cooker
DOST-PCAARRD and DMMMSU		Safety protocol regulations and packaging	ATBI Converting milkfish residues into ingredients for feed formulation E-marketing

the growout operators said that they are open to exploring the new feeding technologies.

Finally, noncompliance by small-scale milkfish processors to food safety standards can be addressed through the Agri-Aqua Technology Business Incubator (ATBI) program of the DMMMSU and DOST-PCAARRD. DOST Region I can provide support services, such as trainings, provision of equipment, and food safety-related tests.

Intervention Models to Facilitate Access to Information and Technology Adoption

To create a smart food value chain, each actor in the value chain needs to have better access to high-quality information. Technology adoption along the chain is equally important. Hence, three intervention models were formulated to facilitate the creation of a smart food value chain. The ultimate goal of the following models is to facilitate technology adoption and access to information.

a. Establishment of a regional milkfish seedstock command center

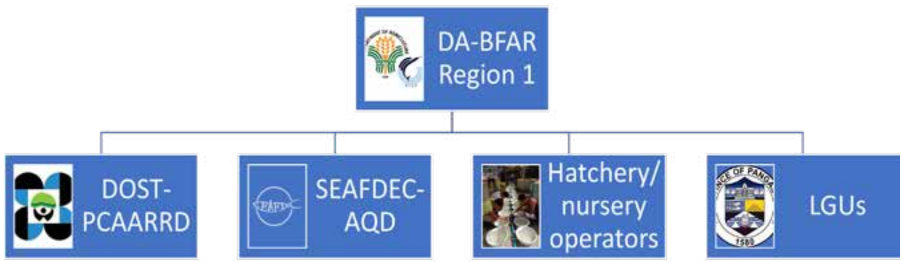
As discussed earlier, the problems in the milkfish seedstock sector can be addressed through proper coordination. Technological interventions and services of various agencies should be harmonized to minimize gaps and overlaps in providing technical support. Moreover, good coordination will allow hatchery and nursery operators to match the supply and demand of various industry players for milkfish eggs, larvae, and fry.

Hence, the intervention model being proposed is the creation of a regional milkfish seedstock command center (Figure 7). BFAR Regional Office 1 will act as the lead agency with the involvement of concerned agencies such as SEAFDEC-AQD, DOST-PCAARRD, and private companies. The LGUs should also be involved in this initiative since their participation will improve the cooperation with hatchery operators. Prior to technology transfer, it is necessary to validate the demands of the operators to determine the suitable interventions that will address the concerns of industry players. This will enable better communication in response to the needs of the sector.

The following are the functions of the proposed regional milkfish seedstock command center:

1. Determine strategic locations for legislated and satellite hatcheries.
2. Maintain up-to-date database of available milkfish technologies developed by various Research and Development Institutions (RDIs).
3. Maintain up-to-date directory of hatchery and nursery operators.
4. Facilitate exchange of information (e.g., availability of excess fry, technological solutions, etc.) among hatchery and nursery operators.
5. Provide feedback to RDIs on how to improve technological interventions.
6. Identify research gaps and harmonize RDE initiatives.

Figure 7. Structure of the proposed regional milkfish seedstock command center



b. Establishment of a science and technology community-based farm (STCBF)

To abate environmental degradation due to unsustainable farming practices, it is being proposed that technological solutions[6] be introduced to milkfish farmers. The stakeholders' consultation showed that growout operators are willing to use alternative feeds and feeding practices as long as these are practical, effective, and cheaper Moreover, DOST-PCAARRD has milkfish farming and green technologies that are ready for commercialization. While green technologies are yet to be adopted in the field, an effective technology transfer strategy is important.

DOST-PCAARRD has developed the STCBF to showcase the efficiency and effectivity of various agricultural technologies. Capitalizing on the initial success of the STCBF, the same modality is proposed to be used to facilitate transfer of technologies, such as automatic feeders and plant-based feeds, to milkfish growout operators. This intervention is proposed to be implemented in partnership with the Department of Environment and Natural Resources to harmonize the efforts of both government agencies.

STCBF has the following proposed goals:

1. Showcase various technological interventions for sustainable milkfish production.
2. Offer diverse options that would match the skills and available resources of milkfish farmers.
3. Demonstrate how sustainable farming practices would not only reduce production and legal-political risks but also improve productivity and income.

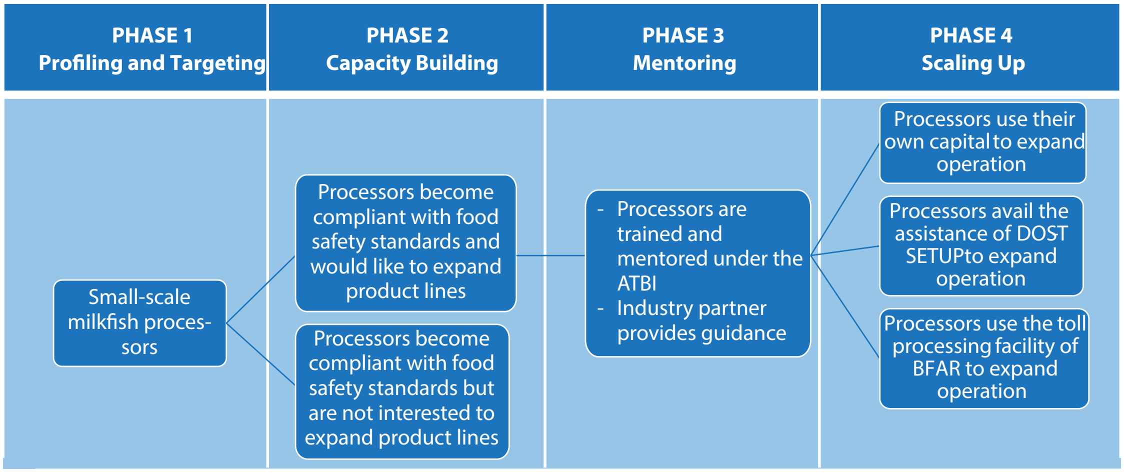
c. Creation of a bangus *processing enterprise development hub*

Small-scale fish processors must be equipped with skills and technology to expand their product lines and to improve their compliance to food-safety standards. This should be accompanied by market incentives that would motivate them to adopt technological solutions. Hence, it is being proposed to create a *bangus* processing enterprise development hub (Figure 8).

Figure 8. Structure and role of the bangus processing enterprise development hub

6 Pertain to green technologies, such as automated feeders and plant-based feeds, which reduce water pollutants caused by excessive feeding; improves farm operations' sustainability.

Figure 9. Implementation phases of the bangus processing enterprise development hub



With DOST Region 1 as the lead agency, the hub will perform the following roles:

1. Harmonize all interventions for milkfish processors.
2. Become the one-stop shop for technical and enterprise development support.
3. Maintain up-to-date directory of home-based and commercial-scale processors.
4. Develop programs that will cater to the specific needs of milkfish processors.
5. Assist in the marketing and distribution of processed milkfish products.

The intervention model could be implemented in four phases (Figure 9). In the first stage, the hub will profile the small processors and determine what aid they already received and what additional assistance they need. Initially, the strategy will focus on identifying assistance that is needed by small-scale processors in coordination with DMMMSU, BFAR Regional Office 1, and LGUs.

In the second phase, the small-scale processors will be trained and equipped to meet the minimum requirements for food safety. This may involve providing common-use facilities in strategic locations. The progressive small-scale processors will advance to phase 3, wherein the processors will learn new techniques in milkfish processing.This involves new product development and market planning. Also, the role of mentors from the academe and the industry will be crucial during this stage.

In the last phase, the small-scale processors will be assisted to scale up their operations. Some would opt to use their own funds for the expansion. However, for those with limited financial resources, they may avail of DOST-SETUP[7] assistance in acquiring processing equipment and tools. On the other hand, some may opt to simply use the toll processing facilities of BFAR Region 1.

CONCLUSION

Milkfish or *bangus* (*Chanos chanos*) is the most popular fish species cultured in the Philippines. Region 1, particularly the province of Pangasinan, remains to be the largest producer in the country. However, persistent issues in the industry hinder its productivity and growth. The value-chain

[7] The Small Enterprise Technology Upgrading Program (SETUP) provides micro-, small-, and medium enterprises with equipment and technical assistance through: (1) seed fund for technology acquisition, (2) needed equipment/upgrading, (3) technical trainings and consultancy services, (4) packaging and label design, (5) database information systems, and (6) support for establishment of product standards, including testing, and calibration of equipment (https://ncr.dost.gov.ph/program_setup.php).

approach was used to dissect these issues. The key actors in the value chain are the hatchery operators, nursery operators, growout operators, market intermediaries, processors, and retailers. Through KIIs and stakeholder consultations, the following major challenges in the seedstock, growout, and processing nodes were identified: (1) insufficient supply of milkfish eggs and fry, (2) environmental degradation in growout operation, and (3) noncompliance with food safety standards of small-scale processors.

Various intervention models were proposed to create a smart food value chain for milkfish in Region 1. The first model is the creation of a regional milkfish seedstock command center, aimed to harmonize various institutions' efforts to introduce technological solutions in the seedstock sector. It would also enhance coordination among industry players to manage the supply and demand for milkfish eggs and fry. The second model is the STCBF developed by DOST-PCAARRD. STCBF will be used to assist growout operators in adopting and implementing sustainable farming practices. Finally, a *bangus* processing enterprise development hub is also proposed to achieve proper coordination and targeting among key agencies supporting the milkfish processing sector. Through a four-phase approach, the hub will guide the small-scale processors not only in complying with food-safety standards but also in growing into a more agile enterprise that could tap a bigger market.

In general, the aim of the models presented is to facilitate the integration of technological solutions to the value chain through proper coordination among key institutions, such as DOST Region 1, BFAR Region 1, DOST-PCAARRD, the DMMMSU, SEAFDEC-AQD, the LGUs, and private companies.

This paper discussed how access to information and technology adoption could be facilitated along the milkfish value chain. However, it is unable to quantify the impact of technology adoption on the milkfish producers and consumers. Future research on smart food value chain may, thus, examine the economic impact of technological interventions.

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