Uncertain Supply Chain Management 12 (2024) 2635–2650

Contents lists available at GrowingScience

Uncertain Supply Chain Management

homepage: www.GrowingScience.com/uscm

Supply chain pattern of blue swimming crabs in the north coast of Java, Indonesia

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A B S T R A C T

The blue swimming crabs (BSC) fishing industry in Indonesia is heading towards an imbalance between demand and sustainability of its resources, a factor in supply. The mismanagement of traceability data and information in the supply chain is suspected to be one of the causes adding to the complexity of recent BSC fisheries management. This research aimed to identify BSC supply chain patterns and their issues, especially on two coastal regencies on the North Coast of the Java Sea. The research was conducted during June and December 2023 in Cirebon Regency and Rembang Regency. The study enlisted 70 participants, comprising fishermen, traders, processors, and exporters, with data acquisition facilitated through surveys, interviews, and focus group discussions. Respondent selection employed purposive sampling, while snowball sampling identified pertinent informants within the supply chain. Data analysis encompassed qualitative description and Likert-type scale perception analysis. The findings show that the BSC fishing industry on the North Coast of the Java Sea operates as small-scale fisheries (SSF), with unique vessel types, gear, and socioeconomic conditions crucial for livelihoods. Fishermen prioritize sustainability by using small vessels and traditional gear despite limited education. The BSC supply chain involves stakeholders offering high-value products, yet by-product utilization potential is untapped, requiring improved coordination and innovation. Challenges include export standards, market fluctuations, and product safety, addressed through regulatory support and collaboration. Government regulations, fishermen groups, and data traceability enhance market transparency and sustainability. Therefore, collective action and innovative approaches are vital for long-term economic prosperity and environmental stewardship in the BSC supply chain.

Article history:
Received March 28, 2024
Received in revised format April 27, 2024
Accepted May 7 2024
Available online
May 7 2024

Keywords:
Blue swimming crab
Supply chain
Small-scale fisheries
Fisheries management
Livelihood

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1. Introduction

Blue swimming crab (BSC) fisheries have proliferated since the 1990s, becoming an important income source for coastal communities (USAID, 2015). The fishing grounds are distributed in Fisheries Management Areas (WPP) 712, WPP 713, WPP 711, and WPP 571, and the most significant contribution is in the waters of the Java Sea. During this period, there have been fluctuations in the increase in volume and value. The productivity of BSC catches tends to decrease, and the size of BSCs caught is getting smaller. This condition indicates that there has been more overfishing in BSC fishing efforts (Juwana, 2004; Juwana et al., 2009; Susanto, 2006). Overfishing in the utilization of crab resources is expected to cause changes in the natural environment.

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ISSN 2291-6830 (Online) - ISSN 2291-6822 (Print)
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doi: 10.5267/j.uscm.2024.5.007

The imbalance between the demand side and supply side of these commodities influences the current exploitation of BSC resources in Indonesian waters. The demand for these commodities has not been anticipated with the proper arrangements. Thus, the existence of commodities in nature is increasingly uncontrolled with the encouragement of the economic needs of users or the community to get the maximum benefit. Meanwhile, policy changes have not significantly affected the paradigm of utilizing fishery resources from exploitative to more sustainable use efforts. According to (Aris Budiarto, 2015), crab fisheries management in Indonesia pays more attention to socioeconomic and community interests than environmental health. This condition has resulted in social conflicts both between resource users and policymakers. The emergence of illegal practices in the fishing business has caused the economic vulnerability of fishing households.

The high value of BSC causes the magnitude of increased fishing efforts. Management strategies that pay attention to the carrying capacity of crabs must be a reference so that the utilization of crab resources can be carried out sustainably. The management of BSC fisheries is currently regulated by ministerial regulations that seek to provide signposts in crab resource management. In the ministerial regulation, the utilization of crab resources is limited by the size of the crab. Another perspective of BSC resource management that pays attention to the characteristics of the crab life cycle and the socioeconomic characteristics of crab fishermen has not been the basis for consideration in crab resource management. Related to the life cycle, (Adam et al., 2006) mention that the migration of swimming crabs from coastal to open waters impacted the population distribution in both environments. According to (Zamroni et al., 2023), one of the governance approaches that can be used is the open-closed season. The Open-Closed Season (OCS) approach has short-term objectives focused on the welfare of fishermen and ensuring fairness in business practices, alongside long-term goals aimed at ensuring the sustainability of BSC. However, technical implementation in crab management is still being pursued related to optimal crab resource management mechanisms, including paying attention to the socioeconomic characteristics of crab resource utilizers. Ervinia et al. (2023) study findings mention that the stock evaluation of BSC in Indonesia benefits from substantial enhancement, mainly through heightened attention to the species' life history within distinct geographical locales.

The demand for crab meat from the export market causes the price of crabs to be higher in the domestic and export markets, particularly post-COVID-19 of 2020 ((Huda et al., 2022). The conditions that cause fishermen's efforts to exploit these resources are also increasing. All supply chain processes benefit business actors obtained from sales margins (Cendrakasih et al., 2023). If this is not balanced with proper management, it will cause *depletion* of these resources, which will not rule out the possibility of extinction. Another problem is the relatively growing number of fishing fleets and fishing methods that do not pay attention to the life stages of crabs and the use of fishing gear that is not selective.

The sustainability of BSC fishing in Indonesia is greatly influenced by mini plants spread in crab-producing centres in Indonesia. The existence of a mini plant guarantees the marketing aspect of fishermen's crab production, most of which is produced to meet export needs. A typical pattern of BSC production flow in Indonesia is that crab catches from fishermen are sold to collecting traders, which are then processed by mini plants in collaboration with collecting traders. The crab processing business in the mini plant goes through several stages, namely receiving raw crabs from fishermen or traders (*bakul*), washing, boiling, and stripping. All of these stages require workers, especially for the stripping stage. BSC stripping requires special techniques that can only be done by skilled and trained workers (Nugroho & Bahtiar, 2012). The large number of workers involved in the production, processing, and distribution of crabs shows that crab commodities provide alternative jobs for the community, especially around crab centers.

The traceability of BSC catch data is a considerable obstacle to supporting crab fisheries' management policy-making in Indonesia. In addition, the socioeconomic data of BSC fisheries in series has added to the difficulties of maintaining and increasing the competitiveness of crab exports. According to Zamroni et al. (2020), crab fishermen are fully aware of the decreasing crab production, size, and crab quality in their area, but due to the economic pressure of household needs, they often ignore it. Seeing the pattern of fishermen carrying out crab fishing operations continuously throughout the year can reduce crab catches in quality and quantity. If this continues to be allowed, in the next few years, crab stocks may continue to decline without any efforts to manage and preserve them properly. In some instances, there are also collecting traders mixing meat types, causing some factories or exporters to buy crab meat at an average price applied to all kinds of meat and not based on the type of meat. Two things cause this phenomenon: first, the size of the crab caught is getting smaller, which causes less meat to be produced. Second, exporters find it increasingly difficult to meet production targets given by buyers.

The crab fisheries governance policy will be right on target under factual problems in the field if supported by data collected based on specific methods and periods so that utilization patterns and problem maps will be read and mapped correctly. In addition to environmental and biological data, socioeconomic data information is crucial in photographing crab fishery activities' social and economic dynamics from fishing to the export stage. Therefore, this research aims to identify crab supply chain patterns and their issues, especially on the North Coast of the Java Sea. This research will provide their novelty on the uniqueness of small-scale crab fishermen in continuing their livelihoods with the challenges of environmental change, uncertainty in commodity prices, and patron-client relationships. In addition, specific supply chain patterns can be mapped, starting with catches, meat, and other derivative products.

2. Literature review

2.1. Supply Chain Management

In 2001, Mentzer et al. (2001) wrote a fundamental article on the definition of supply chain/supply chain management (SCM) that has been cited more than 9,000 times. Mentzer et al. (2001) concluded that the then-existing definition saw SCM as (1) a management philosophy, (2) an implementation of a management philosophy, or (3) a series of processes of management activity. When the first perspective is used (SCM as a management philosophy), the supply chain management process is defined as managing resources from suppliers to end consumers. While SCM is considered an implementation of a management philosophy, companies tend to view SCM as building relationships with suppliers and consumers. From the latter perspective, SCM means managing all suppliers' activities for consumers. This study defines supply chain management as the systemic and strategic coordination of business functions within a company and with other companies in a supply chain to improve the long-term performance of all companies (Mentzer et al., 2001; Min et al., 2019). Another definition of SCM was put forward by (Christopher & Towill, 2001, 2000), where SCM should expand its focus to accommodate uncertainties and external changes that can affect the supply chain, such as fluctuating customer demand, changes in market competition, or risks associated with raw material supply. This renews the previous opinion of focusing too much on internal coordination and integration in the supply chain and considering external dynamics. This opinion later evolved into Transformative Supply Chain Management (TSCM), which emphasizes the importance of fundamental transformation in understanding, designing, and managing supply chains to survive and thrive in an ever-changing business environment (Wieland, 2021). The transformation attaches importance to adaptation to new technologies, work culture structures, and business processes by the challenges faced. The underlying factor is rapid changes in the supply chain due to market changes, technological developments, and regulatory changes. Therefore, several strategic steps need to be taken, such as using information technology and collaborating with all stakeholders in the supply chain, such as suppliers, manufacturers, distributors, and customers. One of the other essential concepts in TSCM is environmental, economic, and social sustainability in the supply chain (Wieland, 2021). Therefore, environmentally friendly, ethical, and sustainable business practices must be encouraged.
The main objective of supply chain management is to create value for consumers through *cost leadership* or product differentiation to create *a competitive advantage* for all businesses in the supply chain. The focus is quality, both objective quality (technical specifications of the product) and subjective quality (customer satisfaction) (KetchenJr. & Craighead, 2020). SCM can be used to ensure that a business can consistently produce quality products/services as efficiently as possible. In the context of this study, SCM can be used to analyze and ensure that companies involved in the seaweed supply chain can consistently produce quality seaweed derivative products.

In the BSC industry, the factor of supply uncertainty that can affect production, distribution, and overall business stability is relatively high. Several influencing factors (Ervinia et al., 2023; Marks et al., 2021): 1) Season and Weather: Crab production is often influenced by the seasons and weather conditions in the waters where crabs live. 2) Utilization rate: Overuse or unsustainable utilization can lead to a decline in crab populations and threaten the sustainability of the resource 3) Environmental Change: Changes in the environment, including habitat degradation and pollution, can affect crab populations. 3) Fisheries Regulation: Government regulations on fishing seasons, catch quotas, and other restrictions may restrict access to BSC resources. 4) Global Climate Change: Global climate change can significantly impact the marine ecosystems where crabs live. 5) Global Market Conditions: Global market demand is also a factor that can affect crab supply. Fluctuations in demand from major markets such as America or Europe can affect the price and supply availability of BSCs.

2.2. Sustaining a Supply Chain with a Blue Economy Approach

Coastal and marine environments contribute to the Blue Economy (March et al., 2023). Within the context of sustainable fisheries management, the blue economy integration model encompasses multiple dimensions, including 1) technological innovation and advancements; 2) environmental and ecological sustainability; 3) fisher's and fish farmers' alignments; 4) government policy; and 5) research and development. Achieving food security, economic growth, and environmental sustainability are the three fundamental goals of fisheries management based on the blue economy (Sari & Muslimah, 2020). Small-scale fisheries (SSF) and industrial-scale fishing differ in specific ways, most notably in the socioeconomic aspects that would make SSF more suited to accomplishing some of the stated objectives of the blue economy.

The Blue Economy (BE) has emerged as a crucial component in advancing national economic development. Most maritime states try to increase the effectiveness of their utilization of marine resources (Martínez-Vázquez et al., 2023). A "blue economy" approach aims to manage conflicting interests and enable optimal growth in marine environments without putting social or ecological requirements ahead of economic ones (Sambodo et al., 2023). The term “blue economy” has several definitions despite being well-recognized. In line with the Organization for Economic Cooperation and Development's (OECD) definition of ocean economy, the European Commission defines it as “all economic activities related to oceans, seas, and coasts, comprising "the resources, products, and services offered by marine ecosystems”. The “sustainable use of ocean resources for economic growth, improved livelihoods and jobs, and ocean ecosystem and health” is how the World Bank views it. The United Nations Environment Programme (UNEP) uses the term “sustainable blue economy”, which is defined as “one in which the sustainable use of ocean and coastal resources generates equitably and inclusively distributed benefits

for people, protects and restores healthy ocean ecosystems, builds resilience, and contributes to the delivery of global ambitions for a sustainable future", to emphasize the significance of environmental and social considerations. In Indonesia, the term "blue economy" is defined as "an approach to promoting sustainable marine management and the conservation of marine and coastal resources and their ecosystems to generate economic growth through community engagement, resource efficiency, minimizing waste, and multiple incomes". This definition is based on Article 14, Paragraph 1 of Law Number 32 Year 2014 concerning the Sea. Even though the definitions are different, they all have the same basic ideas, which are that it is crucial to strike a balance between the present need to use resources for social and economic development and minimizing, if not eliminating, any potential environmental risk to ocean sustainability (Sambodo et al., 2023).

Industrial fishing is expanding globally because of the increased attention paid to the blue economy. Due to the depletion of local fisheries resources, damage to fishing gear, risk to fishermen's lives, and compromise of market systems and value chain positions, this intensification is having an impact on the livelihoods of SSF, processors, and merchants (Ayilu et al., 2023). Two guiding principles were presented when the Blue Economy idea first emerged. The efficiency of nature is the first consideration, where the blue economy emulates the ecosystem and functions in harmony with what nature gives efficiently, enriching rather than depleting it. The ecosystem's living systems must become balanced and sustainable for the second principle, zero waste, which states that waste from one source must be converted into food or energy for the other (Sari & Muslimah, 2020).

More than half of the BSC composition in the BSC fishery is shell, which will be discarded and negatively impact the environment. After peeling, the percentage of crab body parts is 52.59% shell, 35.68% meat, and 11.73% innards (Anggraeni et al., 2023). BSC trash has the same protein, fat, and dissolved solids as fisheries waste; if improperly managed, it will smell foul. BSC shells carry the risk of decomposition, but they can also be further processed to produce derivatives like chitin and chitosan, animal feed, fertilizer, and stuffed crab goods. Utilizing waste from crabs could enhance value and reduce environmental harm by preventing the release of unpleasant odors caused by the decomposition of organic matter and proteins. The crab industry should view ecological sustainability as a competitive advantage. Repurposing crab shell waste represents an untapped opportunity for adding value within the industry. Embracing a circular economy approach, where all materials are reused, can maximize the overall value, including both captured and uncaptured. Furthermore, employing crab waste aligns with the principles of the blue economy, particularly the goal of achieving zero waste.

3. Methodology

From June to December 2023, research has been conducted in locations that are bases for BSC production or landing and marketing. The distribution of crab production is still dominated in the Indonesian Fisheries Management Area (IFMA) 712. Therefore, the research location is focused on Cirebon Regency, West Java Province, and Rembang Regency in Central Java Province (Fig. 1). However, BSC fishermen in Cirebon and Rembang Regency are still classified as SSF with small vessels (1-6 GT) and a limited range of fishing operations around the coast. BSC collecting and peeling traders at the research locus belong to small to medium-sized enterprises. The above conditions are justified in the selection of BSC supply chain analysis.

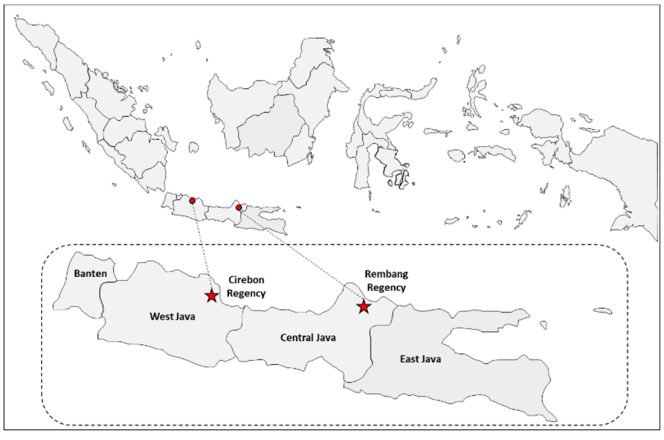


Fig. 1. Research Location

The types of data collected are primary data and secondary data. Primary data were obtained directly in the field through direct recording, and interviews were conducted through questionnaires with respondents. The data includes crab fishermen's characteristics, livelihood patterns, supply chain networks, crab fishery business investment, product prices, crab catch production data, and operational costs. Secondary data is obtained by tracking documented information in various institutions, governments, and communities. Primary data was collected by survey with interviews, Focus Group Discussion (FGD), and in-depth interviews. The respondents selected in this study are community components from various parties and backgrounds

in fisheries resource utilization activities and stakeholders. The samples taken in this study used a purposive sampling approach. Samples were taken as representatives of the characteristics of crab resource utilization at the research site. In this research, the number of interview respondents was 70, consisting of 60 BSC fishermen, and ten respondents were traders and processors. FGDs were conducted with fishermen groups and BSC processing groups. In-depth interviews were conducted with mini plant entrepreneurs and crab exporter companies. Respondents were selected by purposive sampling from fishermen, collecting traders, crab processors/peelers, processing factories, or exporters whose characteristics are known. Meanwhile, the snowball sampling approach is used to trace problems in the distribution chain and crab supply chain network from upstream to downstream. The selection of key informants is people willing to provide and have information related to problems in research as well as data and information that can be used in research. The key informants used in this study are stakeholders/beneficiaries of natural resource goods and services directly and indirectly. Key informants identified are local governments, fishing and marketing groups, community leaders, non-governmental organizations, and academics (Fig. 2).

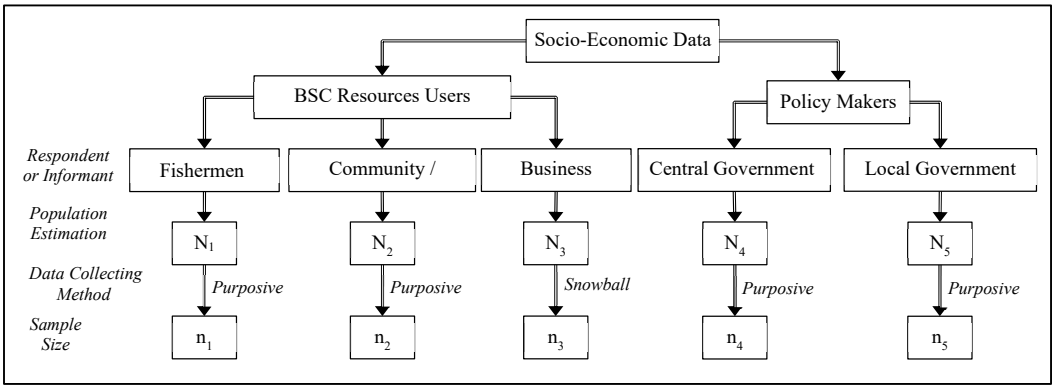


Fig. 2. The Framework of Socioeconomic Data Sampling

Data analysis is carried out with qualitative description, which is used to describe and summarize various conditions and situations or various phenomena of social reality that exist in society and seeks to draw these realities to the surface as a characteristic, character, trait, or description of certain conditions, situations or phenomena (Bungin B., 2007). Sugiono (2009) also emphasized that the method describes or describes the object under study through data or samples that have been collected and makes conclusions that apply to the public. This research uses descriptive analysis to describe the characteristics of crab fisheries, their problems, and the supply chain pattern of crab products from capture to acceptance by processing plants.

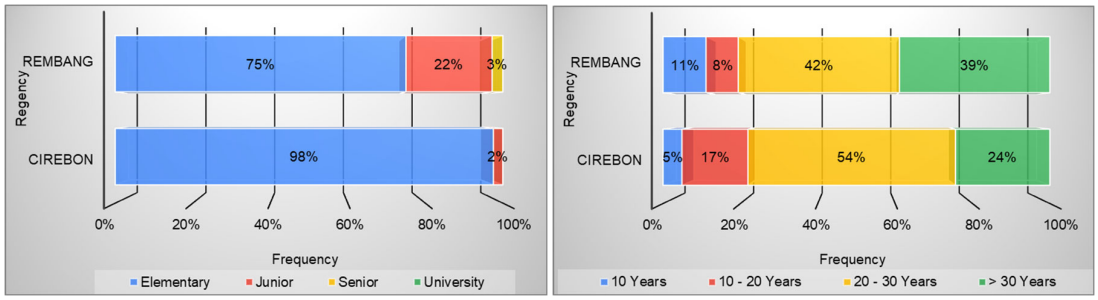
Perception analysis using Likert type-scale. The Likert-type scale is a psychometric scale commonly used in questionnaires and is the most widely used scale in survey research. When responding to questions on the Likert scale, respondents determined their level of agreement with a statement by choosing one of the available options. Five scale options are provided with formats: strongly disagree, disagree, agree, agree, strongly agree. The Likert scale used should be an odd number if the respondent is an expert in their field and has good competence so that there is no bias in answering, while if the respondents are random, the Likert scale used is even (Ma'arif, 2003; Marimin, 2004).

4. Results and Discussion

4.1. The Dominance of Traditional Fishermen in Blue Swimming Crab Fishing

BSC fishing activities in Indonesia are included in SSF. By definition, SSF can be viewed based on the technical attributes of vessels, the characteristics of their capture fisheries, and their socioeconomic attributes (Halim et al., 2019). The definition of SSF according to the applicable law, small fishermen are people whose livelihood is fishing to meet the needs of daily life, both those who use fishing vessels and those who do not use fishing vessels, with the most extensive range of vessel sizes used 10 (ten) gross tons (GT). Furthermore, the use of machines is also the scope of its definition. Referring to the previous ship size, the definition of SSF is a fisherman who fishes without using an engine (Non Powered Boat), using an outboard engine (Outboard Motor) or an inner engine (Inboard Motor) without mentioning the size of the engine used (The Center for Data Statistic and Information MMAF, 2022).

The characteristics of SSF BSC fishermen in the study location are that they have an average elementary school education level but have relatively long experience as crab fishermen, namely 20 years to 30 years (Fig. 3). Education and sea experience have an inverse relationship. Fig. xx shows that as many as 75% of fishermen respondents in Rembang have elementary school education, and Cirebon fishermen experience 98%. However, Rembang fishermen have an average more extended experience of 20-30 years (54%) than Rembang fishermen (42%). Generally, fishermen who have long fishing experience have low education. In both research locations, fishermen do not have a high level of education because they have been fishing since they were children. They fish to help their family economically. However, fishermen's education and fishing experience significantly affect their self-care (Dahlia et al., 2022; Sukono et al., 2021).



(a) (b)

Fig 3. Education (a) and Fishermen's experience ((b) in catching BSC

BSC fishing on the Java Sea's North Coast uses less than 5 GT ships, including traditional fisheries, similar to the characteristics of BSC fisheries in other locations (Jutagate & Sawusdee, 2022; Somboonsuke & Chiayvareesajja, 2007). The type of ship used is included in traditional boats, using wood-based materials made based on experience. The crab fishing boats are generally manufactured around the crab fishing centre village. Three types of fishing gear are used to catch crabs: bottom gillnet (BGN), collapsible trap (CT), and dredged net (DN) (Sara et al., 2019). Based on laws and regulations, BGN and CT are included in the passive fishing gear category, while DNs are included in the active fishing gear category. In some articles, BGN (Supriadi et al., 2020) and CT are also categorized as environmentally friendly fishing gear, while DN is not ecologically friendly (Boesono et al., 2016; Nurdin et al., 2022; Wiyono, 2009). However, all three fishing gears have bycatch (Jutagate & Sawusdee, 2022).

Using these tools on board will also determine the type of BSC ship. BGN is the simplest type of ship compared to the others. The net is placed on the side position of the boat to facilitate the process of lowering and shrinking the net. Lowering and lifting the net manually uses human labour, so the net-pulling machine does not require space allocation. The machine is generally only one piece with a size of less than 15 PK. One BGN boat takes about 2 – 3 people. BGN fishing activities are carried out for 6-10 hours (one-day fishing) in fishing areas between 1-5 miles. The characteristics of DN boats were almost similar to BGN boats. Using one or two machines and allocating space for net towing machines distinguish them from net boats. A DN requires energy so that it can be caught. The fishing gear used to catch crabs and the type of crab fishing vessel can be at least divided into three types based on the fishing gear used (Shabrina et al., 2021).

BSC fishermen in Cirebon use CT to catch crabs. They use Global Positioning System (GPS) as a tool to find location points. Catching crabs is not near the beach but in the middle, with a journey of about 2 hours. There were few catches when the research was conducted because there was still a famine season. However, from January to February, they shifted to the sea area of Karawang Regency to catch crabs. The number of CTs used depends on the number of crew (ABK) working. For example, if there are three crews, the division of the number of CT between boat owners and crew is as follows: ship owners 800 units, ABK 1: 400 units, ABK 2: 300 units, and ABK 3: 500 units. The catch of ABK is entirely its property. The crew will be charged ration and diesel fuel fees, but if the income is from the crew, the ship owner will ask for 10% of the crew's catch. For example, the provision of rations and diesel as much as IDR. 200.000, - will be divided by 3 (if two crew members are on board).

In Cirebon, the location of crab fishing using CT is moving. For example, it is dropped off at one location. If there are many catches, then the area is tagged using GPS. The use of the CT is most common in June – December or in lousy weather, east wind, and turbid water, and the position of the CT is at a depth of 8 - 18 meters. Also, fishermen already use GPS on Android-based devices, namely *Maverick.* In both research locations, fishermen use at least four tools to fish, namely GPS, Maverick, Fishing Point, and Windy Application. The Maverik app is most accessible because it uses satellite signals. Thus, fishermen can always use it even if it's far from the ground. The fishing point application serves to mark a maximum of five fishing locations. If fishermen want more fishing locations, they must pay for Windy application. This application uses a colour indicator to see if there is a strong wind before going to sea as a safety tool. Blue means low wind. Green indicates a bit high, and red means very high/strong wind. Fishermen's use of these tools has the main aim of fishing efficiency. BSC fishermen's behavioural intentions toward Android are determined by education, income level, and experience (Mazuki et al., 2013).

Fishermen also catch BSC using nets. The net used is BGN, with a net height of 2 meters (inches). One unit is 45 meters (30 fathoms) long. The use of units varies. In one boat, some carry 100 units, with the division of owners 50 units, ABK 1: 30 units, and ABK 2: 20 units. This system will determine the fisherman's profit-sharing system. Generally, ship owners receive a larger share than member fishermen (Faizal et al., 2021; Primyastanto, 2017; Wijayanto et al., 2019). Fishermen who use landing nets usually leave for the sea at 23.00, then around 03.00 make settings, and then at 5 am throw the anchor, 6 am has been withdrawn, and noon go home. They mark the crab fishing location as a guide for the next trip. If there are BSC, the fishing location can be shared with relatives and groups.

The average size of crabs caught with CT is 6 to 9 heads per kg. If 1 kg equals six crabs, the meat produced is approximately 2 kg. The BSC shell is still garbage because no one has processed it into other products. Amelia et al. (2021) emphasize that the discarded shell, comprising around 40-60% of the crab's total weight, typically requires further utilization. Meanwhile, shells can be used as animal feed and derivative products. If the fisherman has debts, the sale of crabs is carried out in a whole form (safe), directly sold to collectors, and then sold to mini-plants. However, if the fisherman has no debts, after boiling and peeling by the fisherman's wife, the crab meat is sold to collectors and mini-plants.

BSC fishermen in Rembang Regency are spread in Gegunung Wetan Village, Tambak Sari Village, and Kabongan Lor Village, and most use CT and nets with *a one-day fishing* system. BSC fishermen use CT fishing gear, BGN, and three-layer nets. For CT fishing gear, they use petek fish bait, which has been replaced with cowhide. Fishermen's crab fishing operations use the "nunut" system, meaning each boat consists of collaboration on using boat together between the owner and two crew members. These two fishermen do not have boats, but they can bring their fishing gear. Usually, this system is used for boats that use a bottom gill net. In the "nunut" system, dues for operations are deducted based on crab catches. Fishermen who use CT leave at 3-4 am and leave at 10 am. The operating costs of the boat are borne by the boat owner, not the collector. As for fishermen who use nets, they leave at 03.00 and return at 11.00 WIB. The fishing ground was 8-9 miles, and CT (25 miles).

The catch on the periphery tends to be small with a mixed size and an average of 5 cm and above, while the catch of middle fishermen has a crab size of about 10 cm and above. According to Arios et al. (2013), the structure of size, weight, and frequency of crabs caught with crab traps is primarily dominated by classes ranging from 161.1 to 187.9 grams. The crab yield is usually 3:1, meaning 3 kg of crabs (logs) becomes 1 kg of meat. However, the various designs of folding traps impact the quantity of captured crabs, while differences in bait types do not affect the outcome (Boesono et al., 2016).

The operational cost per trip ranges from IDR. 50,000 - 60,000. However, the price can reach IDR. 100,000 if the fishing ground is about 9 miles away (Fig. 4). Fishermen also look for spotted snails and red crabs, which generate additional profits. In addition, fishermen's operations also require ice worth IDR. 40,000 and 3 kg of gas, as much as two cylinders per day, can increase to 6 cylinders if the catch is large. However, there will be a shipping quota and a price reduction of up to IDR. 50.000 in the new year. The price difference among bosses reaches IDR—10,000 per kilogram. Crab meat shipments are carried out as much as 30-50 kilograms per day using GPS to determine the location of collectors.

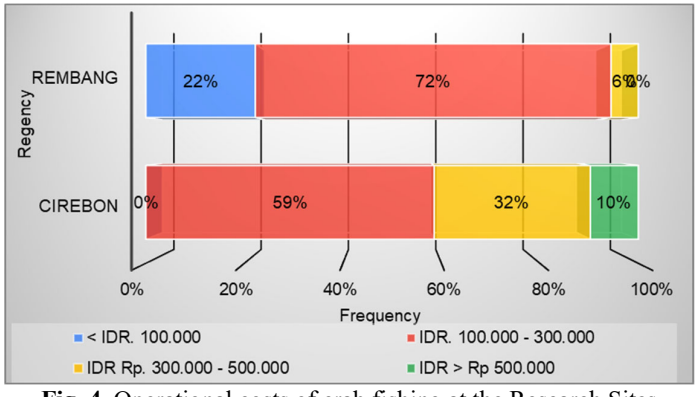


Fig. 4. Operational costs of crab fishing at the Research Sites

The crab industry faces declining quality of raw materials, such as soft and empty crab meat, caused by using DN fishing gear. BSC has unique characteristics with flesh in the form of body fluids similar to egg whites, which will harden when boiled. The crab stripping process is done in Gegunung Wetan and Kabongan Lor Villages. The remaining crab meat attached to the shell, called *lemi*, is processed into crackers or fish feed in Kaliori Village. The stripping fee per kilogram is given to peelers at IDR 2,000, while the selling price of 1 kilogram of raw crab is IDR 90,000. Peeled meat is priced at IDR 315 per Kg. Crab shells often become garbage, causing odour problems, although some are taken by collectors in Gegunung Wetan and Lor villages to be used as fish feed. The unstable price of crab meat is still a significant problem in crab fishing. The cost of BSC tends to drop by up to 50%, especially from November to February. In December 2022, crab prices range from IDR 30,000-40,000 per kg but can reach a high of IDR 85,000-90,000 per kg. Other obstacles include the difficulty of finding crabs at this time, which is different from previous seasons.

Factors affecting the fishing business (Investment, Operational Cost, and BSC Production) can also be seen from individual differences or socioeconomic variables on the BSC fishermen, such as age, education, primary income, working experience, family income, and family expenditure (Daw et al., 2012; Ochiewo, 2004). Abu Samah et al. (2019) state that it has been indicated that variables such as age, income, and work experience are frequently utilized in correlational analysis, with age serving as a common factor among respondents. Fig. 5 shows that the age of BSC fishermen respondents has a strong correlation only with working experience variables. At the same time, other variables have a weak correlation. This condition shows that age does not significantly affect related to BSC business or other family characteristics.

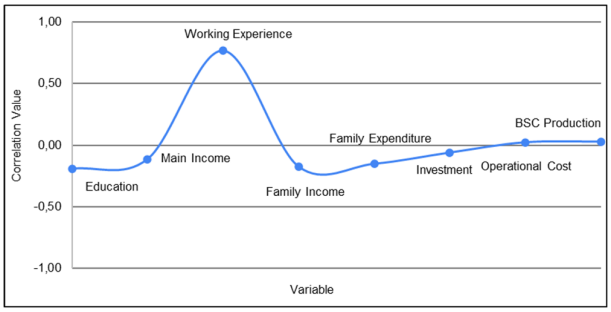


Fig. 5. Correlation between Age and Other Variables

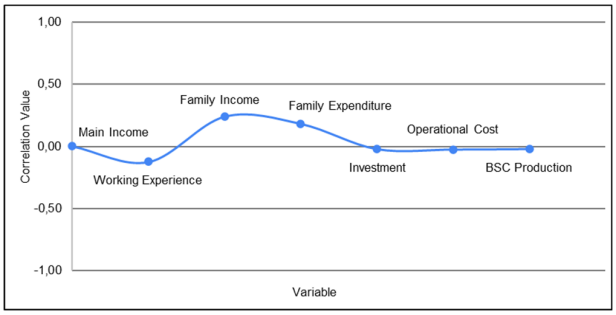


Fig. 6. Correlation between Education and Other Variables

Education level can also be used as an analytical tool to see the correlation relationship of variables. Fig. 6 shows data that is almost similar to the age variable. That education level is weakly correlated with primary income, working experience, family income, family expenditure, investment, operational cost, and BSC production. The findings are the same as the results of the study Blanden & Gregg (2004). They found no correlation between education and income.

4.2. The Supply Chain Pattern of Blue Swimming Crabs

BSC is an economic sea and estuarine crab species distributed throughout the Indo-Western Pacific (Ajik-Cerbas et al., 2022). BSC is rich in proteins, saturated fatty acids, polyunsaturated and monounsaturated fatty acids, and minerals, such as magnesium, calcium, zinc, and iron (Pathak et al., 2021). The nutritional content of BSC varies significantly according to sex and edible part. Previous studies have stated that BSC offers products with higher added value for commercial use due to its high nutrient content. For example, ready-to-eat pasteurized BSC, as well as BSC waste products in the form of *lemi,* also have the potential to add to the taste of food, such as crackers, crab balls (Ajik-Cerbas et al., 2022; Gunawan et al., 2020; Sasongko et al., 2018). In addition, BSC shells (or carapace) can be processed into chitin andish/poultry feed ingredients (Amelia et al., 2023).

BSC is one of the vital and abundant fishery resources and a source of livelihood for coastal communities in Indonesia, especially along the north coast of Java. As the fourth largest exporter of pasteurized crab meat in the world after Russia, Canada, and China (Amalia et al., 2021), Indonesia has BSC potential spread across eleven WPP NRIs. Based on the Decree of the Minister of Marine Affairs and Fisheries of the Republic of Indonesia Number 19 of 2022, the estimated potential of BSC in eleven fisheries management areas is 57,947 tons with an allowable catch of 36,267 tons. BSC stocks in waters affect Indonesia's ability to meet BSC demand abroad. The export volume of Indonesian pasteurized crab meat tends to increase annually. Indonesia's leading export destination country's crab meat to the United States is exported to Singapore, Thailand, Malaysia, the European Union, Taiwan, China, and Japan. High export performance will bring high state revenue, so it must be maintained by maintaining and improving the quality of BSC.

Integration of upstream and downstream production systems in fishery products is needed to increase the scale and quality of production, productivity, competitiveness, and added value (Nurhayati et al., 2023). The supply chain is a channel that describes the process from pre-production, production, and processing to marketing in the business system (Saribanon et al., 2024). The dynamic supply chain involves three constant flows: product, financial, and information. However, the main goal of the supply chain remains to meet consumer needs. Horizontally, the supply chain has five main components or actors: producers, suppliers, distributors, retailers, and consumers. Vertically, there are five main chain provision components: buyers, carriers, warehouses, sellers, and so on (Nurhayati & Purnomo, 2020). Our analysis highlights several exciting patterns in BSC's supply chain in Cirebon District, West Java, and Rembang Regency, Central Java. First, the BSC meat supply chain involves many actors in each BSC supply node, and the supply chain pattern depends on BSC price dynamics influenced by demand from buyers and the supply of BSC meat (fresh and frozen) is sold in the domestic market and fish processing units/meat canning plants for foreign markets. Second, the supply chain of BSC by-products in the form of *glue* and BSC shells has the potential to produce innovative processed products that can increase the income of people's families.

4.2.1. BSC Meat Supply Chain

95% of BSC supply chain actors in Indonesia generally consist of fishermen, mini-plants, and fish processing units (Setyaningrum et al., 2022). SSF dominates the BSC fishing business in the northern coastal waters of Java with low productivity, efficiency, and income levels. There are four types of fishing gear used by fishermen to catch BSC. The main fishing gear commonly used by fishermen to catch BSC in the waters of the north coast of Java are *CT*, *BGN,* other trawls, and DN. In Cirebon Regency, the main fishing gear for BSC fishermen is BGN and DN, while the CT net is only owned by *Andon* called "*bambangan"* fishermen with fishing grounds in the waters of Lampung, Sumatra, and Kalimantan. In Rembang Regency, all four BSC fishing gear are used by small-scale BSC fishermen. According to Huda et al. (2022), fishermen demand DN gear more because it has a minor investment cost, can be operated daily, and the profits obtained by fishermen are the

greatest. Cases of rejection of BSC products still often occur from exporters because SSF businesses have not been able to meet the requirements of export actors related to ecolabelling and product safety. The rejection of Indonesian BSC exports by the United States in 2003-2012 resulted in as many as 381 cases due to contamination of BSC products (Simbolon et al., 2020). This problem needs to be addressed through supply chain analysis from each actor so that they can understand the product safety assurance mechanism following applicable standards. In addition, supply chain actors also need to be aware of the importance of information related to traceability, which is a requirement for export products, namely the ability to identify and trace the origin, distribution, location, and application of products, materials, and services (ISO 9000-2005).

The quality of BSC influences the selling price of BSC received by fishermen (Huda et al., 2022). Good handling of BSC is by steaming the surviving BSC. BSC catches produced by fishermen are usually directly boiled on boats to maintain their quality. According to (Simbolon et al., 2020), boiling and storage activities are critical points in BSC's efforts. Some fishermen do BSC boiling on land due to the limited size of the vessel. However, the consequences of boiling on land will degrade the quality of BSC meat. BSC is classified as perishable food, so it depends on post-arrest handling. If live BSC is directly boiled, it must produce good-quality BSC meat. BSC should not be frozen; it will decrease quality and quantity by 50%.

BSC supply chain actors distribute products (in the form of crab meat) to meet consumer desires (both domestic and foreign) while receiving rewards in the form of money flows. Both parties also provide information to each other to ensure the continuity of cooperation. The product distribution process starts with fishermen who catch crabs. There are three characteristics of post-catch BSC treatment, namely: raw/fresh BSC produced by fishermen who catch at fishing grounds on the edge of coastal waters, cooked/boiled BSC produced by fishermen who catch at fishing grounds in the middle of the sea, and peeled BSC from fishermen's wives. Furthermore, there were differences in the characteristics of actors after producers in the supply chain at the two research loci. In Rembang Regency, fresh BSC is sold to collectors or peeling services for the stripping process and then sold to suppliers/miniplants, while boiled and peeled BSC is directly sold to collecting traders and sold to suppliers/miniplants. In Cirebon Regency, fresh BSC from fishermen can be sold to two actors, namely collectors and mini-plants for the stripping process, while boiled BSC is peeled first by the fisherman's wife and then sold to mini-plants. There is a bond between fishermen and collecting traders in the provision of business capital (to buy boats and fishing gear). On average, collecting traders have 12-20 assisted fishermen (2 fishermen per boat). That bond affects the selling price of crabs between fishermen with ties and those without ties, with a difference of IDR 5,000. The average cost of raw and boiled crabs from fishermen is IDR.90,000 per kg, while the price of peeled crab meat is IDR.315,000 per kg.

Each mini-plant has a place for stripping, and some mini-plants have cold storage. The employees receive a daily wage due to uncertainty in supply. The employee's wages depend on the length of work because all crabs will be processed on the same day they are received. The type of body part groups the BSC stripping process (Fig. 7). The weight reduction of BSC before stripping (called *safe*) and after stripping (into meat) or often called yield, namely: 1) if BSC is good, 3 kg of boiled BSC will produce 1 kg of meat, 2) if BSC is super, 3 kg of boiled BSC will become 1.7 kg of meat, 3) if BSC is porous, 3.5 kg of boiled BSC will become 1 kg of meat (no profit/loss), and 4) if BSC meat is soft, 4 kg of boiled BSC becomes 1 kg of BSC meat. The peeled parts of BSC products consist of a *jumbo lump* or *colossal* (white meat associated with swimming feet), *backfin* (white meat / small jumbo and jumbo fragments), *unique* (white meat on the body), *claw meat* (red meat from claws to feet), *claw fingers* (claw first part and movable claw part) (Figure 1). The composition of BSC meat according to type is influenced by the size of BSC. The larger the size of BSC, the larger the jumbo lump composition. That composition also aligns with research by Huda et al. (2022), Setyaningrum et al. (2022), and Simbolon et al. (2020).

(a) (b)

Fig. 7. The peeling process (a) and meat products (b) of Blue Swimming Crab

After sorting and packing BSC meat by mini plant/supplier into jars according to the type and the requested specifications, BSC products are sold to the processing plant (called *the Fish Processing Unit* (*UPI*)). Some plants collaborate with several supplier partners or fishermen groups to make it easier to maintain the sustainability of the quantity and quality of the products produced—ties between *plants* and suppliers and fishermen partners in the form of business capital support. *The plant* will receive a type of crab peeled and in fresh condition. Therefore, mini plants only need to maintain the quality of products to keep them fresh when received by processing companies. Costs and risks at the time of delivery to product quality are the responsibility of the mini plant. The seaming and pasteurization stages are critical in the crabbing process. The seaming process (packaging closure) can cause packaging failure and damage. Failures in this part can be handled through repackaging. In addition, other failures occur in the coding process. Updating the coding system can cause coding errors if no re-inspection

is carried out on the packaging. Therefore, packaging code checks must be carried out periodically every 200 cans to maintain the conformity of the production code with the origin of crab products. Another critical point occurs in controlling the duration of time and temperature in the pasteurization process (Simbolon et al., 2020).

The processing company meets most export demand through a pasteurization process to kill bacteria and extend the shelf life of peeled crabs. *The plant* meets export demand based on buyer orders from abroad. *The plant* will accept BSC products the mini plant sells if they meet the required specifications. *Plants* usually set a minimum target of shipments from mini plants if the number of crab harvests exceeds the number of requests. BSC products are then processed by the processing plant into pasteurized crab meat and packaged in cans to be ready to be exported to the USA (dominant), Europe, and other countries. Currently, crab canning companies in Indonesia (2023) are about 27-30 companies survive. The highest demand for BSC Indonesia products usually occurs before summer (June – August, 2-3 months). Often, demand is not met by 25%. In winter, Americans are reluctant to leave the house and rely on food stocks in their refrigerators. All processing companies exporting their products must have Marine Stewardship Council (MSC), Seafood Watch, and Sustainable Fisheries Partnership (SFP) labels to ensure safe quality from catch to finished product. BSC peels that do not meet export qualifications will be processed into processed products for local market consumption and marketed at partner restaurants of processing companies such as Carrefour. The flow of goods in the BSC meat supply chain can be seen in Fig. 8.

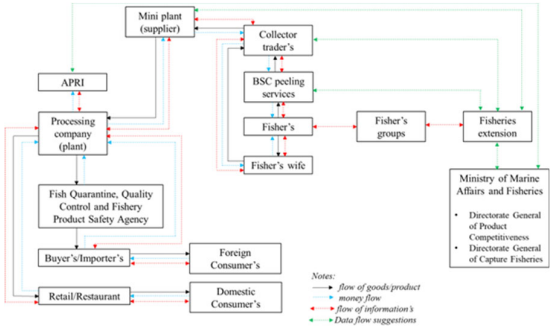


Fig. 8. Blue Swimming Crab (*Portunus pelagicus*) meat supply chain

In addition to the BSC goods/products flow, Fig. 8 shows the money flow and information between supply chain actors. Payment transactions to sellers are carried out by buyers when product handover transactions occur. However, there is an attachment between fishermen and traders, collectors, and peelers related to accounts receivable made by fishermen for business capital purposes (usually the purchase of fishing gear and operational costs). This relationship makes it impossible for fishermen to sell crab meat freely to other gatherings or peeling traders. The cost of bonding fishermen with collectors (with the condition that they must sell their catch crabs to collectors) is IDR 3 million to 10 million per boat. We need to pay attention to opinions (Ivanov & Dolgui, 2020) that state that supply chain resistance to disruption should be assessed within the framework of survivability or sustainability to prevent disruptions in supply chains and market falls and ensure the safe provision of goods and services. Supply chain actors should realize that a continuous and accurate flow of information can increase trust and commitment in establishing cooperation between BSC supply chain actors.

For this reason, exporters have taken the initiative to seek information about prices, target markets, and demand for product types from overseas buyers. This information is conveyed to all supply chain actors through pasteurization companies. This information flow occurs in stages between supply chain actors who make transactions. Thus, supply chain actors will handle raw materials (crab meat) based on the standardization of consumer demand. The poor handling process at a level of the supply chain will have an impact on decreasing the quality of crabs, thus affecting prices, income levels, and even rejection of processed crab products. Changes in colour, smell, taste, and texture in BSC meat characterize the decline in crab quality.

External and internal data traceability problems occur in the BSC supply chain. External traceability is related to the exchange of crab product information between supply chain actors, from processing/peeling traders to crab product export companies (Fig. 8). As the first actors in the supply chain, Fishermen do not provide any information related to crab catches to other actors. Information about the origin (technology and fishing area) and food safety is cut off from fishermen, so even collectors have no official information to pass on to pasteurization companies. In addition, collectors do not provide information about the origin and handling process of crab meat when selling it to peelers. Unlike when collectors sell it to pasteurization companies, they must complete documents about the shipped crab meat. In the context of supply chain complexity in the fisheries sector, implementing advanced information communication technology is essential for companies or industry stakeholders, given the speed of technological change and innovation that continues (Callinan, 2022). The same thing is done by crab peelers when selling crab meat to pasteurization companies. The collector must include information about the supplier's identity, the type and quantity of crab meat, and the packaging medium used in a document and then submit it to the pasteurization company.

Including information related to the origin of crabs from suppliers is vital for pasteurization companies to implement internal traceability. The challenges of BSC supply chain management in the future are expected to be able to traceability of BSC fisheries socioeconomic data from all actors/actors from upstream to downstream (fishermen, collecting traders, crab peelers, mini-plants, BSC processing companies, and APRI) in an information technology-based system with facilities and assistance from fisheries extension workers and centralized in the data and information system of the Ministry of Marine Affairs and Fisheries, especially the Directorate of Capture Fisheries and Directorate of Marine and Fisheries Competitiveness Improvement to maintain price stability, sustainable BSC governance and increase export competitiveness.

4.2.2. Blue Swimming Crab (BSC) by-Product Supply Chain

The by-products of BSC treatment consist of solid and liquid waste. Solid waste from crab processing in the form of crab carapace (shell) is 55%, body reject is 5%, and liquid waste is 40% (Amalia et al., 2021; Sasongko et al., 2018). After stripping, the proportion of BSC body parts is 52.59% shell, 35.68% meat, and 11.73% offal. The supply chain of glue and BSC shells is in detail as follows:

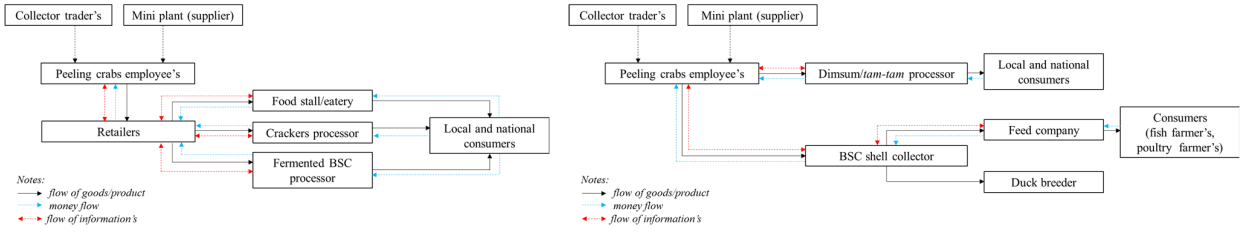
a. Lemi

Lemi is included in the solid waste body reject group produced from the BSC boiling/steaming process. *Lemi* has a high protein content of as much as 15.65%, consisting of amino acids. One of the amino acids contained in its proteins is the amino acid glutamate. Glutamic amino plays a vital role in giving an umami taste to food. The flavors formed by food are sweet, sour, salty, bitter, and umami. One of the uses of crab *lemi* is to process it into flavoring dishes. The supply chain of *lemi* is shorter than crab meat. *Lemi* is a *fee* given by collectors and miniplant traders to BSC peel workers as a bonus (excluding daily wages). Crab peelers sell *lemi* to retail traders in traditional markets. The benefits of crab *lemi* include *pepes lemi* (food stall) processors, crab cracker processors, and crab *petis* processors. The price of crab *lemi* is currently IDR25,000 per kg. BSC *lemi* processed products are in great demand by local people and consumers in several cities in Indonesia. BSC *lemi* processing provides added product value. For example, *lemi* crackers are priced at IDR40,000 per kg (with *lemi* only needing 2 kg). The *lemi* supply chain containing information on the flow of goods, money, and information is shown in Fig. 9a.

b. Crab shell

The fish processing unit (UPI) receives raw materials from BSC meat from mini-plants and crab peeling services. This peeling process leaves a large enough BSC shell waste of around 50-60%. The utilization of shell waste in derivative products has not been optimally carried out, and most of it is thrown into the environment so that it can cause environmental problems such as odor pollution, the transmission of various diseases, and disturbing public comfort. BSC shell waste has great utilization potential, in line with previous research that shell waste can still be used, among others, as a mixing agent/feed supplement, fertilizer, chitin, chitosan, food products, and others (Amalia et al., 2021 Amelia et al., 2023; Käll et al., 2022).

In Rembang Regency, Central Java, using BSC shells as a dim sum container can attract consumers at the national level. In addition, crab shells are also used as raw materials for fish and poultry feed and are used by local duck farmers. Utilization of BSC shells at the research locus from wet shells, then dried in the sun, for further sale to fishmeal/animal feed (duck) factories. However, the informant did not know the price of dried shells sold to feed mills. There has been no further processing of BSC shells in Cirebon Regency, West Java. If abundant BSC shells are only stockpiled on vacant land, they can have environmental impacts on coastal communities. Crab shells are given free of charge to benefit the environment. The BSC shell supply chain containing information on the flow of goods, money, and information is shown in Fig. 9b. There are still many opportunities to utilize crab shells in derivative products with high added value, but investors have not glimpsed them.



(a) *Lemi* supply chain (b) *Crab Shell supply chain*

Fig. 9. By-product supply chain of Blue Swimming Crab (*Portunus pelagicus*)

4.3. BSC Supply Chain Issues

BSC management is the responsibility of all supply chain actors in every production process. Actors who play a role in the crab handling process include 4 clusters, namely fishermen, collecting traders, crab peelers, and pasteurization companies. They have different activities but must be interrelated so that the supply of raw materials can produce products that meet

exporters' preferences. However, supply chain management faces several problems at the upstream and downstream levels and implications for institutions and government policy. There are several issues in Indonesia's BSC supply chain management. First, the stock of raw materials is decreasing. Some factors related to BSC capture under egg-laying conditions and required undersize (carapace width above 10 cm or weight size 55 grams); unreported BSC fishing, particularly in statistics data; the number of processing companies is decreasing; the condition of overfishing due to high demand of crabs meet; massive utilization of destructive fishing gears. Second, high-profit disparity occurs between upstream and downstream supply chain actors. The high and low prices of BSC are controlled by mini-plants/suppliers who have patron-client relationships with fishermen to provide operational costs for fishing. This factor may affect the power of fishermen to bargain with their patrons. This problem is a classic in the supply chain. Therefore, a more adaptive approach is needed. A review by (Wieland, 2021) related to Panarchy theory reconceptualizes the supply chain as regards a social-ecological system, departing from a modernist perspective of supply chain management (SCM) and embracing a more contemporary notion of "engaging with the supply chain dynamically—third, limited access/facilitation of financial capital for small-scale fishermen. Fourth, there is a low level of knowledge and awareness of actors regarding the sustainability of BSC resources. Poore & Nemecek (2018) argued that producers vigilantly observe their effects, adaptively achieve environmental objectives by selecting various methodologies, and convey their impacts to consumers to mitigate this issue—the fifth, low intensity of law enforcement and implementation of BSC fishing regulations/policies. Sixth, fishermen still have poor participation or involvement in the decision-making process. Seventh, there is inadequate data traceability in the supply chain process. Eight, small fishermen still have weak knowledge and compliance with the certification rules.

5. Conclusions

BSC fishing industry in Indonesia, particularly on the north coast of the Java Sea, falls under small-scale fisheries. It demonstrates distinct characteristics in terms of vessel types, equipment, and the socioeconomic status of fishermen. SSF encompasses a wide array of practices crucial for sustaining livelihoods. BSC fishermen primarily utilize small vessels equipped with traditional gear, such as BGN and CT, with a focus on promoting sustainability. Despite having limited educational backgrounds, the extensive experience of fishermen significantly affects their well-being. Operational methods vary with technology adoption to improve efficiency and safety. Socioeconomic factors such as age and educational level influence the sector. BSC's supply chain is intricate, involving various stakeholders from fishermen to exporters, offering a range of high-value products, including pasteurized meat and innovative by-products like *lemi* and crab shells. While opportunities for value addition and environmental sustainability exist within the supply chain of BSC by-products, the optimal utilization of these by-products remains constrained, with untapped potential for further innovation and investment. Enhanced coordination among supply chain actors and the utilization of technological advancements can facilitate improved management and utilization of by-products, leading to maximized economic and environmental benefits.

Nevertheless, challenges persist in meeting export standards, fluctuation in market price, decline in the quality of crab catches, ensuring product safety, and optimizing by-product utilization. Overcoming these challenges hinges on quality assurance, efficient handling practices, and regulatory compliance. Collaboration, innovation, and regulatory support are paramount for fostering sustainable practices, enhancing market competitiveness, and promoting environmental stewardship within the BSC supply chain. Consequently, government regulations play a pivotal role in governing BSC fisheries and promoting sustainable practices, with initiatives such as fishermen groups and extension services to bolster collaboration, compliance, and resilience within the supply chain. Moreover, enhancing data traceability and information exchange among supply chain actors can foster market transparency, trust, and responsiveness.

Addressing the challenges and capitalizing on the opportunities within the BSC supply chain necessitates concerted efforts, regulatory backing, and innovative approaches across the value chain. The BSC supply chain can significantly contribute to long-term economic prosperity, environmental stewardship, and market competitiveness by championing sustainable practices, elevating product quality, and optimizing by-product utilization.

Acknowledgement

The authors are grateful to the National Research and Innovation Agency, the Republic of Indonesia, and *LPDP* for providing the first-year research fund—many thanks to all parties who support this research activity and publication process.

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