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Unlocking Octopus Export Potential in Indonesia: Logistics, Seasonality, and Certification Challenges from Bone Regency

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ABSTRACT

Indonesia's expansive maritime territory and biodiversity position the country at the forefront of the global seafood trade, particularly in the octopus export market. This study assesses the export feasibility of octopuses through a case study of CV. Lintas Samudra Mandiri (LSM) in Bone Regency, South Sulawesi. Using a mixed-method approach—including literature review, field surveys, stakeholder interviews, and case analysis conducted throughout 2025—the study evaluates ecological conditions, species composition, harvesting practices, seasonal trends, and cold chain logistics. Findings show that Fisheries Management Area (WPP-RI) 713, where Bone is located, contributed 12.9% of Indonesia's total octopus production between 2021 and 2023, with growth exceeding 200%. *Octopus cyanea* is the dominant species, harvested mainly through traditional hook-and-line methods, while *O. vulgaris* appears only sporadically. LSM operates with a daily processing capacity of 8 tonnes and a cold storage capacity of 50 tonnes, supported by a network of 13 ports and compliance with HACCP and SKP certifications. The company primarily exports to Japan, benefiting from a reliable cold chain system and independent export licensing. Seasonal fluctuations in catch volumes, influenced by oceanographic dynamics, underscore the importance of adaptive fisheries management. Overall, the findings highlight Bone's strategic role in Indonesia's cephalopod sector and demonstrate the scalability of LSM's integrated export model for other coastal regions.

INTRODUCTION

Indonesia, the world's largest archipelagic country, comprises over 17,000 islands spanning the equator between the Pacific and Indian oceans. Its geographical position and vast maritime territory endow the country with some of the richest marine biodiversity on the planet **(Asaad *et al.*, 2018)**. These waters host numerous ecologically and economically significant species, making Indonesia one of the top global seafood producers.

Among these marine resources, the octopus (*Octopus* spp.) has emerged as a high-demand commodity in international markets. Rising demand in Europe, Japan, and North America is driven by culinary trends and nutritional attributes **(FAO, 2020a)**. As a result, the octopus represents a promising export opportunity for Indonesia, offering foreign exchange income, employment, and livelihood security for coastal communities. However, export competitiveness depends not merely on resource abundance but also on effective harvesting practices, reliable supply chains, and institutional governance.

Indonesia's octopus fishery is still largely artisanal, characterized by small-scale fishers using traditional methods and facing challenges in cold chain infrastructure and product traceability. Inconsistent post-harvest handling reduces product quality and marketability in premium destinations. Meanwhile, sustainability certifications, sanitary and phytosanitary (SPS) standards, and documentation requirements increasingly shape access to global seafood markets **(Tran *et al*., 2013; Ainsworth *et al*., 2023)**.

Supply chain fragility is a major constraint because octopus is highly perishable and requires immediate cooling and transport. Seasonal fluctuations in catch ("musim paceklik") further complicate sourcing, while fragmented value chains hinder integration from harvest to export. Without systematic improvements in logistics, storage, and transport, Indonesia's octopus sector risks losing competitiveness. Moreover, compliance with HACCP, catch documentation schemes, and sustainability labeling is now essential **(FAO, 2020b)**; yet, small- and medium-scale producers often lack the capacity to meet these standards consistently.

Despite these challenges, limited research has examined how Indonesian producers navigate ecological constraints, logistical bottlenecks, and certification requirements simultaneously. Previous studies tend to emphasize ecological assessments or trade statistics, leaving a gap in understanding the integrated dynamics of export readiness in specific production hubs. In this context, CV. Lintas Samudra Mandiri (LSM), a seafood company in Bone Regency, South Sulawesi, provides a valuable case study. Bone is among eastern Indonesia's key octopus-producing areas, benefiting from the biologically productive Bone Gulf and port access **(Junaedi *et al*., 2020)**. By linking small-scale fishers with international buyers, LSM highlights the opportunities and systemic barriers that shape Indonesia's octopus exports.

The contribution of this case study lies in demonstrating how a local enterprise adapts to sustainability standards, logistical constraints, and regulatory requirements in one of Indonesia's priority Fisheries Management Areas (WPP-RI 713 and 714). Unlike general assessments, this study anchors the analysis in a real-world operational setting, highlighting transferable lessons for scaling sustainable octopus exports. Accordingly, this study aimed to analyze Indonesia's octopus export potential through the case of Bone, focusing on three dimensions: ecological (sustainability and stock availability), logistical (cold chain and supply efficiency), and institutional (compliance and coordination). By addressing these interrelated factors, the study contributes to identifying integrated pathways for transforming Indonesia's octopus industry into a competitive, sustainable, and inclusive export sector.

MATERIALS AND METHODS

1. Time, location, and approach

This research employed a mixed-methods approach to assess the potential for octopus exports from Bone Regency, South Sulawesi. Conducted over the course of 2025, the study focused on CV. Lintas Samudra Mandiri (LSM) facilities and operational sites. The combination of qualitative and quantitative methods allowed the research to capture ecological, logistical, and institutional dimensions influencing the viability of octopus exports. Data collection occurred at the company's processing plant and surrounding fishing communities, enabling direct observation of field operations and stakeholder interactions.

To enhance rigor, the research followed a sequential strategy: beginning with a literature review to establish context, followed by field surveys, interviews, and case study analysis. Triangulation was applied across all stages to ensure reliability and validity.

2. Literature review

A comprehensive review of secondary data was undertaken to provide the theoretical and contextual foundation of the study. Sources included academic journals, government reports, policy documents from the Ministry of Marine Affairs and Fisheries (KKP), and publications from relevant institutions such as the Marine and Fisheries Polytechnic of Bone. The review focused on Indonesia's maritime potential, cephalopod species distribution, octopus grading standards, and export logistics. To ensure up-to-date contextualization, recent publications (2021–2024) on octopus fisheries, certification schemes, and cold chain development were also analyzed.

3. Field survey and interviews

Primary data were collected through site visits in Bone Regency, with direct observations at CV. LSM's processing facility and nearby fishing ports, particularly PPI Lonrae. Semi-structured interviews were conducted with key stakeholders, including:
a) Local fishermen engaged in octopus capture
b) Representatives and technical staff of CV. LSM
c) Government officials from the local fisheries agency

A purposive sampling strategy ensured diversity of perspectives across stakeholder groups. In total, 25 respondents were interviewed: 15 local fishers (representing different age groups and fishing practices), 5 LSM staff (covering managerial, processing, and logistics roles), and 5 government officers from the fisheries agency. Selection criteria required active involvement in octopus capture, processing, or regulation within the past three years, ensuring respondents had relevant and current experience.

The interviews explored seasonal catch variability, fishing techniques, product quality control, and cold chain management. Each interview lasted between 30–60 minutes, conducted in Bahasa Indonesia, and later transcribed and thematically coded for analysis.

4. Case study analysis

The research adopted a single-case study approach, selecting CV. LSM as a representative enterprise to illustrate opportunities and constraints within Indonesia's octopus export industry. The selection was justified by LSM's unique position as one of the few HACCP-certified companies in Bone Regency that directly source octopus from artisanal fishers and export to international buyers. Its operations integrate procurement, processing, cold chain management, and compliance, making it a critical case for examining systemic challenges and transferable lessons in export readiness.

The case study focused on LSM's operational practices, infrastructure capacities, sourcing networks across Sulawesi, and compliance with market standards. Findings were triangulated using national statistics and direct site observations. Combining qualitative data (interviews, observations) with quantitative sources (catch records, export data) enhanced both validity and replicability.

5. Summary of research methodology

To ensure clarity and transparency, Table (1) summarizes the research components and corresponding data collection techniques.

Table 1. Summary of research methods

Method Component	Description	Data Source and Tools
Literature Review	Review of existing academic and government publications	Journal articles, ministry reports, and online databases
Field Survey	On-site observations at processing facilities and ports over 1 year	Direct field visits (January–December 2025)
Interviews	Semi-structured interviews with stakeholders	Local fishers, LSM staff, and fisheries officials
Case Study Analysis	Single-case analysis of CV. LSM's operational capacity	Triangulation with national statistics and field data

Data Triangulation	Cross-checking multiple sources to validate findings	Qualitative and quantitative comparison

RESULTS AND DISCUSSIONS

1. Overview of Indonesia's Maritime and Fisheries Potential

Indonesia encompasses a vast marine area of approximately 6.4 million km², which includes territorial waters, the continental shelf, and the Exclusive Economic Zone (EEZ) **(Ministry of Maritime Affairs and Fisheries, 2018; Puspasari, 2022)**. The country possesses exceptional marine biodiversity, with more than 17,000 islands and a coastline stretching over 80,000km. As the heart of the Coral Triangle, Indonesia hosts between 500–800 coral species that sustain complex ecosystems and provide habitats for numerous marine species, including economically significant cephalopods such as the octopus (*Octopus cyanea*) **(Hasyim & Paskalis, 2024)**. Its strategic location between the Indian and Pacific oceans offers favorable ecological conditions and direct access to global maritime trade routes **(Indonesian Information Portal, 2023)**. This positioning not only enhances export capacity but also establishes Indonesia as a key actor in marine resource governance.

Bone Regency in South Sulawesi exemplifies this national maritime advantage. Covering approximately 4,600km²—equivalent to 9.78% of the province's total area—the regency has 138km of coastline along Bone Bay **(Bone District Government, 2017)**. Its tropical climate, characterized by high humidity (77– 86%) and moderate temperatures (24.4– 27.6°C), provides an ideal environment for marine species such as *O. cyanea* **(Rahmatang *et al.*, 2023)**. In 2017, Bone Regency recorded 3,301 fishing vessels, most under 5 GT, and more than 9,300 registered fishermen, many affiliated with the Mitra Mina Bahari cooperative **(Bone District Government, 2017)**.

The region also benefits from supporting infrastructure, including multiple fish auction sites (TPI), fish landing centers (PPI), cold storage facilities, and ice factories capable of producing approximately 6,060 ice blocks daily. Among these, PPI Lonrae stands out as a central landing hub. It also serves as the operational base of CV. Lintas Samudra Mandiri (LSM), which benefits from direct access to fresh daily landings—illustrating how local infrastructure directly shapes value-chain efficiency.

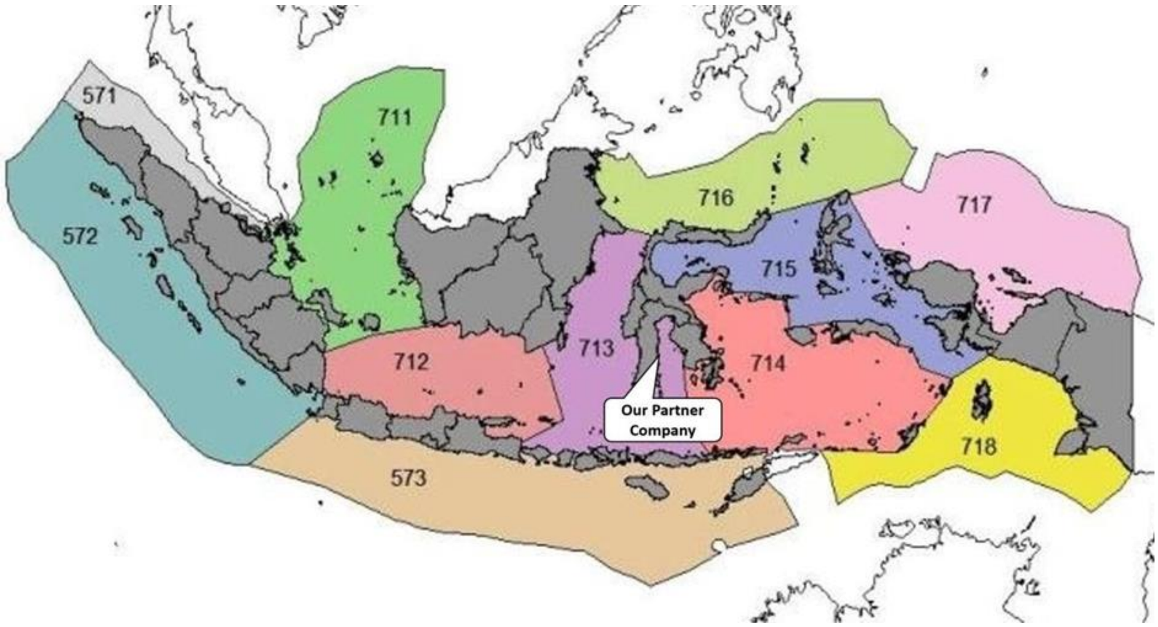

Fig. 1. Map of Indonesia's Fisheries Management Areas (FMA-RI) **(Krisnafi *et al.*, 2017)**.

Bone's proximity to Fisheries Management Areas (Wilayah Pengelolaan Perikanan Republik Indonesia, WPP-RI) 713 and 714 further strengthens its role in national octopus production. Between 2021 and 2023, WPP-RI 714 contributed an average of 27.2% to Indonesia's total octopus production, while WPP-RI 713 contributed 12.9% **(Ministry of Marine Affairs and Fisheries, 2025)**. WPP-RI 713, which encompasses the Gulf of Bone and serves as the focus of this study, experienced a remarkable production increase of more than 200% during this period. This trend illustrates how ecological productivity and improved supply logistics can jointly reinforce regional competitiveness. Importantly, such growth underscores the need for targeted governance, since unmanaged expansion risks undermining sustainability.

Table (1) presents octopus production data across 11 WPP-RI zones from 2021 to 2023. The highest average production was recorded in WPP-RI 714 (5,444.23 tons), followed by WPP-RI 573 (4,140.32 tons) and WPP-RI 571 (3,852.37 tons). In contrast, WPP-RI 716 contributed the least, averaging only 188.10 tons annually, highlighting significant spatial disparities in octopus productivity across Indonesia's fisheries management areas.

Fig. (2) illustrates the average production distribution by percentage: WPP-RI 714 contributed 27.2%, WPP-RI 573 contributed 20.7%, and WPP-RI 571 contributed 19.2%, while WPP-RI 713 ranked fourth, contributing 12.9% to national production. These figures indicate that eastern Indonesia—particularly WPP-RI 714 and 713—dominates national octopus fisheries. The consistent lead of WPP-RI 714 is likely attributable to its rich coral reefs and seagrass ecosystems, which provide critical habitats for commercially valuable species such as *O. cyanea* **(Rahmatang *et al*., 2023)**. Meanwhile, the more than 200% increase in WPP-RI 713, from 1,393.51 tons in 2021 to 4,301.74 tons in 2023, reflects not only improved ecological conditions but also enhanced fishing efficiency and better logistics coordination.

Table 1. Number of octopus catches per WPP-RI in 2021–2023 **(Ministry of Marine Affairs and Fisheries, 2025)**

Area	Sum of Production (Ton)			
	2021	2022	2023	Average
WPP-RI-714	5,969.50	5,431.64	4,931.57	5,444.23
WPP-RI-573	5,019.15	3,456.25	3,945.56	4,140.32
WPP-RI-571	2,844.78	3,048.21	5,664.13	3,852.37
WPP-RI-713	1,393.51	2,040.21	4,301.74	2,578.48
WPP-RI-572	806.51	1,469.56	1,250.74	1,175.60
WPP-RI-712	1,076.92	995.40	1,234.46	1,102.26
WPP-RI-711	1,234.52	216.67	25.76	492.32
WPP-RI-715	360.69	471.14	613.99	481.94
WPP-RI-718	216.03	409.58	286.09	303.90
WPP-RI-717	12.56	721.86	99.50	277.97
WPP-RI-716	148.84	251.74	163.73	188.10

The recent expansion in octopus catch is mirrored by improved operational capacity in Bone Regency, where companies such as CV. Lintas Samudra Mandiri have strengthened cold chain systems and sourcing networks. Their proximity to WPP-RI 713 enables rapid transport of freshly caught octopus for immediate processing and storage. The warm tropical waters of Sulawesi (25– 28°C), combined with rocky benthic substrates and abundant prey, create optimal ecological conditions for cephalopod growth **(Ghofar, 1998)**. Additionally, the reproductive resilience of cephalopods—particularly their short life cycles and high fecundity—may be contributing to the observed increase in yields. However, without adaptive harvest strategies and effective monitoring, these same biological traits can mask early signs of overexploitation.

Despite this promising outlook, several challenges remain. Octopus populations are subject to seasonal fluctuations, influenced by monsoonal currents, temperature variability, and spawning cycles **(FAO, 2020a)**. These temporal dynamics necessitate flexible and adaptive harvesting strategies, coupled with real-time monitoring, to mitigate the risk of overexploitation. Moreover, international market requirements now demand strict compliance with sustainability and traceability standards, including HACCP certification, sanitary and phytosanitary (SPS) measures, and catch documentation systems **(Jacquet *et al*., 2010)**.

Thus, ecological potential alone is insufficient. Aligning production with policy reforms, digital traceability systems, and fisher training is essential to ensure that Bone's ecological advantage translates into sustained export competitiveness.

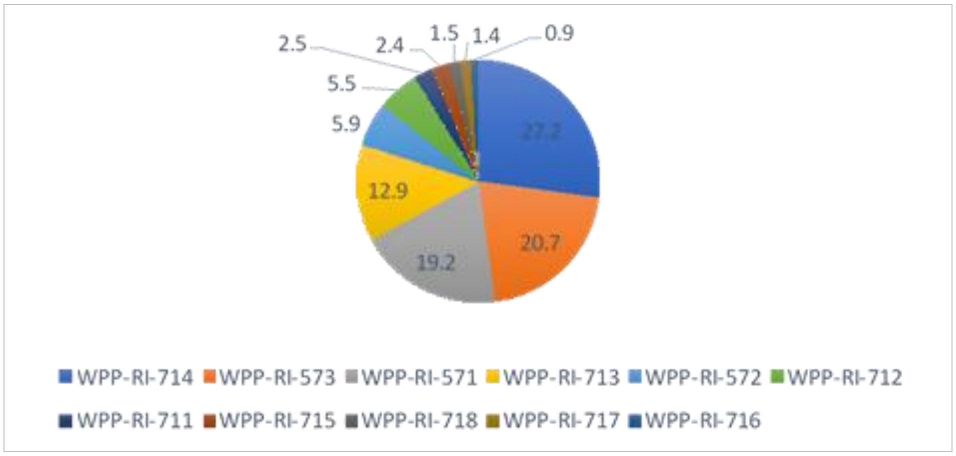

Fig. 2. Distribution of average production sum per WPP-RI in percent **(Ministry of Marine Affairs and Fisheries, 2025)**

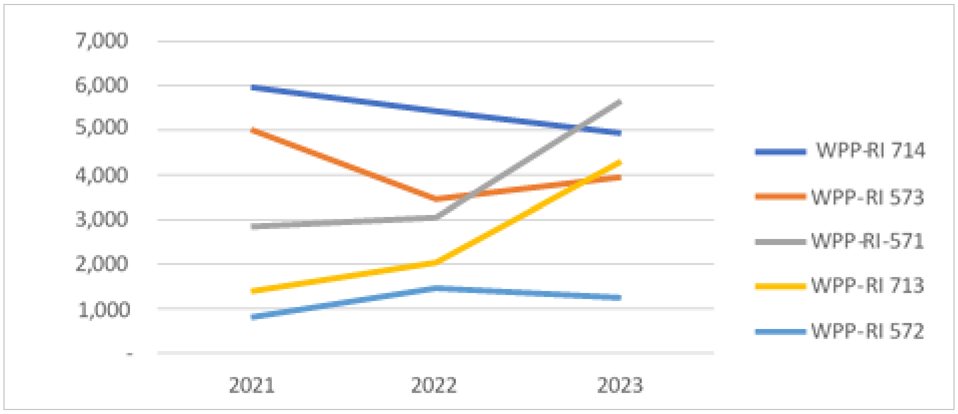

Fig. 3. Trend in catch quantity variation between 2021 and 2023 **(Ministry of Marine Affairs and Fisheries, 2025)**

Analysis of octopus production trends from 2021 to 2023 (Fig. 3) reveals notable spatial and temporal variations among WPP-RI zones. WPP-RI 713 demonstrated the most dramatic growth, more than tripling its output in just three years—a trend that may be driven by improved catch efficiency, favorable oceanographic conditions, or shifting octopus distributions in response to ecological and anthropogenic factors **(Putri *et al.*, 2019)**. In contrast, WPP-RI 573 experienced a production dip from 5,019.15 tons in 2021 to 3,456.25 tons in 2022, before partially recovering to 3,945.56 tons in 2023. Such fluctuations may reflect localized environmental disturbances or temporary overfishing, followed by stock regeneration **(FAO, 2020b)**. These dynamics highlight the importance of adaptive management tools—such as seasonal closures, effort limits, and habitat protection—to ensure that productivity gains do not come at the cost of resource depletion.

WPP-RI 572 showed a modest increase from 806.51 tons in 2021 to 1,469.56 tons in 2022, but declined again to 1,250.74 tons in 2023. This brief productivity peak may correspond with seasonal cycles or erratic stock-recruitment patterns characteristic of short-lived cephalopods. Meanwhile, WPP-RI 714, despite being the country's top producer, experienced a gradual decline from 5,969.50 tons in 2021 to 4,931.57 tons in 2023. This trend may indicate increasing fishing pressure, declining catch-per-unit-effort (CPUE), or underlying ecological stress, thereby necessitating localized management actions such as seasonal closures or gear regulations **(Cömert *et al*., 2025)**.

From a management perspective, these trends underscore the need for spatially targeted interventions. For example, areas showing rapid production growth, such as WPP-RI 713, may require enhanced monitoring and adaptive harvest strategies to prevent overfishing. In contrast, zones with persistently low yields, such as WPP-RI 716, could benefit from investment in habitat restoration, fisher training, or infrastructure improvements. Overall, Table (1) demonstrates that raw production data alone cannot guide sustainable fisheries policy; analytical interpretation linking ecological conditions, operational capacity, and governance mechanisms is essential for informed decision-making.

Both ecological and socio-economic factors drive spatial and temporal variability in octopus yields. Environmental parameters such as sea surface temperature, ocean currents, and habitat integrity play critical roles, while human factors—including fishing intensity, market incentives, and governance capacity—amplify or mitigate outcomes. Owing to their fast life cycles and responsiveness to environmental change, cephalopods are widely recognized as sensitive bioindicators of marine ecosystem health and fishery sustainability **(La Torre *et al*., 2024)**. Consequently, emerging production patterns across WPP-RI zones highlight the need for adaptive, spatially nuanced management that aligns with Indonesia's blue economy objectives and adopts precautionary approaches to ensure long-term viability **(Habibullah *et al*., 2023)**. In this sense, the Bone case not only illustrates regional potential but also provides broader policy lessons on balancing ecological resilience with export-oriented growth.

2. Species, grading classification, and product form of Octopus in Bone

The primary octopus species harvested in Bone, South Sulawesi, is *Octopus cyanea*, locally known as *Shima-dako*. This species flourishes in the region's tropical marine environment, where seawater averages around 28°C with salinity levels of approximately 34% **(Rahmatang *et al*., 2023)**. Its dominance reflects strong ecological adaptation to local benthic and oceanographic conditions, which supports relatively stable catches and underpins the economic viability of the fishery. However, findings from direct surveys conducted in 2025, including structured interviews with local fishermen, revealed that *Octopus vulgaris* is also occasionally captured. Although less abundant, the presence of *O. vulgaris* introduces species diversity that may influence grading selectivity and market strategies, since mixed-species catches require careful sorting to maintain export quality. In some instances, fishermen reported that *O. vulgaris* may dominate the catch, although this remains anecdotal due to the absence of comprehensive species composition data. Robust species-level monitoring is therefore essential to avoid overexploitation, ensure sustainability, and optimize economic returns. Despite this uncertainty, *O. cyanea* remains scientifically recognized as the predominant species in Bone's coastal ecosystem **(Omar *et al*., 2020a)**.

Both *O. cyanea* and *O. vulgaris* are classified as cephalopods and are marketed collectively under the generic label "octopus." While this practice streamlines trade and processing, it may also obscure species-specific population trends, complicating sustainability assessments and risk management. CV. Lintas Samudra Mandiri (LSM), the leading company operating in the area, applies a grading system that categorizes octopuses primarily by weight. This classification affects market segmentation and determines product suitability for export markets. The grading scheme and internal company protocols are presented in Table (2). Grading decisions directly influence fisher income, as only high-grade specimens (Grade A) qualify for premium markets. This system incentivizes selective harvesting but may also increase pressure on larger individuals.

Table 2. Octopus grading criteria

Weight (kg)	Grade	Description
> 2	A	Suitable for export
1 – 2	B	Suitable for the domestic market
0.5 – 1	C	Reject
0.3 – 0.5	D	Reject

For export purposes, CV. Lintas Samudra Mandiri (LSM) only accepts Grade A octopus, which meets the stringent quality requirements demanded by international buyers, particularly in Japan. The combination of weight and quality checks—including intact tentacles, natural coloration, firm flesh, and the absence of off-odor—ensures product reliability, reduces rejection rates, and maintains market trust **(Zamuz *et al*., 2023)**. This multi-parameter inspection guarantees that only high-grade specimens enter the export value chain, safeguarding product reputation and minimizing rejection risks in destination markets.

LSM's primary product form is frozen block octopus, a format preferred by Japanese importers for storage efficiency and bulk handling. However, the company also produces alternative forms such as flower-shaped, ball-type, boiled, or semi-processed formats (slices or cubes), illustrating strategic product diversification. This approach enhances market responsiveness, mitigates risks associated with singleproduct dependence, supports value addition, and improves fisher livelihoods by increasing demand for different size grades. Collectively, the species composition, grading strategy, and product diversification contribute to both ecological sustainability and economic resilience in Bone's octopus fishery.

2. Fishing season and seasonal variability

Oceanographic and climatic conditions significantly influence the seasonal dynamics of octopus fishing in Indonesia by affecting nutrient upwelling, water temperature, and consequently, octopus behavior and spatial distribution **(Liang *et al*., 2025)**. Species such as *Octopus cyanea* are highly responsive to short-term ecological shifts, making their availability strongly dependent on ocean productivity. Seasonality therefore plays a central role in shaping fisher livelihoods and export system reliability.

Traditionally, two primary fishing seasons are recognized based on prevailing monsoonal patterns. The west season (January–June) is characterized by stronger winds and increased wave activity that enhance vertical mixing of water columns. This process brings nutrient-rich waters to the surface, fostering plankton growth and overall ecosystem productivity. As a result, octopus availability increases, with peak catches typically observed between March and May **(Lumban-Gaol *et al*., 2021)**. In contrast, the east season (July–December) is marked by calmer seas and weaker vertical mixing, resulting in reduced nutrient circulation and lower biological productivity. Octopus catch rates decline accordingly, and fishermen often refer to this period as *musim paceklik* (lean season), reflecting reduced yields and income. For small-scale producers, this seasonal downturn limits cash flow, constrains investment capacity, and increases economic vulnerability.

Interestingly, internal surveys by LSM conducted in 2025 indicate a deviation from this traditional pattern. According to operational records and fisher interviews, the high season now extends from October through March, sometimes continuing until May. This shift may be attributed to interannual oceanographic variability driven by large-scale climatic phenomena such as the Indonesian Throughflow and the El Niño–Southern Oscillation (ENSO). These systems influence sea surface temperature, current velocity, and nutrient distribution across the Coral Triangle, disrupting conventional planning and complicating the synchronization of harvests, processing schedules, and export contracts **(Pascual *et al*., 2019)**.

The observed discrepancies in seasonal timing underscore the need for adaptive management frameworks that incorporate real-time environmental data, localized knowledge, and stakeholder engagement. From a policy perspective, this calls for flexible harvest regulations and investment in early-warning systems to anticipate ecological fluctuations. Accurate seasonal forecasting is vital to optimize fishing efforts, align export scheduling, and ensure sustainability amid climate variability. From a business perspective, supply volatility places pressure on cold storage, inventory turnover, and pricing stability. Firms like LSM must therefore balance short-term stockpiling with long-term sustainability goals to maintain buyer trust and market competitiveness **(FAO, 2017)**.

3. Fishing capacity and vessel size

CV. Lintas Samudra Mandiri (LSM) collaborates extensively with local fishing communities in Bone Regency and across Sulawesi to strengthen supply chains in the octopus fishery. This network not only ensures raw material availability but also enhances operational resilience by diversifying sourcing across 13 key fishing ports, only one of which—Lonrae—is located in Bone Regency. The remaining 12 ports, though outside Bone, play a strategic role in stabilizing supply and buffering against localized catch variability.

Each of these 13 ports typically supports 11–15 active fishing vessels (Fig. 4). Vessel sizes range from small boats under 5 GT to medium-sized vessels up to 20 GT, with catch capacities between 1 and 5 tonnes per trip, depending on specifications **(Bone District Government, 2017; LSM internal data, 2025)**. Vessel capacity directly affects daily procurement volumes and introduces fluctuations that must be managed to meet export commitments. It is generally accepted that net tonnage (actual holding capacity) is approximately one-ninth of gross tonnage. For example, an 18 GT vessel can hold roughly 2 tonnes of octopus. This ratio underscores the logistical limitations of small-scale fleets and highlights the importance of coordinated aggregation and rapid transport to processing facilities to maintain product quality.

Fig. 4. Fishing vessel. A) 1 – 1.5 GT; B) 5 – 7 GT; C and D) 10 – 20 GT

LSM's operational capacity is anchored by its octopus processing facility at Lonrae Port, which has a maximum throughput of 8 tonnes per day. This ceiling represents a critical bottleneck: even if catch volumes exceed this level during peak season, the facility's throughput limits the supply available for export channels. Effective alignment of vessel landings with processing capacity is therefore essential to prevent post-harvest losses and maintain market competitiveness. Assuming a five-day work week, LSM can process up to 40 tonnes per week and approximately 160 tonnes per month under ideal high-season conditions. However, balancing procurement volume with product freshness and processing efficiency requires dynamic operational planning, particularly when seasonal peaks coincide with limited cold storage capacity.

Official data from the Ministry of Marine Affairs and Fisheries, combined with field observations, indicate that monthly octopus landings in Bone Regency can reach as high as 150 tonnes during peak months, declining to around 20 tonnes during the lean season (Fig. 5). Assuming 20 fishing days per month, this translates into an average of 7.5 tonnes landed daily at Lonrae Port. As the sole processing operator at this central hub, LSM effectively governs supply consolidation, mitigating fragmentation risks and enhancing overall supply chain efficiency. Access to 12 additional ports further strengthens this role, allowing LSM to stabilize export volumes despite spatial and temporal variations in catch.

The discrepancy in seasonal definitions between government data (2023) and those reported by **Rahmatang *et al*. (2023)** or LSM's 2025 internal observations may reflect temporal variability or differences in sampling sites. While Rahmatang's team collected data from a minor port, government statistics represent activity at a central hub where catches from surrounding smaller ports are consolidated. Thus, these apparent differences in seasonality are likely due to logistical aggregation patterns rather than inconsistencies in biological availability.

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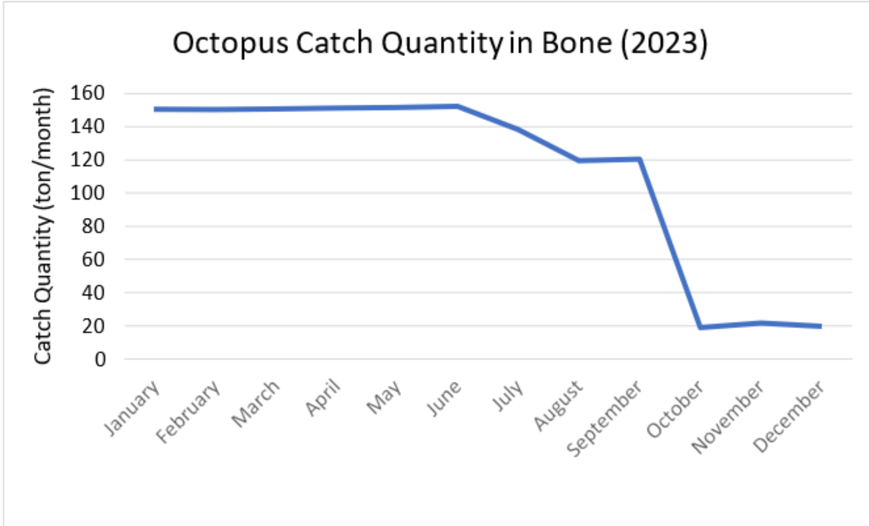

Fig. 5. Octopus catch quantity in Bone across 2023

Monthly catch trends in 2023 reveal a clear seasonal pattern: production remained high and stable from January through June, declined moderately in July–August, and then dropped sharply from October to December. This sustained early-year availability likely reflects favorable oceanographic conditions—such as optimal temperature, salinity, and nutrient concentrations—that enhance cephalopod productivity and catchability **(Pascual *et al*., 2019)**. A moderate decline begins in July, with catches falling to around 120 tonnes by August. This downturn may be linked to the onset of the southeast monsoon, which brings stronger winds and currents to the southern Makassar Strait and can restrict access for small-scale vessels **(Utama *et al*., 2017)**. A dramatic drop is observed in October, when catches fall to approximately 20 tonnes and remain low through December. Several factors may explain this decline. Biologically, the period may coincide with a spawning phase for *Octopus cyanea*, during which adult populations temporarily decrease **(Raberinary & Benbow, 2012)**. Behaviorally, fishers may shift effort to other target species or adjust strategies in response to market demand or declining availability. Logistically, the rainy season may create post-harvest challenges—such as limited ice supply, poor port accessibility, or transport delays—that reduce landings or discourage fishing activity.

These fluctuations illustrate how biological cycles, weather conditions, and logistical constraints collectively affect supply continuity. Low catches during reproductive periods or adverse weather highlight the need for adaptive management strategies, such as temporary closures, dynamic allocation of fishing effort, and investment in ice and cold storage infrastructure. Vessel capacity, port distribution, and processing limitations directly shape Bone Regency's competitiveness and the sustainability of its octopus fishery. Policy implications include prioritizing investments in mid-sized vessel fleets, upgrading port facilities, strengthening cold chain infrastructure, and enforcing spatial–

temporal fishing regulations. Such measures would stabilize supply, safeguard octopus populations, and reinforce Indonesia's position in global seafood markets **(FAO, 2020a)**.

2. Fishing methods and initial handling

The predominant method used for octopus fishing in Bone Regency is hook-and-line fishing, locally known as *pancing*, which employs specialized lures called *kulepas*. These lures mimic the appearance and movement of natural prey, such as crabs and mollusks, stimulating visual and tactile responses from octopuses **(Rahmatang *et al*., 2023)**. Across Indonesia, variations of these hooks have emerged, including crab-shaped baits and articulated *pocong-pocong* models. While functionally similar, these designs are low-impact and minimize environmental disturbance, particularly to coral habitats and non-target species, compared with more invasive methods such as trawling or spearfishing **(Bagaskoro, 2018; Bubun & Mahmud, 2019; Omar, 2020b)**.

Fishing operations typically occur within 1.5 nautical miles of the shoreline, an area dominated by shallow coral reefs, rocky substrates, and crevices where octopuses seek refuge. Fishers rely on surface-level cues, such as water turbulence or benthic terrain patterns, to identify promising sites. Lures are then deployed at depths ranging from 1 to 12 meters, depending on tidal conditions **(Rahmatang *et al*., 2023)**. This nearshore strategy improves catch selectivity and reduces both bycatch and habitat degradation, reinforcing the sustainability of Bone's octopus fishery.

Post-capture handling is critical for maintaining quality, especially for export markets with stringent freshness standards. Octopuses are immediately placed into plastic bags, then stored in styrofoam containers filled with ice to maintain internal temperatures around 5°C during transport. Simple interventions—such as immersing octopuses in aerated seawater before icing—can reduce stress, improve muscle tone, and preserve textural quality, thereby enhancing export-grade outcomes. Fishing trips are typically single-day operations, with most grounds located within 1.5 nautical miles of port. At average boat speeds of 9 knots, the journey from catch to landing is completed within hours **(LSM survey, 2025)**. This operational efficiency strengthens cold chain management at the earliest stage of the supply chain.

Adherence to these handling protocols aligns with internationally recognized best practices in seafood hygiene and preservation. By combining selective, low-impact fishing with stress-reduction techniques and rigorous cold chain management, LSM safeguards product quality while promoting environmentally responsible practices. Proper temperature control minimizes enzymatic degradation and microbial growth, preserving organoleptic quality, structural integrity, and shelf life before freezing and export **(Zamuz *et al*., 2023)**. These integrated strategies enhance both market competitiveness and ecological sustainability, reinforcing Bone Regency's role as a reliable supplier of high-quality octopus to global markets.

3. Transportation and cold chain management

The logistical network connecting 13 fishing ports to LSM's processing facility at Lonrae Port ensures efficient transfer of octopus from capture to export-ready condition. Among these ports, those accessible by land—including Lonrae itself—are prioritized daily to minimize transport time and preserve freshness. Transport durations typically range from 2 to 5 hours, depending on distance and road conditions (Table 3). This prioritization reduces spoilage, lowers waste, and decreases energy consumption by limiting time-dependent refrigeration losses.

At the core of LSM's post-harvest system is an advanced refrigeration setup. The facility operates two air blast freezers (ABFs), each with a 4-ton capacity, enabling rapid freezing of freshly processed octopus. Quick temperature reduction is critical for microbial control, tissue integrity, and energy efficiency **(Pascual *et al*., 2019)**. Complementing the ABFs is a total cold storage capacity of 50 tons, comprised of one 40-ton and one 10-ton unit. These serve as buffer stock facilities, ensuring consistent export readiness while accommodating fluctuations in daily landings. Opportunities for sustainable innovation include integrating renewable energy sources, such as solar-powered freezers or energy-saving ABF technologies, to reduce both operational costs and carbon footprint.

Once processed and frozen, products are loaded into refrigerated containers equipped with generator sets (gensets) to maintain cooling during transit. These containers are transported overland to Soekarno-Hatta Port in Makassar, Eastern Indonesia's largest cargo hub and the primary gateway for international exports. From Makassar, sea routes connect directly to major overseas markets, particularly Japan—LSM's principal export destination **(LSM operational data, 2025)**. The use of insulated containers with efficient gensets further mitigates product losses, reduces energy waste, and supports consistent quality assurance.

The seamless integration of freezing, storage, and refrigerated transport highlights the robustness of LSM's cold chain management. Despite Indonesia's fragmented geography of more than 17,000 islands, the company's operations are strategically concentrated around major ports on large, well-connected islands such as Sulawesi. Many ports in its network—including those in Bone, Kendari, and Wakatobi—benefit from road and sea links that reduce delays and energy-intensive inefficiencies.

Table 3. Transport duration between key ports to CV. LSM

Port	Transport Duration by Land to LSM (Hours)
Paotere	4
Untia	4
Bebar	5
Bonto Bahari	3 – 4

Bira	4
Kajang	3
Lappa Sinjai	2
Lonrae (Bone)	0
Kendari	Transport by sea
Wakatobi	Transport by sea
Luwuk Banggai	Transport by sea
Labuan Maros	3 – 4
Cempae (Pare-Pare)	4 – 5
Soekarno-Hatta Makassar Port	4 – 5

Significantly, the effectiveness of this cold chain system is reinforced by national policy frameworks and regulatory oversight from institutions such as the Ministry of Marine Affairs and Fisheries. The Ministry plays a critical role in supporting infrastructure development, enforcing food safety standards, and ensuring alignment with international quality and traceability protocols **(Ministry of Maritime Affairs and Fisheries, 2018)**. This institutional backing enhances operational reliability, reduces product losses, and provides a foundation for adopting energy-efficient innovations in cold chain management. Overall, LSM's integrated approach demonstrates how traditional fisheries can be combined with modern cold chain technologies to minimize waste, optimize energy use, and maintain high-quality standards, offering a model for sustainable, export-oriented seafood logistics in archipelagic contexts.

2. Certification, legality, and key facilities

CV. Lintas Samudra Mandiri (LSM) operates a processing facility in Bone Regency that complies with both national and international food safety standards, establishing the company as a credible player in the global seafood market. The facility holds a Class B Hazard Analysis and Critical Control Points (HACCP) certification, which covers frozen cephalopods and other seafood products, ensuring systematic identification, evaluation, and control of hazards throughout the production process **(LSM internal documentation, 2025)**.

Additionally, LSM has obtained the *Surat Kelayakan Pengolahan* (SKP) from the Indonesian government. This certification confirms its compliance with domestic fish processing regulations and affirms its readiness for commercial-scale seafood handling. Beyond regulatory compliance, LSM implements regular training programs for local fishers and staff, focusing on quality control, hygiene practices, and proper octopus handling. These initiatives enhance community capacity, strengthen adherence to international standards at the source, and integrate local stakeholders into the export value chain.

Fig. 6. A) Air Blast Freezer (ABF); B) Vacuum; C) Receiving Room and Preliminary Cutting Area; D) Weighing and Grading

LSM operates under an independent registered exporter license, which grants the authority to issue key export documentation—including health certificates, catch certificates, and vessel records—without reliance on third-party intermediaries. This autonomy enhances traceability, streamlines regulatory compliance, and ensures that the company can meet documentation requirements from importing countries, particularly high-standard markets such as Japan **(Ministry of Marine Affairs and Fisheries, 2025)**. The internal management of compliance also enables LSM to provide direct feedback and guidance to its suppliers, strengthening knowledge transfer and quality assurance throughout the supply chain.

Field observations conducted during the 2025 survey confirm that LSM's processing facility is equipped with a comprehensive suite of cold chain and processing infrastructure, as illustrated in Figs. (6, 7). These include a receiving room and preliminary cutting area, a weighing and grading station, a trimming room, and a CO_2 injection system, all essential for structured and hygienic material flow. Core cold storage and preservation technologies—such as an air blast freezer (ABF), vacuum packaging system, and chiller

(Cool Storage)—complement these functional areas. The facility's design and workflow reflect strict adherence to food safety principles, ensuring both quality assurance and operational efficiency.

Fig. 7. A) CO Injection; B) Trimming Room; C) Personnel complying with strict hygiene, sanitary, and safety standards; D) Chiller (Cool Storage)

Each of these components plays a vital role in preserving product quality. The ABF, for instance, rapidly reduces product temperature to −40°C, which is critical for maintaining cell structure integrity and suppressing microbial growth, thereby ensuring that freshness and texture are retained throughout the freezing process **(FAO, 2022)**. Vacuum packaging and CO_2 injection further extend shelf life by minimizing oxidation and reducing the risk of bacterial spoilage during storage and long-distance transport **(Onyeaka & Nwabor, 2021)**.

The facility's dedicated cutting, trimming, and grading rooms enable systematic quality control at every processing stage. These operational zones align with HACCP protocols, which require continuous monitoring of biological and physical hazards **(U.S. Food and Drug Administration, 1997)**. In parallel, stringent hygiene measures are enforced, including mandatory gowning, sanitation checkpoints, and regular staff training sessions. Notably, these training initiatives are also extended to local fishers, ensuring proper handling practices before octopus enters the facility. This dual emphasis supports both product quality and the improvement of community livelihoods. Such measures are essential for compliance with sanitary and phytosanitary (SPS) standards enforced by major seafood-importing markets such as the European Union, Japan, and the United States **(Jacquet *et al*., 2010)**.

In Indonesia's fisheries sector—where infrastructure fragmentation and post-harvest losses remain persistent—LSM's facility stands out as a vertically integrated, export-oriented seafood processing model. Its infrastructure and institutional readiness reflect the objectives of Indonesia's blue economy strategy, which prioritizes value-added production, sustainability, and global competitiveness **(Ministry of Marine Affairs and Fisheries of Indonesia, 2023)**. Consequently, LSM's success not only strengthens Bone Regency's position as a viable octopus export hub but also demonstrates the broader potential for scaling knowledge-transfer practices, strategic investments, and governance frameworks across other coastal regions of Indonesia.

CONCLUSION

This study confirms that Indonesia—particularly Bone Regency—holds strong potential for octopus exports, with CV. Lintas Samudra Mandiri (LSM) well-positioned to capitalize on this opportunity. Proximity to productive fisheries zones (WPP-RI 713 and 714), favorable marine conditions, and supportive infrastructure provide a solid foundation for growth. LSM demonstrates export readiness through certified processing facilities, robust cold chain capacity, and well-established sourcing networks. Nonetheless, seasonal variability and limited species-level data remain challenges. These constraints can be mitigated through systematic monitoring, adaptive management, and strengthened stakeholder coordination. Addressing such issues will not only enhance sustainability but also improve market competitiveness. Overall, Bone Regency offers a promising model of regionally grounded yet globally connected octopus exports, aligning with Indonesia's broader blue economy agenda and highlighting pathways for scaling sustainable seafood trade across other coastal regions.

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