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Analysis of Tuna Loin Agroindustry Supply Chain Configuration: Case Study in Maluku Province, Indonesia

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ABSTRACT

Tuna loin is a high-value fishery commodity with growing demand, but its sustainability is threatened by various challenges. Analyzing the configuration of the tuna loin supply chain in Maluku Province, Indonesia, is crucial for understanding the role of each actor and for identifying opportunities for improving business processes to enhance efficiency and sustainability. This research aimed to analyze the tuna loin agroindustry supply chain using four frameworks proposed by Van der Vorst: chain structure, chain management, chain resources, and business processes. In Maluku Province, six distinct patterns of tuna loin agroindustry supply chain networks were identified. However, the dominant patterns are Type 1 (traditional fishermen → collectors/mini plants → processing companies → consumers) and Type 2 (traditional fishermen → processing companies → consumers). The partnership in the supply chain involves fishermen, collecting traders, processing companies, and exporters, and is built on mutual benefit and trust, which enhances the efficiency and sustainability of tuna production. The success of the tuna loin supply chain in Maluku depends heavily on physical resources, such as fishing vessels and freezing facilities, as well as the quality of human resources, including skills, knowledge, and collaboration among stakeholders. The business processes in the supply chain involve relationships between members, seen through two perspectives: cycle view and push/pull view. The findings from this research provide valuable insights for improving chain management in the tuna loin agroindustry and assist supply chain stakeholders in developing strategies to promote sustainable practices in the supply chain.

INTRODUCTION

Maluku Province, Indonesia, is an archipelagic region with a total area of 712,479km², of which 658,294km² (92.4%) is the sea, making it an area rich in marine fishery resources. One of the most valuable of these resources is tuna, which plays a vital role in the welfare of the local community **(Marine and Fishery Office of Maluku**

Province, 2019). Tuna is a highly valuable fishery commodity in Indonesia, and Maluku Province, as a key national fisheries center, holds great potential in developing the tuna processing agroindustry, particularly for tuna loin products, which are available in both fresh and frozen forms. These products have reached international markets, meeting the required quality standards **(Zedha *et al.*, 2023)**.

According to data from the Ministry of Marine Affairs and Fisheries (Kementerian Kelautan dan Perikanan, KKP), Indonesia's tuna production continues to rise, with a total catch volume of 409,016 tons in 2018, marking a 28.87% increase compared to the previous year **(KKP Statistical Data, 2019)**. This growth positions Maluku Province as a strategic hub in the tuna supply chain, spanning from catching to distribution to both domestic and international markets.

However, this significant fisheries potential is accompanied by several challenges, particularly regarding resource sustainability and supply chain complexity. One of the key concerns is the efficient and sustainable supply chain management. The tuna loin agroindustry involves various primary and secondary stakeholders with differing goals and interests. Their relationships from upstream to downstream need to be managed carefully to ensure sustainability and efficiency **(Vural, 2015; Parenreng *et al.*, 2016; Paillin *et al.*, 2024)**. Therefore, understanding the configuration of the tuna loin supply chain in Maluku Province is crucial to identifying the role of each actor and to improving business processes for greater efficiency and sustainability.

While several studies have explored fishery product supply chains, many have not fully addressed the role of each actor, the partnership dynamics, and the business processes involved. For example, **Tumanan *et al.* (2017)** mapped the fish supply chain on Ambon Island by analyzing accessibility, availability, and cost. **Paillin and Tupan (2021)** and **Pailin *et al.* (2022)** assessed risks in the tuna supply chain in Ambon City, focusing on the identification, evaluation, and mitigation of risks. **Karningsih *et al.* (2018)** proposed a framework for identifying and assessing tuna supply chain risks based on activities such as sourcing, production, and delivery. Additionally, **Athaillah and Hamid (2018)** and **Khadijah *et al.* (2019)** measured tuna supply chain performance using the SCOR model and proposed strategies for performance improvement.

The novelty of this research lies in its mapping of the roles of key actors in the tuna loin agroindustry supply chain and the analysis of the partnership relationships between them. This study fills a gap in the literature by providing new insights into the tuna loin agroindustry supply chain.

This research focused on analyzing the configuration of the tuna loin agroindustry supply chain in Maluku Province, using four main frameworks: network structure, chain management, resources, and business processes. These frameworks, adapted from **Van Der Vorst (2005)**, allow for the identification and analysis of supply chain network patterns and the roles of key actors, which influence the sustainability of the supply chain. The findings of this study will contribute to supply chain literature, particularly for

the fisheries sector and the tuna loin agroindustry, and provide strategic recommendations for stakeholders as they face future challenges.

MATERIALS AND METHODS

This research was conducted from March to June 2024 to gather technical data, information, and insights through discussions with relevant experts and sources. These sources include actors in the tuna loin agroindustry supply chain—specifically, seven groups of fishermen, five collectors, and two processing companies—along with stakeholders from the Marine and Fishery Office (Dinas Kelautan dan Perikanan, DKP) of Maluku Province, the Marine and Fishery Office of Central Maluku Regency, the Marine and Fishery Office of South Buru Regency, the Fish Quarantine and Quality Control Center (Balai Karantina Ikan Pengendalian Mutu, BKIPM) in Ambon, academics at the Faculty of Fisheries, Pattimura University Ambon, and the Indonesian Pole & Line and Handline Tuna Fisheries Association (Asosiasi Perikanan Pole & Line dan Handline Indonesia, AP2HI).

The research was conducted in the Republic of Indonesia's State Fisheries Management Area (Wilayah Pengelolaan Perikanan Negara Republik Indonesia, WPPNRI) 714, which includes Ambon City (Ambon Island), South Buru Regency (Buru Island), and Central Maluku Regency (Seram Island) in Maluku Province. This location was chosen because it is the largest producer of tuna in Maluku Province, with local/traditional fishermen primarily using handline methods and fishing fleets with a capacity of less than 5 GT.

Data were collected from both primary and secondary sources. Secondary data were obtained through literature reviews, including relevant scientific journals, research reports, and publications from the Central Statistics Agency, the Ministry of Marine Affairs and Fisheries, and the tuna loin agroindustry. Primary data were collected through field observations and in-depth interviews. These methods allowed for direct observation of the operational activities of the tuna loin agroindustry supply chain and engagement with stakeholders to verify and enrich the information gathered during the research process.

Data processing involved identifying and analyzing the configuration of the tuna loin agroindustry supply chain. The supply chain was examined descriptively based on the framework proposed by **Van Der Vorst (2005)**. The four main frameworks used in this analysis are:

1. **Chain Structure**: This framework identifies the primary actors in the supply chain, their roles, the boundaries of the supply chain network, and the institutional elements that support its functioning.
2. **Chain Management**: This framework describes the coordination and management structure of the supply chain, including partnership forms,

contractual ties, transaction systems, and the role of government in regulatory oversight, policy formulation, and infrastructure development.

3. **Chain Resources**: This framework explains the resources available at each stage of the supply chain, including physical infrastructure, technology, and human resources (HR) used by the chain members.
4. **Business Processes**: This framework focuses on the processes and activities within the tuna loin agroindustry supply chain, including logistics (operations, production, and distribution), process integration, risk management, product development, and capital utilization.

These frameworks collectively provide a comprehensive understanding of the tuna loin agroindustry supply chain in Maluku Province and are essential for developing strategies to improve the sustainability and efficiency of the supply chain.

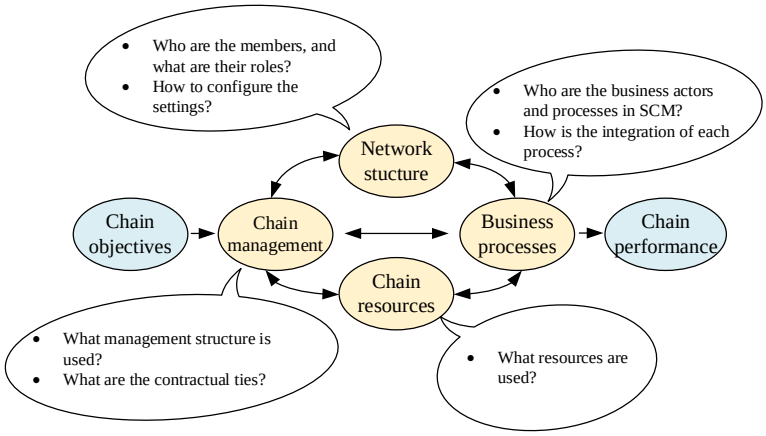

Fig. 1. Framework of supply chain configuration analysis

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RESULTS AND DISCUSSION

1. Supply chain network structure

Supply chain members

The tuna loin supply chain consists of several key members, each playing a vital role in ensuring that high-quality products reach consumers. The process begins with fishermen, who are the primary actors responsible for catching tuna in the sea. They use methods that preserve the fish's quality and freshness. Once the tuna is caught, it is transferred to collecting traders, who gather fish from various fishermen, sort them, and prepare them for the next stage of the supply chain.

Next, the processing units take over, where the tuna is processed—frozen and cut into loins—adding value to the product while ensuring that it meets quality standards required for both local and export markets. Local traders and exporters also play a crucial role in distributing the tuna loins, ensuring they reach domestic and international markets.

Each member of the tuna supply chain has a specific role, and effective collaboration among fishermen, collecting traders, processing units, local traders, and exporters is

essential for maintaining a smooth supply chain, ensuring product quality, and supporting the sustainability of the tuna loin industry. Further details of the roles and functions of these actors can be seen in Table (1).

Table 1. Role, capabilities, and market objectives of the tuna loin agroindustry supply chain members

Supply chain member	Role	Financial capability	Market objectives
Traditional fishermen	• Tuna loin supplier • Processor	Limited capital (<IDR. 1 million)	• Local traders • Collector traders/mini plans • Processing company
Local traders	• Buyers and marketers • Capital lenders	• Relatively small capital (±IDR. 2 to 5 million) • Limited purchasing ability (30 to 150 kg)	• Local consumers (households)
Collector traders/mini plans	• Buyers and marketers • Capital lenders • Processor • Provider of ice and plastic wrap	• Relatively moderate capital (±IDR. 20 to 50 million) • Maximum purchasing ability ± 500kg/day	• Local traders • Processing company • Fisheries SMEs
Processing company	• Buyers and marketers • Capital lenders • Processor • Provider of ice and plastic wrap	Quite large capital (> IDR 1 billion)	• Overseas consumers • Domestic Consumers • Local consumers • Buyer/exporter
Exporters	• Buyers and marketers	Quite large capital (>IDR 1 billion)	• Overseas consumers • Domestic Consumers
Consumer	• Buyer	-	-

Supply chain network

The tuna loin supply chain network in Maluku Province (Fig. 2) can be divided into several distinct network patterns, including:

Network 1: Traditional fishermen → local traders → local consumers

Network 2: Traditional fishermen → collectors/mini plans → local traders → local consumers

Network 3: Traditional fishermen → collectors/mini plans → processing companies → consumers (local, domestic, overseas)

Network 4: Traditional fishermen → collectors/mini plans → processing companies → exporters → consumers (domestic, overseas)

Network 5: Traditional fishermen → processing companies → consumers (local, domestic, overseas)

Network 6: Traditional fishermen → processing companies → exporters → consumers (domestic, overseas)

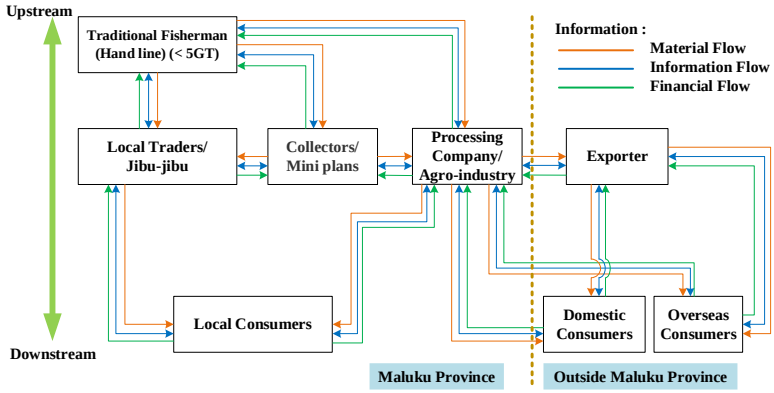


Fig. 2. Tuna loin supply chain configuration in Maluku Province

Product

In general, tuna loin products produced by processing companies are in fresh or frozen form for export, according to the quality requirements set by the national standardization body, as regulated in SNI 7530: 2018.

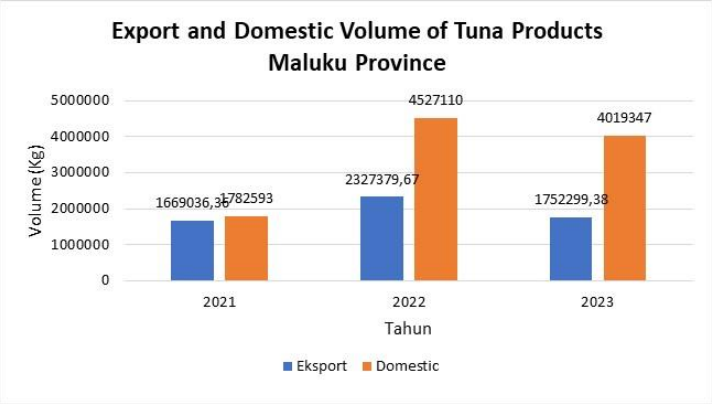
The grading or quality selection process is carried out to differentiate tuna fish that are suitable for export from those that are not. This sorting is carried out by checkers in the company. The inspection includes an assessment of the fish's physical appearance and flesh quality, with the additional criterion of eye color to assess the quality of the whole tuna. The quality of the fish is then classified into four categories: AAA, AA, and A. This process is crucial as it ensures only premium-quality tuna reaches the international market, safeguarding the product's reputation. The grading process plays a significant role in maintaining customer trust and satisfaction, as it guarantees that the products meet the quality standards expected by global consumers. Moreover, it enables companies to determine appropriate selling prices based on quality, supporting effective marketing and sales strategies. Further details of the grading criteria are presented in Table (2).

Table 2. Tuna loin grade criteria

No	Grade	Special characteristics			Rainbow
		Meat	Oil	Color	
1.	AAA	Chewy	Lots of oil	Bright red and even	No
2.	AA	Chewy	There's a little oil	Pink-red	No
3.	A	Chewy	No oil/fat.	Pink – dark red	A few

Market

Tuna loins processed at processing companies are then marketed to the domestic and export markets. Fig. (3) shows the export and domestic volume of tuna products in Maluku in the last three years.



(Source: BKIPM Ambon, 2024 (processed data))

Fig. 3. Maluku Province export and domestic tuna marketing volume

Overall, domestic consumption consistently outpaces exports every year. In 2021, the export market was 48.4%, almost on par with the domestic market at 51.6%. This balance continued in 2022, with the domestic market at 66.4% and the export market at 34%. For the year 2023, a decrease was anticipated in both the domestic market by 11.2% and the export market by 24.7%.

2. Chain management

Partnership pattern

The partnership pattern within the tuna loin supply chain in Maluku Province illustrates strong cooperative relationships among essential actors, including fishermen, collecting traders, processing companies, and exporters. Each actor plays a specific role and is interdependent, ensuring the smooth and sustainable production of high-quality, legally compliant tuna loins. This partnership is grounded in mutual benefit and trust, which fosters enhanced efficiency, productivity, and the overall sustainability of the tuna industry in the province. Furthermore, support from the government and relevant institutions is vital in reinforcing this collaboration through the implementation of supportive regulations, training programs, and expanded market access. The partnership pattern across the tuna loin supply chain in Maluku Province involves a network of actors, all of whom contribute to the system's operation. This relationship provides both benefits and challenges, as outlined in Table (4).

Table 3. Advantages and challenges in partnership patterns

Partnership pattern	Advantages	challenges
Traditional fishermen and collector traders	• Providing capital loans for tuna fishing operations • Certainty in purchasing catches • Providing fishing aids	• Price determination is the responsibility of the collector • Dependence on collectors for operational capital

Partnership pattern	Advantages	challenges
Traditional fishermen and processing company	• Fish sales are fast, so quality is guaranteed • Assistance with ship licensing • Prices according to fish quality standards • By-products are also valued • CPIB training • Assistance with MSC certification • Providing fishing aids (ice, plastic wrap, cutting knife, styrofoam box)	• Prices fluctuate following international markets • Price determination is the company's authority • Strong enough ties for partner fishermen
Traditional fishermen and local traders	• Providing capital for fishing operations • Quick sale of fish	• Price determination is the local trader's authority • Strong ties because fishermen are socially bound
Collector traders and processing company	• Fish sales are fast, so quality is guaranteed • Prices according to fish quality standards • CPIB training • Provision of processing aids (ice, plastic wrap, cutting knife, styrofoam box)	• Prices fluctuate • Price determination is the company's authority • Strong enough ties for collecting partners • Limited infrastructure in transportation and distribution
Processing company and eksporter	• Access to international markets • Certainty in marketing the processing results	• Prices fluctuate following international markets

In the partnership between actors within the tuna loin supply chain, the cultural value of the Saemaul Undong Spirit (an empowerment movement initiated by Park Chung Hee in South Korea during the 1970s) can be effectively integrated. Rooted in the principles of cooperation, solidarity, and hard work, this spirit can be adapted into the Seamaul Undong Spirit in the context of Maluku. This adapted spirit encourages active collaboration and participation among supply chain actors, including fishermen, processing companies, the government, and local communities. By embracing these values, each actor in the supply chain can contribute to improving product quality, expediting distribution flows, and mitigating environmental risks, such as overfishing. Integrating the Seamaul Undong Spirit within the tuna loin supply chain configuration can enhance both the social and economic dimensions of this agroindustry. Strengthening the capacity of fishermen, increasing access to technology, and developing adequate infrastructure will ultimately make the supply chain more efficient and sustainable.

Transaction system

The transaction system in the tuna loin supply chain in Maluku Province operates on a kilo/scale basis. Fishermen sell their tuna directly as coarse tuna loins to collectors or processing companies. Typically, collectors accept coarse tuna loins weighing at least

2kg per piece; if the tuna loins fall below this minimum weight, they are sold to local market traders instead. The transaction method used is cash and carry, where payment is made in cash at the time of delivery, based on the agreed price.

For fishermen who borrow capital from collectors, the loan is repaid through the tuna catch. The sales proceeds are deducted to cover the loan amount, and the remaining balance is given to the fishermen. Similarly, when collectors borrow capital from processing companies, the sales proceeds are also deducted to cover the loan, and the remaining amount is given to the collector after the fish are received and the price is assessed.

Price

Tuna loin prices are determined by processing and collecting companies because global market dynamics influence them. The main factors affecting the price of tuna loin are the quality of the fish, its size, and its weight. Higher quality tuna, which has brighter flesh and better texture, will command a higher price on the market. Fishing season factors also influence the cost of tuna loin. When it's not fishing season, catches are smaller, so the price of tuna loin will rise.

The price of tuna loin sold by fishermen to collectors ranges from IDR 40,000/kg to IDR 62,000/kg, depending on the quality and size of the tuna loin. When sold to processing companies, the price of tuna loin increases, ranging from IDR 75,000/kg to IDR 90,000/kg. Subsequently, tuna loins are sold to exporters for approximately IDR 130,000/kg.

In addition to the tuna loin, processing companies also value by-products such as tuna molasses, which is priced at IDR 10,000/kg, and belly tuna, which is priced at IDR 12,000/kg. Tuna that does not meet the company's quality or weight standards is typically sold to local market traders.

Government support

Government support in the tuna loin supply chain in Maluku Province is very diverse and touches on various aspects, from empowering fishermen to developing infrastructure and export policies. The government provides several forms of support, such as empowering fishermen, developing infrastructure and export regulations and policies, and protecting fish resources.

The government has implemented various programs to empower fishermen, such as increasing human resource capacity through training and technical assistance to improve their skills in catching and processing tuna, providing fleet and fishing gear assistance, improving fishermen's institutions, assistance with ship licensing, and fuel subsidies for fishermen. Fishing boats are also offered to reduce operational costs. Developing supporting infrastructure such as fishing ports, cold storage, and fish processing facilities is one of the government's main focuses. The fishing port in Maluku has been equipped with modern facilities to support fish catching and processing activities and maintain tuna quality to meet export standards. The government has established various regulations and

policies to ensure that tuna exports in Maluku province meet international standards. Quality and food safety certification, such as Hazard Analysis and Critical Control Points (HACCP), is required for all exported fishery products. This aims to increase the competitiveness of Indonesian tuna in the global market and ensuing that the products exported are safe and of high quality. Apart from that, processing documents for export purposes is faster because it has been integrated with the system between the relevant agencies, thereby reducing practices detrimental to supply chain actors.

The government implements various conservation policies and sustainable fisheries management to ensure the sustainability of fish resources. Policies prohibiting fishing gear that damages marine ecosystems aim to protect tuna fish populations and Indonesia's aquatic environment. The government also encourages environmentally friendly and sustainable fishing through education and certification programs.

3. Resources

Physical resources

The success of the tuna loin supply chain in this province is highly dependent on the existence and quality of physical resources such as fishing vessels and freezing facilities. Fishing vessels are the main component in the tuna loin supply chain, which fishermen use to catch tuna in Maluku waters. Fishing vessels in this province vary from small to large, with different fishing technologies.

KKP statistical data for Maluku Province shows that around 21,122 fishing vessels are operating in Maluku waters in 2021. Most of these vessels are small and <5 GT (long boats) and are used by local fishermen. These small vessels are generally equipped with simple fishing equipment such as handlines, which are efficient for catching tuna. Apart from that, there are also medium-sized (5-10 GT) and large (more than >30 GT) vessels which large fishing companies usually use. These vessels are equipped with modern fishing technology, such as longlines, which enable fishermen to catch large quantities of tuna and to maintain the quality of the fish caught.

Freezing and cooling facilities such as air blast freezers, contact plate freezers, immersion freezers, and other types play an important role in ensuring the quality and freshness of tuna fish from the moment of capture to processing and delivery. Table (4) shows several active freezing and cooling facilities spread across various districts/cities in Maluku Province. The total production capacity of freezing and cooling facilities in Maluku is more than 18,000 tons. These freezing and cooling facilities allow tuna fish to be handled to standards that meet export quality requirements, and thus tuna products from Maluku can compete on the global market.

Table 4. Distribution of freezing and cooling facilities in Maluku Province

No	Regency/City	Air Blast Freezer (ABF)		Cold Storage (CS)		Cold warehouse	
		Quantity (unit)	Capacity (ton)	Quantity (unit)	Capacity (ton)	Quantity (unit)	Capacity (ton)
1	Buru	2	6	3	90	3	0,03
2	Seram Bagian Barat	0	0	0	0	1	3
3	Ambon	42	142,335	26	3515,04	10	30,001
4	Maluku Tengah	29	120,504	27	6445,075	6	12,014
5	Tual	6	803	5	915	0	0
6	Maluku Tenggara	5	121	7	670	0	0
7	Kepulauan Aru	35	239	29	6640	0	0
8	Kepulauan Tanimbar	8	20	9	480	0	0
9	Maluku Barat Daya	0	0	1	30	0	0
	Total	**127**	**1451,839**	**107**	**18785,115**	**20**	**45,045**

Source: DKP Maluku Province, 2024 (data processed)

Human resources

The success of the supply chain also depends significantly on the capacity of human resources, such as skills, knowledge, and collaboration between all parties involved. Efforts to support the development of human resources in the tuna loin supply chain have been carried out by the government through cross-sectoral cooperation and collaboration with several non-governmental organizations such as the Indonesian Pole & Line and Handline Fisheries Association (AP2HI) and the Indonesian Community and Fisheries Foundation (MDPI) such as the formation of a Committee Tuna Fisheries Joint Management (KPBP).

Various forms of training, counseling, and strengthening fishermen's organizations are essential components of human resource development in the tuna supply chain. These initiatives include providing information and certification on Good Fish Processing Practices (CPIB) for fishermen and collectors, training on household financial management for fishermen, and offering practical skills such as outboard motor engine maintenance. Additionally, fishermen's groups receive assistance in obtaining ecolabeling certificates like the Marine Stewardship Council (MSC) certification. Training also focuses on sustainability and traceability, including guidance on maintaining logbooks and other practices that support the long-term viability of the tuna industry.

Technology

The application of technology in the tuna loin supply chain in Maluku Province covers various aspects, from catching, storing, and processing to information technology. This technology is vital in increasing efficiency, maintaining quality, and supporting the sustainability of the tuna loin agroindustry supply chain.

The commonly used tuna fishing technology is handline fishing, a traditional method that positively impacts the marine ecosystem. Cold storage technology is a vital component in Maluku's tuna loin supply chain. Modern cold storage units help maintain the quality and freshness of tuna until it is ready for processing or export. Cold storage

technology includes rapid freezing facilities capable of reaching very low temperatures quickly to avoid damage to fish quality. The processing facility uses modern tuna loin freezing and processing technology, such as vacuum packing technology, to package the tuna loin, which helps extend the shelf life and maintain product cleanliness. Using information and communication technology in the tuna supply chain in Maluku helps increase operational efficiency. A GPS-based tracking system (spot trace) on fishing boats allows real-time monitoring of fishing activities. Using Spot Trace helps maintain safety at sea because it reduces the risk of accidents and getting lost. This technology can help fishermen increase their awareness of illegal, unregulated, and unreported fishing and the importance of endangered, threatened, and protected species. Excellent and reliable data collection aims to maintain fish stocks. Data collection at sea is carried out by installing several devices, such as the Spot Trace and Pelagic Data System and time-lapse cameras on fishing vessels. The collected data are then uploaded to the Indonesian Fisheries Information System (i-Fish) database, which stores important information about sustainable fisheries.

4. Business process

The business processes within the fresh tuna supply chain illustrate the mechanisms that drive operations between various stakeholders. Understanding the relationships formed between these members is crucial for maintaining smooth and efficient business processes. Business relationships in the tuna supply chain can be adapted from a model developed by **Chopra *et al.* (2016)**. These processes are examined from two perspectives: cycle view and push/pull view.

The cycle view provides a method for understanding the numerous business activities that occur throughout the supply chain. In contrast, the push/pull view focuses on how stakeholders respond to demand and supply dynamics. In the cycle view, the pull process refers to activities triggered by actual consumer orders, while the push process involves activities driven by anticipated consumer demand. The pull approach offers the advantage of reducing inventory costs and minimizing the risk of overstocking, which can lead to the bullwhip effect. Conversely, the push approach aims to ensure product availability in anticipation of future consumer demand, maintaining warehouse stock levels accordingly **(Prayoga *et al.*, 2018)**.

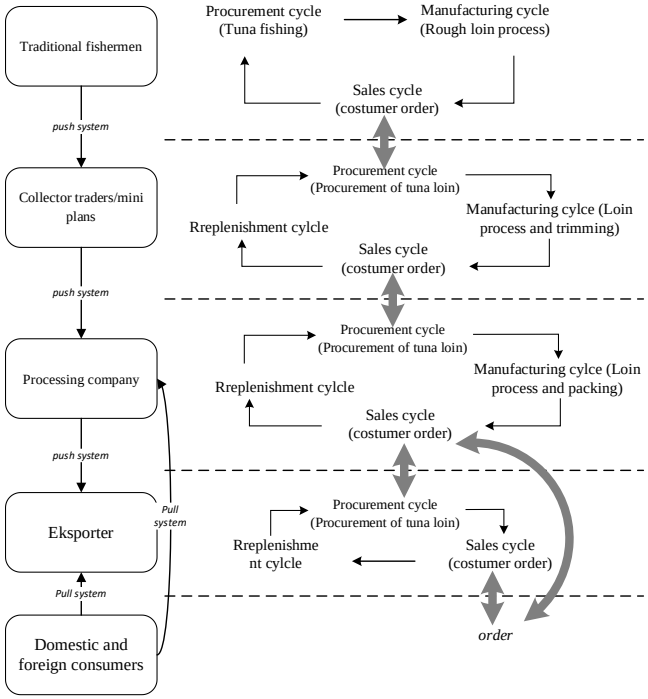


Fig. 4. Business process and overview of the tuna loin agroindustry supply chain cycle in Maluku Province

Each stakeholder plays a vital role in the supply chain cycle. A cycle view in the tuna loin agroindustry supply chain reveals that the push process occurs at the fishermen, collector/mini plan, processing company, and exporter levels, while the pull process takes place between processing companies and consumers, and exporters and consumers, as shown in Fig. (4).

CONCLUSION

The tuna loin agroindustry supply chain in Maluku Province involves various key actors, including traditional fishermen, local traders (jibu-jibu), collectors/mini plants, processing/agroindustry companies, exporters, and consumers (both local and international). Six distinct supply chain network patterns for tuna loin are identified in Maluku Province. However, the most dominant patterns are Type 1 (traditional fishermen → collectors/mini plants → processing companies → consumers) and Type 2 (traditional fishermen → processing companies → consumers).

The partnership within this supply chain involves fishermen, collecting traders, processing companies, and exporters, all working together based on mutual benefit and trust. This cooperation enhances the efficiency and sustainability of tuna production. Moreover, the success of the tuna loin supply chain heavily depends on physical resources such as fishing vessels and freezing facilities, as well as on the quality of

human resources, including skills, knowledge, and effective collaboration between the various parties.

The business process within the fresh tuna supply chain involves two primary perspectives: the cycle view and the push/pull view. In the push process, activities are based on estimated demand to ensure product availability, while the pull process responds to consumer demand to reduce inventory costs. In the tuna loin supply chain, the push process typically occurs at the fisherman-to-exporter level, while the pull process happens between processing companies, exporters, and consumers.

This study has certain limitations, and there are opportunities for future research. One potential direction is measuring the sustainability index for each type of agroindustrial supply chain pattern using sustainability dimensions, employing models such as ANFIS and MDS-RAPS. Future studies could also focus on analyzing risks within the tuna loin agroindustry supply chain and could propose mitigation strategies to enhance its sustainability.

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