EREM 81/3
Journal of Environmental Research, Engineering and Management
Vol. 81 / No. 3 / 2025
pp. 50–62
10.5755/j01.erem.81.3.39725

Assessing the Sustainable Supply Chain Management Performance of Ornamental Coral in the Bali Strait Using the RAPFish Method

Received 2024/12 | Accepted after revisions 2025/04

https://doi.org/10.5755/j01.erem.81.3.39725

Assessing the Sustainable Supply Chain Management Performance of Ornamental Coral in the Bali Strait Using the RAPFish Method

Candra Adi Intyas[1]*, Djoko Koestiono[2], Agus Tjahjono[1], Suhartini Suhartini[2], Fitria Dina Riana[2], Illisriyani Ismail[3]

[1] Department of Fisheries and Marine Socio-Economy, Faculty of Fisheries and Marine Science, Universitas Brawijaya, Indonesia

[2] Department of Social Economy Agriculture Plant, Faculty of Agriculture, Universitas Brawijaya, Indonesia

[3] Centre For Policy Research, Universiti Sains Malaysia, Malaysia

***Corresponding author:** candra.intyas@ub.ac.id

Coral reef ecosystems exert a pivotal role in fisheries from ecological, social, and economic perspectives. Components of coral reefs, particularly ornamental corals, currently hold significant economic value for aquarium hobbyists and as public facility accessories in international markets. However, sustaining their production requires effective supply chain management to prevent overexploitation. Despite the optimal supply chain performance and sustainable exploitation status, fluctuating ornamental coral abundance over the past three years indicates that long-term sustainability remains uncertain. Therefore, this study analysed the performance of sustainable supply chain management (SSCM) for ornamental corals in the Bali Strait using the RAPFish (Rapid Appraisal for Fisheries) method. A descriptive case study approach and snowball sampling were employed to collect data from exporters, suppliers, and fishers. Results indicated an average SSCM performance score of 67.28%, categorized as moderately sustainable. This result indicated that SSCM for ornamental corals was generally not yet sustainable, with the least sustainable dimension being government policy (46.99%), where the most sensitive attribute was economic and social policy.

Keywords: ornamental corals, RAPFish, sustainable supply chain management (SSCM).

Introduction

Coral reef ecosystems, among the most vulnerable to change, are highly significant in Indonesia, which boasts the largest habitat for ornamental corals globally, covering 9703 km². This area represents approximately 12.5% – 18% of the world's coral reefs and is part of the Coral Triangle, home to about 69% of the world's coral species (Allen and Erdmann, 2013; Karim et al., 2021; Susiloningtyas et al., 2018). Coral reef ecosystems are vital both ecologically and socio-economically, supporting 93,000 species of marine biota (Bellwood and Wainwright, 2002; CRITC Coremap-LIPI, 2016; EPA, 2022).

Well-maintained mangrove and coral reef ecosystems hold significant economic value in marine ecotourism. (Mahmudah et al., 2023; Swara and Intyas, 2021). Beyond ecotourism, coral species, the main components of coral reefs, have become high-value commodities in the hobbyist market, especially for aquarium enthusiasts. Despite their beauty, maintaining ornamental corals is costly, making this hobby predominantly appealing to high-end consumers and the export market (Intyas et al., 2023a; Rhyne et al., 2014).

Producers of ornamental corals come from various regions in Indonesia, centred around the Bali Strait waters, and supply exporters. The United States is the largest importer of Indonesian ornamental corals, accounting for about 60% of total exports, followed by Japan, China, and Europe (Suriyani, 2020). There are 38 ornamental coral businesses around the Bali Strait waters, consisting of local companies and exporters. The ornamental coral trade is dominated by exports, with exporters as the focal firms, selling finished products from suppliers working with fishers. Any disruptions in the supply chain can significantly affect other members.

In recent decades, growing domestic and international competition has forced organizations to enhance their internal processes to remain competitive. Failure to meet these demands will lead customers to seek more accommodating businesses (Intyas et al., 2022). Optimal supply chain management performance is essential for enhancing competitiveness and achieving integrated upstream and downstream management.

Supply chain management supports and coordinates resources to ensure timely and efficient flows. It does so by forecasting demand, controlling inventory, strengthening relationships with customers, suppliers, and distributors, and receiving feedback on the status of each link in the supply chain (O'Brien and M. Marakas, 2007).

Data from 2019 indicate that coral reefs in Western Indonesia have improved, with a rising proportion classified as good or fair (Hadi et al., 2020). However, the increasing utilisation of coastal fisheries resources can threaten the ecosystem, so sustainability needs to be maintained even though fishery resources are renewable. Efforts to increase the production of ornamental corals require good supply chain management, particularly in terms of supply, to prevent overexploitation that could disrupt the ornamental coral supply chain. Government regulations related to strict licensing and annual quota restrictions are policies that were adopted to ensure the sustainability of coral reefs (Intyas et al., 2023b).

Sustainability is defined as meeting the needs of the present generation without compromising the ability of future generations to meet their own needs (Brundtland, 1987). The most common (conventional) sustainability model is based on three overlapping dimensions: environmental, economic, and social justice (Caradonna, 2014). The broadest definition of sustainability involves actions taken today that combine human behaviour with natural ecosystems to maintain their health and productivity for future generations (Isdianto et al., 2022). As the world changes, behaviours intended to ensure sustainability must also change and adapt. This behaviour causes issues because users and consumer groups might perceive sustainability as a static attribute for example, 'product x is sustainable' but it is a continuous movement towards more sustainable practices based on ecosystem changes (Rhyne et al., 2014).

Although the supply chain performance is optimal and the exploitation status is sustainable, this does not guarantee sustainability (Intyas et al., 2023b). This condition is evidenced by the fluctuating fulfillment of ornamental corals over the past three years. Sustainability is mandatory in business, including in supply chain management. A supply chain management theory that considers sustainability incorporates the concept of sustainability into supply chain management processes to assess the environmental, social, and economic impacts of business activities. This concept is known as Sustainable Supply Chain Management (SSCM).

SSCM encourages companies to extend their economic, environmental, and social efforts throughout the supply chain (Croom et al., 2000). SSCM improves the interconnections among these integrated supply chain activities to achieve a sustainable competitive advantage. Systematic coordination presents significant challenges in SSCM, particularly when managing long-term strategic decisions. The structural dimension of a sustainable supply chain integrates economic, social, and environmental factors, each with distinct characteristics (Joshi, 2022).

SSCM strengthens the integration of supply chain activities to achieve a sustainable competitive advantage. This study employs the RAPFish (Rapid Appraisal for Fisheries) method to analyze SSCM, enabling the identification of vulnerable variables within each dimension. Building on this framework, the research aims to evaluate the performance of SSCM for ornamental corals in Indonesia. However, no prior studies have systematically evaluated SSCM in ornamental coral supply chains using the RAPFish method to identify dimension-specific vulnerabilities.

SSCM is comprehensively analysed using the Interpretive Structural Modeling (ISM) approach, which is illustrated in four quadrants and targets seven (7) SSCM practices (supplier, design, management, consumer, worker, internal, and logistics) in the mineral and mining industry in China (Jia et al., 2014). The Analytic network process (ANP) – evidential reasoning (ER) is another method used in the marine aquaculture industry along the Yellow Sea coast of China. This method is applied to seven dimensions: economic, environmental, social, resilience, stakeholders, value co-creation, and innovation (Wan et al., 2021). The position of variables in SSCM practices is solely determined by the propelling power and dependency of the variables, as illustrated in a Cartesian diagram, using the ISM model approach. Nevertheless, this model is unable to identify the vulnerabilities in each SSCM practice. On the other hand, the ANP-ER approach continues to have constraints in identifying the most vulnerable variables in each dimension, as it only displays sustainability scores and rankings for each dimension. The RAPFish method is a strategy that effectively illustrates SSCM by pinpointing the most vulnerable or influencing elements in SSCM.

Methods

This study employed a descriptive case study method. According to Nazir (2003), descriptive research investigates the status of a group of people, an object, a set of conditions, a system of thought, or a class of events in the future. Case studies focus on specific aspects of the research subject's personality, including individuals, groups, institutions, or communities. The goal is to describe the case's background, characteristics, and unique traits or status, which can then be generalised. Case studies emphasise examining many variables in a small number of units.

This research aimed to systematically, factually, and accurately describe or explain the sustainable supply chain events for ornamental corals, including the coordination of product flows, service flows, and capital flows from upstream to the focal firm. The study was conducted in the Bali Strait waters from August 2023 to January 2024 and involved PT. AAM, an ornamental coral export company.

The sampling method used in this research was non-probability sampling with a snowball sampling technique. The application of the snowball sampling technique involved the following stages:

a Contacting key informant, specifically the focal firm PT. AAM, which could provide information about its supply chain activities.

b Information from the focal firm was used as a guide to further trace supply chain members, namely local company suppliers such as PT. LSA and PT. DAM.

c Gathering information from the local company suppliers to identify supply chain members involved in collaborations with coral-harvesting fishers.

The SSCM for ornamental corals was evaluated using the RAPFish method. According to Pitcher and Preikshot (2001), RAPFish, which stands for A Rapid Appraisal Technique for Fisheries, is a new multidisciplinary rapid assessment technique to evaluate the comparative sustainability of fisheries, where fisheries can be flexibly defined as entities with broad scope. The data analysis with RAPFish consisted of the following analyses:

1 *Multi-Dimensional Scaling* (MDS): Ordination techniques were analysed with MDS to determine the position of good and bad points. The object points in MDS were mapped into two- or three-dimensional space and placed as closely as possible.

2 *Monte Carlo (MC)*: The Monte Carlo analysis evaluated the impact of random errors to estimate the ordination values.

3 *Leverage*: Leverage analysis was conducted to identify sensitive attributes in each sustainability dimension.

Monte Carlo simulation was used to estimate errors, while a stepwise procedure evaluated the leverage of each attribute on the score. The status results were quantified on a scale from 0 to 100%, and scores from several domains were combined into a kite diagram to enhance comparisons across fishery dimensions.

Several studies using the RAPFish method, with dimensions and attributes customized to the researchers' requirements, have been done, including those by: (Yasir Haya and Fujii, 2020a; Franco-Melendez et al., 2021; Jimenez et al., 2021; Lloyd Chrispin et al., 2022; Ainsworth et al., 2023; Geria et al., 2023; Zuhry et al., 2023). The sustainability aspects were reviewed across five dimensions that serve as parameters in SSCM: (1) economic, (2) social, (3) environmental, (4) risk cost disruption, and (5) government policy. Scoring was performed on each attribute within these dimensions to assess the current sustainability level of SSCM. Sensitive attributes that influenced the SSCM sustainability index (existing condition) were identified as key factors in the system, and the influence and dependency levels among these factors were analysed. Subsequently, a needs analysis was conducted to identify the needs of all stakeholders in the system, determining the key factors for further influence and dependency analysis. The key aspects from the existing condition and need analysis were combined to obtain more representative results of the studied system's influencing factors (leverage analysis).

Table 1. *List and definitions of attributes used in the primary MDS RAPFish analysis*

Attributes	Scoring	Good	Bad	Notes
Economic analysis				
Supply chain management performance	1; 2; 3; 4; 5; 6	6	1	Supply chain performance score: < 60 (1); 60–69 (2); 70–79 (3); 80–89 (4); 90–94 (5); 95–100 (6)
Profitability	1;2; 3	3	1	Net Income percentage per year: 10% – 40% (1); 41% – 80% (2); 81% – 100% (3)
Sustainable marketing	1; 2; 3	3	1	Marketing sustainability conditions in industry area: bad (1); average (2); good (3)
Reverse logistics	1; 2; 3	3	1	The activities of business actors in managing the flow of goods from the end consumer back to the beginning of the supply chain: low (1); medium (2); high (3)
Social analysis				
Working environment	1; 2; 3	3	1	The environment of the working area of staff: bad (1); average (2); good (3).
Service issues	1; 2; 3	3	1	Business activities that consider ethics on their service issues: bad (1); average (2); good (3)
Social status	1; 2; 3	3	1	Conditions of business locations and the use of human rights principles: bad (1); average (2); good (3)
CSR activities	1; 2; 3	3	1	Corporate Social Responsibility activities done by Industry: low (1); medium (2); high (3)
Environmental analysis				
Exploitation status	1; 2; 3	3	1	Indonesia Minister of Marine Affairs and Fisheries Decree No. 70: over-exploited (3); fully exploited (2); moderate (1)
Environmental purchasing	1; 2; 3	3	1	procurement of inputs/raw materials that consider sustainability factors: bad (1); average (2); good (3)
Environment management	1; 2; 3	3	1	management to reduce negative impacts on the environment: bad (1); average (2); good (3)
Eco–friendly technology	1; 2; 3	3	1	The implementation of sustainable and eco-friendly technologies within the production process: bad (1); average (2); good (3)
Expected disruption costs analysis				
Penalty costs	1; 2; 3	3	1	The costs incurred by business entities in the event of a breach of governmental regulations or contractual agreements with other enterprises: high (1); medium (2); low (3)

Attributes	Scoring	Good	Bad	Notes
Transportation failure costs	1; 2; 3	3	1	Costs that may occur due to unanticipated force majeure disruptions: high (1); medium (2); low (3)
Backlog/shortage costs	1; 2; 3	3	1	Costs incurred to fulfill stock shortages: high (1); medium (2); low (3)
Lost sales costs	1; 2; 3	3	1	Costs incurred due to imperfect condition of goods or mortality during shipping: high (1); medium (2); low (3)
Damage costs	1; 2; 3	3	1	Costs due to damages the firm sustained include environmental harm, asset impairment, reputational loss, or ecological degradation: high (1); medium (2); low (3)
Recovery costs	1; 2; 3	3	1	Costs incurred during the production or maintenance process of goods: high (1); medium (2); low (3)
Government policy				
Economic	1; 2; 3	3	1	The implementation of the laws and regulations: bad (1); average (2); good (3)
Environmental	1; 2; 3	3	1	The implementation of the laws and regulations: bad (1); average (2); good (3)
Social	1; 2; 3	3	1	The implementation of the laws and regulations: bad (1); average (2); good (3)

Results and Discussion

The sustainability analysis in this study was conducted across five dimensions of sustainability related to supply chain management: (1) economic, (2) social, (3) environmental, (4) expected disruption cost, and (5) government policy. The attributes and scoring were derived from key informant opinions, site observations, and literature reviews. The RAPFish analysis was then performed using Microsoft Excel. Sustainability evaluation results were categorized into four groups: unsustainable, below-sustainable, average-sustainable, and sustainable (Pitcher and Preikshot, 2001). The sustainability performance categories are shown in *Table 2*.

Table 2. *Sustainability performance categories*

No	Index Value (%)	Category
1	0 – 25	unsustainable
2	> 25 – 50	below sustainable
3	> 50 – 75	average sustainable
4	> 75 – 100	sustainable

Source: (Pitcher and Preikshot, 2001).

The SSCM evaluation of ornamental corals across economic, social, environmental, expected disruption cost, and government policy dimensions (*Fig. 1*) yielded an average score of 67.78%, placing it in the average sustainable category. It indicates that the SSCM of ornamental corals still needs to be fully sustainable, necessitating further evaluation of each dimension's issues.

Fig. 1. *SSCM performance of ornamental corals based on multi-dimensional RAPFish analysis*

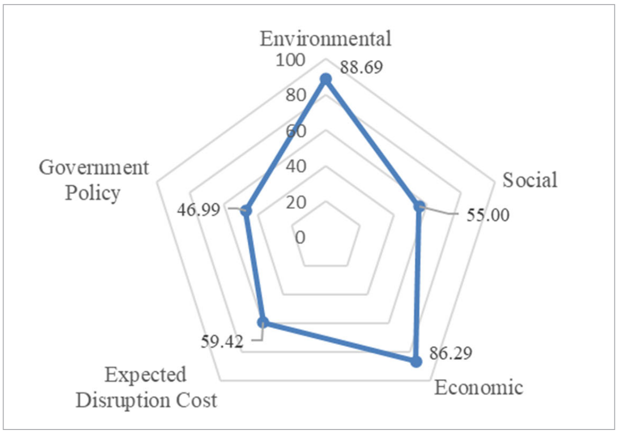


Fig. 1, shows that the SSCM evaluation for ornamental corals was sustainable in the environmental and economic dimensions, average in the social and expected disruption cost dimensions, and below sustainable in the government policy dimension. It indicates that managing the ornamental coral supply chain needs to focus on improving the less sustainable dimensions, particularly government policy. However, sensitive

attributes in other dimensions also need attention to enhance the overall SSCM performance. The five dimensions are discussed as follows:

1 *Economic dimension*

The economic dimension shows significant increases in sales and market share, substantial reductions in waste and waste costs, and significant improvements in resource management efficiency (Zailani et al., 2012). The SSCM performance for the economic dimension was 86.29%, categorizing it as sustainable. It implies that using ornamental coral resources provides long-term financial benefits, supporting SSCM. The dominant attributes in the economic dimension were SCM performance and business profitability. The role of each economic attribute based on leverage analysis is presented in *Fig. 2*.

Fig. 2 shows that the average SCM performance for ornamental corals remains suboptimal, at 88.96, suggesting that companies must improve their performance to achieve sustainable economic goals. Carter and Rogers (2008) suggest that developing clear long-term economic strategies that include SCM activities can create more durable and less imitable processes. Additionally, Mastos and Gotzamani (2022) emphasize that quality improvement is another crucial economic factor through optimal SCM activities.

The second attribute was profitability. Companies did not publicly disclose their financial reports, but the high price multiples of 2–3 times at each channel and the high foreign market demand denote significant profits. The high profitability of ornamental coral businesses leads to intense competition among entrepreneurs, especially with foreign competitors. Riadi et al. (2018) reported that between 2012 and 2016, Indonesia accounted for an average of 5.58% of global ornamental coral exports, making it the world's second-largest exporter after Japan, which held a share of 33.67%. The annual average growth of Indonesia's ornamental coral exports during this period was 5.25%. The high competition in the Indonesian ornamental coral business is driven by significant foreign demand, resulting in an open market. Currently, ornamental coral companies are divided into two associations: AKKII for wildlife coral extraction and KPKHN for coral aquaculture (coral transplantation).

2 *Social dimension*

The social dimension focuses on the health and well-being of individuals within the supply chain and its impact on the community (Beamon, 2005).

The SSCM performance for the social dimension was 55%, which is considered average sustainable. This result indicates that the social aspects of the ornamental coral business significantly influence SSCM. *Fig. 3*, shows the role of each social attribute based on leverage analysis.

Fig 2. *Leverage analysis of the economic dimension on SSCM of ornamental corals*

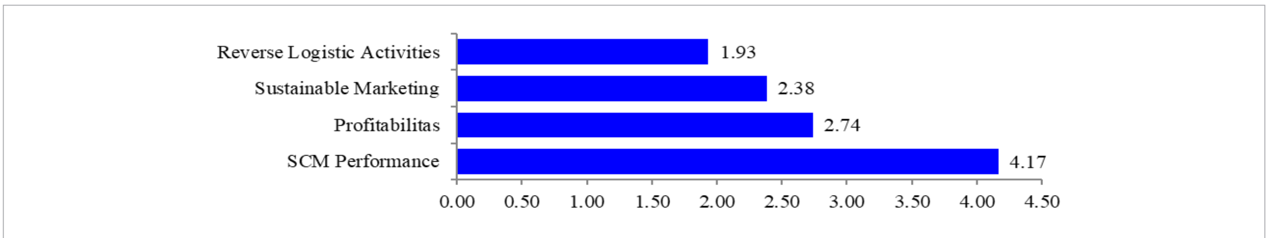


Fig 3. *Leverage analysis of the social dimension on SSCM of ornamental corals*

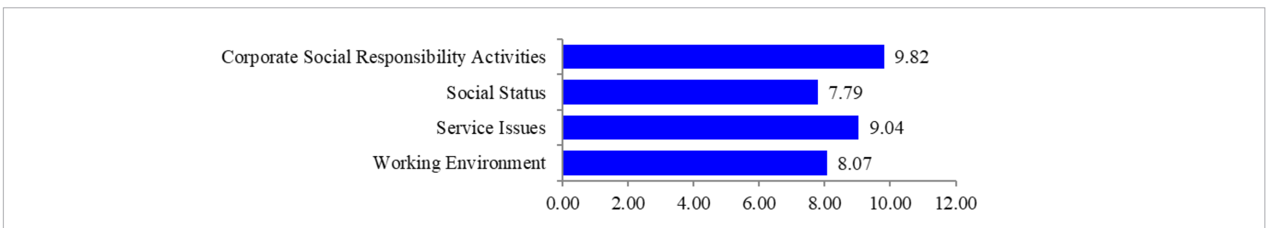


Fig. 3, shows that all social attributes significantly influence ornamental coral supply chain management. The most dominant are corporate social responsibility (CSR) activities and service issues, followed by social status within the supply chain, respect for human rights, and operating in safe working environments.

Workshops and training sessions are conducted for employees, including fishers, on proper coral care and harvesting. Although companies provide complete diving equipment for coral extraction and care, Bajo tribe fishers prefer using wooden goggles and compressors, resulting in inadequate safety measures. Most fishers are elementary school graduates, while office employees are college graduates, which impacts employee mindset and performance. Export companies provide health insurance, while two local companies use a reimbursement system for sick employees. PT. AAM and PT. DAM owns excellent infrastructure, whereas PT. LSA rents semi-permanent warehouses.

CSR is a commitment to improve community welfare through prudent business practices and corporate resource contributions. Company social initiatives are primary activities to support social goals and fulfil CSR commitments (Intyas et al., 2017; Kotler and Lee, 2005). CSR activities by the company include training and workshops on coral transplantation and care for the community, students, fishing groups, POKMASWAS, and others. Additionally, financial assistance is provided upon request for social activities conducted by the community, such as village celebrations, Independence Day festivities, cultural rituals, or religious events. The community typically submits proposals for financial aid to the company. However, CSR activities were not regularly conducted and depended on community requests and the company's capability. The company has yet to initiate CSR activities independently and is relying on external support from the community or academia. Currently, based on research by Intyas et al. (2023b), PT. LSA is the only company that collaborates with academia (University of Mataram) for a regular internship program. CSR activities for restocking were also conducted in several areas. CSR activities by the company were also based on government appeals to plant corals in damaged reef areas, amounting to 10% of the company's annual total sales. Among the three business actors, PT. LSA conducted most coral transplantation activities, collaborating with related parties to protect coral seedlings planted around their area.

Service issues concentrate on company activities related to ethics, including stakeholder inclusion, preservation of cultural values, and benefits to the surrounding community, which should be respected and enhanced economically, socially, culturally, and physically. Equality and fairness are also prioritized. This principle aims to increase employment opportunities for the local community and enhance community-company partnerships (Dehghanian and Mansour, 2009; Intyas et al., 2018). Service issues addressed by all business actors in the ornamental coral supply chain open job opportunities as companies employ local community members and fishers. PT. LSA employed ten fishers, of whom only three were permanent employees, while the rest were freelancers. PT. DAM had only five employees, three of whom were local community members, while PT. AAM employed ten permanent employees from the local community and fishers. PT. AAM also partners with fishing groups using a nucleus-plasma system for coral transplantation at Pandawa Beach.

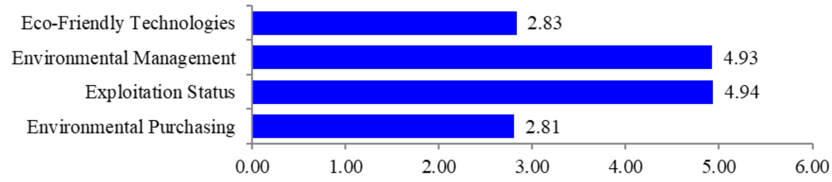
Cultural factors also impact the working environment and quality, with companies adapting to local customs, such as numerous holidays for religious rituals in Pulau Kaung and Bali. This cultural factor affects employee performance, with most workers being residents. Additionally, the lack of waste management in Pulau Kaung leads to littering around the waters, necessitating company intervention to address global marine waste issues.

3 *Environmental dimension*

The environmental goal of supply chain management is to consider the total impact of all processes and products on the environment to protect nature (Beamon, 2005). The environmental dimension focuses on resource usage and its impact on the physical environment (Marshall et al., 2015).

The SSCM performance for the environmental dimension was 88.69%, categorizing it as sustainable. It implies that the environmental quality, coral resources, and wildlife processes are in good condition and support SSCM activities. Proper management can maintain future environmental dimension index values. *Fig. 4*, shows the role of each environmental attribute based on leverage analysis, with environmental management and exploitation status being the most sensitive attributes.

Fig 4. *Leverage analysis of the environmental dimension on SSCM of ornamental corals*



Based on *Fig. 4*, the sensitive attributes were environmental management and exploitation status, while other attributes were satisfactory. This ornamental coral business uses environmentally friendly technology with simple tools that do not harm the aquatic environment. Likewise, environmental purchasing starts with packaging, products, and warehousing that do not pollute the environment.

Implementing environmental management offers benefits like pollution reduction, process efficiency, compliance improvement, and enhanced environmental performance (Putri and Indriana, 2017). Good environmental management protects the environment from ornamental coral business impacts, ensuring optimal and sustainable resource utilization. Ornamental corals are living organisms, and their extraction and care processes do not cause environmental damage or pollution, with minimal ammonia used for care. Ammonia levels used for maintenance are only about 5 litres per week, and local companies precipitate them first to be used as plant/soil fertilizer. In contrast, exporters treat the water used for maintenance using *steamer* technology so that the water wasted from the coral maintenance process does not contain ammonia levels. Coral transplants carried out in in situ areas in the waters provide habitat for fish and marine animals and become a food source for fish and seabirds.

Resource utilization levels are assessed by comparing fisheries resource production with maximum sustainable yield (MSY) values. The value of the utilization rate is expressed in units of percent, which states the condition of the utilization status of fish resources in a body of water using the Schaefer biological approach (Fauzi, 2010). The environmental dimension's exploitation status reflects fisheries' resource utilization levels. Based on this study, only the local company PT. LSA engaged in moderate wildlife extraction. At the same time, PT. DAM only transplanted corals and bought broodstock from other companies, and PT. AAM acted solely as an exporter.

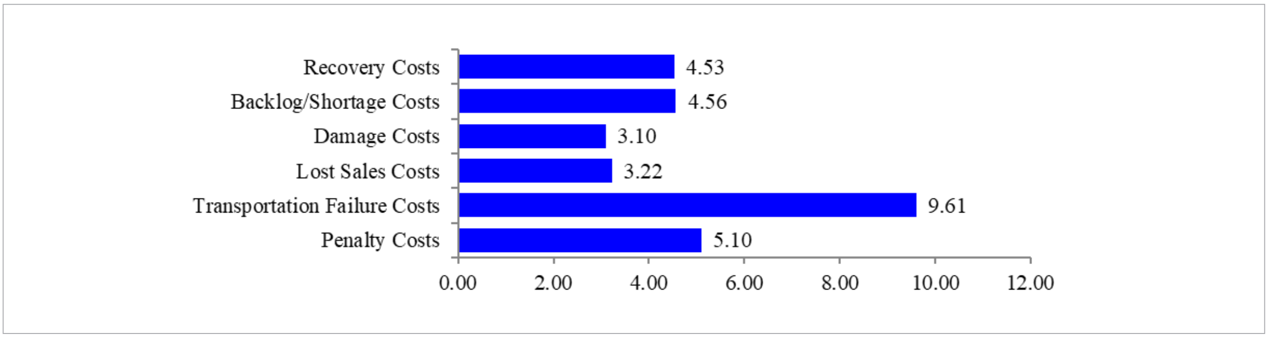
4 *Expected disruption cost dimension*

Although the likelihood of disruption is low, its potential impact on the entire supply chain network can be significant. Therefore, it is essential to account for these risks to maintain uninterrupted supply chain operations. These disruption risks are dynamic because the parameters used to measure these risks change over time. Factors such as natural disasters, political crises, financial crises, human-caused disasters, pandemics, weather, and others are causes of disruption (Joshi, 2022). Disruption risks result in costs within supply chain management.

The SSCM's performance in the disruption cost risk dimension was 59.42%, indicating that this study's disruption cost dimension for ornamental coral supply chain management falls into the average sustainable category. This means that the disruption cost risks arising in the ornamental coral business significantly affect the management of the ornamental coral supply chain. The role of each disruption cost attribute based on leverage analysis can be seen in *Fig. 5*.

Based on *Fig. 5*, the most dominant attribute in expected disruption cost was transportation failure costs, followed by penalty costs. Product recovery costs occur if only the cultivated coral is damaged due to weather factors, making this cost challenging to predict. However, the company has invested in ex-situ cultivation areas to mitigate this risk. Stockout costs only occur at the beginning of transactions with new consumers, as the established trust system is solely based on competence trust. If such costs arise, the company is likely to discontinue future cooperation. Damage costs typically account for only 1–10% of the total products shipped, and these costs are borne by the seller, who risks non-payment or the obligation to replace the goods.

Fig 5. *Leverage analysis of the expected disruption cost dimension on SSCM of ornamental corals*



Transportation failure costs were also dominant, often caused by weather conditions. Unpredictable weather can delay shipments, particularly for international deliveries. The short lifespan of coral becomes a significant issue if there is a transportation failure, which can result in the death or injury of many ornamental corals. Transportation failures usually occur via sea and air routes, ultimately delaying departures. The length of these delays can also affect permit documents, such as a Domestic or International Fish Transport Permit, due to expiration. Transportation failure costs are higher for exported coral products.

Penalty costs arise from company violations, and the exact amount is often unclear and undetermined. The company frequently incurs penalty costs when the fishers it employs do not adhere to regulations or engage in illegal coral harvesting.

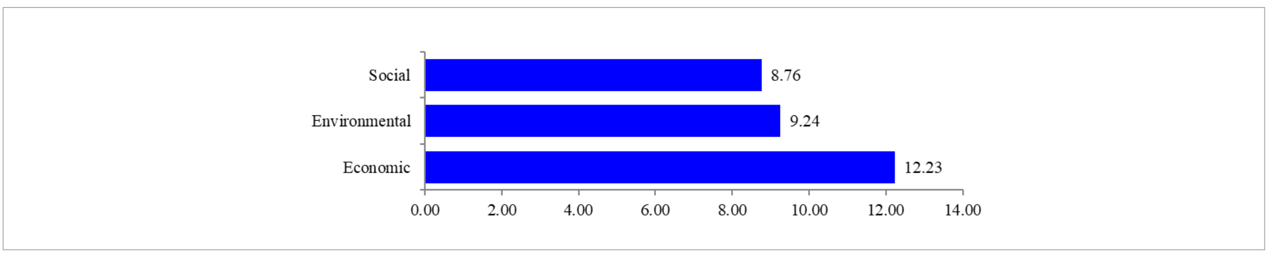
5 *Government policy dimension*

The term policy refers to the behaviour of some actor or group of actors, such as officials, government agencies, or legislative bodies, in areas of activity such as public transportation or consumer protection. A policy is a set of purposeful and relatively stable actions followed by an actor or set of actors in addressing a problem of concern. Regulatory policies impose restrictions on the behaviour of individuals and groups. This condition means this regulation reduces the regulated parties' freedom of action. In this regard, this policy differs from distributive policies, which increase the freedom or discretion of the affected person or group (Anderson, 2003).

SSCM's performance in the government policy dimension was 46.99%, which shows that this study's government policy dimension for ornamental coral supply chain management is included in the below sustainable category. It implies that ornamental coral supply chain management remains suboptimal from a public policy perspective, even though explicit legal permits for coral collection and transplantation have been obtained. The role of each policy attribute from the leverage analysis is illustrated in *Fig. 6*.

Fig. 6 reveals that economic and social policies are the most influential attributes in the dimension of government policy. Notably, the environmental policy has seen significant changes with the introduction of the 2024 Marine Spatial Planning (MSP) policy. This policy has led to the establishment of quota restrictions and a tagging system for coral transplants, marking a crucial shift in the industry.

Fig 6. *Leverage analysis of the government policy dimension on SSCM of ornamental corals*



The government's economic policy regulates the trade of ornamental corals. The policy includes tax policy, non-tax state revenue (PNBP), retribution, licensing, and stringent regulations since some coral species are listed under CITES, requiring detailed quota limitations as follows:

- The company tax policy is similar to other businesses, but a specific PNBP policy exists for the soft corals' ornamental trade. It includes transportation fees and PNBP Trade Levies based on Government Regulation Number 85 of 2021 issued by the Ministry of Marine Affairs and Fisheries.
- Licensing needs to be clarified as it is regulated by two ministries: the Ministry of Environment and Forestry (KLHK) for hard corals and the Ministry of Marine Affairs and Fisheries (KKP) for soft corals, making the licensing process more complex. The trade of different coral types varies; hard corals have quota restrictions, while soft corals can be freely traded but only by those with the necessary permits. This limited licensing has resulted in fishers becoming mere laborers due to a lack of capital and knowledge. Field conditions indicate that illegal fishing practices are also prevalent among fishers.
- Rapid changes in regulations make the ornamental coral industry highly volatile. For instance, in mid-August 2016, the Minister of Marine Affairs and Fisheries issued a moratorium on ornamental coral trade due to increased coral damage from trade activities without providing solutions for the affected businesses. This policy was analyzed by (Hadi et al. 2018; Riadi et al., 2018), who found that coral damage was primarily due to climate change and environmentally unfriendly fishing practices, as assessed by LIPI through the COREMAP-CTI program. Direct losses reported by businesses and workers in the ornamental coral farming sector indicated that throughout 2018, association members suffered losses exceeding IDR 100 billion, and 12,000 workers lost their jobs.

Those conditions align with Shohibudin's (2018) arguments that existing economic policies merely facilitate the interests of a select elite. Policy implementation in the field tends to be urban-biased, with control over agrarian resources concentrated in the hands of a few. As a result, agrarian conflicts, with downstream effects such as loss of livelihood and upstream root causes like unequal distribution of resources, are addressed superficially at the downstream level without tackling the comprehensive upstream root causes.

Social policy is a set of policies and actions to enhance social welfare and well-being. Social policy can encompass all policies with a social dimension or social welfare implications. Social policy is where the government strives for social protection and citizen welfare (Wahyunengseh, 2011). The government has attempted to implement social policy in the ornamental coral industry by encouraging companies to employ local fishers or community members in coral utilization activities. However, this policy has provided them with minimal protection and welfare. Although employment levels have increased, only a few fishers have benefited from these opportunities. Additionally, fishers receive the least profit because their income depends on the companies. Fishers who do not have licenses or are not employed but are aware of market prices ultimately choose to sell corals illegally. Despite the significant revenue from the ornamental coral trade, the local fishing communities affected by the industry have not benefited substantially, mainly due to their limited capital and knowledge.

Furthermore, Monte Carlo (MC) analysis was used to evaluate the impact of random errors on the dimension by examining (1) the effect of errors in attribute scoring, (2) the impact of score variation, (3) the stability of the repeated MDS analysis process, and (4) errors in data entry or missing data. The accuracy of the RAPFish analysis was determined by calculating the S-Stress values and the coefficient of determination (R^2). The comparison results are presented in *Table 3*.

Table 3. *Comparison of multi-dimensional scaling (MDS) with Monte Carlo (MC) and goodness of fit for sustainability in SSCM ornamental corals*

Dimension	MDS	MC	Difference MDS-MC	R^2	S– Stress
Economic	86.29	85.64	0.65	0.93	0.19
Social	55.00	54.65	0.35	0.93	0.22
Environmental	88.69	87.89	0.80	0.93	0.17
Expected Disruption Cost	59.42	58.51	0.91	0.92	0.16
Government Policy	46.99	46.89	0.10	0.92	0.24
Average				0.93	0.19

The low error difference between MDS and MC values suggests that the MDS values have a high confidence level due to minimal misinterpretation or procedural errors regarding the indicators. The variation in dimension scoring produces a slight difference between MDS and MC, indicating that the discrepancy calculations are acceptable (Pitcher and Preikshot, 2001). *Table 3* depicts the five dimensions yield an average determination calculation (R^2) of 0.93 or 93%, approaching the 100% value, and an average S-Stress value of 0.19, below 0.25. Therefore, the model is considered good or highly accurate. The most significant difference in the sustainability index results with Monte Carlo is 0.90%, indicating minimal error affecting the MDS results in this study, suggesting that the MDS values have a high confidence level. The low S-Stress values indicate high accuracy (goodness of fit). A good model is indicated by S-Stress values less than 0.25 (< 25%) with a coefficient of determination (R^2) close to 1.0 or 100%.

Conclusions

The performance of the SSCM for ornamental coral, assessed multidimensionally based on economic, social, environmental, disruption cost risk, and government policy dimensions, yields an average score of 67.28%, categorizing it as average sustainable. This result indicates that the SSCM for ornamental coral is not yet fully sustainable. The dimension below sustainable is government policy (46.99%), with the most sensitive attributes being economic and social policies. Economic policies include the magnitude of retribution per coral species, the licensing process, and regulations governing coral utilization through two ministries. Rapidly changing regulations, such as the 2016 moratorium on ornamental coral trade, were implemented without providing solutions for affected businesses, causing significant losses. The government has attempted to implement social policies in the ornamental coral industry by encouraging companies to employ local fishers or community members in coral utilization activities. However, these policies have not provided adequate protection and welfare for them. Including the grassroots community, specifically fishers, in formulating social policies through outreach initiatives and support in establishing cooperative business organizations to secure distribution and trade permits is imperative. This will empower them to enhance their negotiating leverage in establishing selling prices. Furthermore, as the corals for sale must be in optimal health, fishers will inherently aid in preserving local coral reefs and refrain from unlawful fishing activities that could jeopardize businesses and governmental interests.{Gurauskiene, 2006, Eco-design methodology for electrical and electronic equipment industry}

Acknowledgements

We would like to express our sincere gratitude to the Kelompok Pembudidaya Karang Hias Nusantara (Indonesian Ornamental Coral Cultivation Group) for granting permission to conduct this research among its member companies. We are especially thankful to Mr. Deddy Kusuma, S.Pi., owner of PT. Lombok Samudera Abadi, for his consistent willingness to provide information and support throughout the research process. We also thank Mr. Junaedi, S.Pi., Mr. Zainul Arifin, S.Pi., M.Si., and Mr. Brilliant Rudzaky, S.Pi., for their valuable assistance with data collection. We thank the Center for Coastal and Marine Resource Management of Denpasar (BPSPL Denpasar), particularly Ms. Rizka Dzulfikar, S.Pi., M.Ec.Dev., for providing essential secondary data. Finally, we acknowledge Mochammad Fattah, S.Pi., M.Si., for his support in data analysis.

References

Allen G. R., and Erdmann M. V. (2013) Reef Fishes of The East Indies. Journal of Fish Biology 83(5): 1483–1484.

Anderson J. E. (2003) Public Policymaking: An Introduction (fifth). Houghton Mifflin Company.

Beamon B. M. (2005) Environmental and sustainability ethics in supply chain management. Science and Engineering Ethics 11(2): 221–234. Available at: https://doi.org/10.1007/s11948-005-0043-y

Bellwood D. R., and Wainwright P. C. (2002) The History and Biogeography of Fishes on Coral Reefs. In P. F. Sale (Ed.), Coral Reef Fishes Dynamics and Diversity in a Complex Ecosystem. Academic Press. Available at: https://doi.org/10.1016/B978-012615185-5/50003-7

Brundtland G. H. (1987) Report of the World Commission on Environment and Development: Our Common Future. In World

Commission on Environment and Development (WCED). Available at: https://doi.org/10.9774/gleaf.978-1-907643-44-6_12

Caradonna J. L. (2014) Sustainability: A History. Oxford University Press, Inc. Available at: https://books.google.co.id/books?id=G2vrAwAAQBAJ&pg=PA8&source=gbs_selected_pages&cad=3#v=onepage&q&f=false

Carter C. R., and Rogers D. S. (2008) A framework of sustainable supply chain management: Moving toward new theory. International Journal of Physical Distribution and Logistics Management 38(5): 360–387. Available at: https://doi.org/10.1108/09600030810882816

CRITC Coremap-LIPI. (2016) Tentang Terumbu Karang [About Coral Reefs]. CRITC Coremap-LIPI. Available at: http://coremap.oseanografi.lipi.go.id/berita/520 *(in Indonesian*).

Croom S., Romano P., and Giannakis M. (2000) Supply chain management: An analytical framework for critical literature review. European Journal of Purchasing and Supply Management 6(1): 67–83. Available at: https://doi.org/10.1016/S0969-7012(99)00030-1

Dehghanian F., and Mansour S. (2009) Designing sustainable recovery network of end-of-life products using genetic algorithm. Resources, Conservation and Recycling, 53(10), 559–570. Available at: https://doi.org/10.1016/j.resconrec.2009.04.007

EPA (United States Environmental Protection Agency) (2022) Basic Information about Coral Reefs. United States Environmental Protection Agency. Available at: https://www.epa.gov/coral-reefs/basic-information-about-coral-reefs

Fauzi A. (2010) Ekonomi Perikanan Teori, Kebijakan dan Pengelolaan [Fisheries Economics Theory, Policy and Management]. PT. Gramedia Pustaka Utama *(in Indonesian*).

Hadi T. A., Abrar M., Giyanto B. P., Johan O., Budiyanto A., Dzumalek A. R., Alifatri L. O., Sulha S., and Suharsono. (2020) The status of Indonesian coral reefs 2019 In Research Center for Oceanography-Indonesian Institute of Sciences, Jakarta.

Hadi T. A., Giyanto Prayudha B., Hafizt M., Budiyanto A., and Suharsono. (2018) Status Terumbu Karang Indonesia 2018 [Status of Indonesian Coral Reefs 2018]. Pusat Penelitian Oseanografi – Lembaga Ilmu Pengetahuan Indonesia *(in Indonesian*).

Intyas C. A., Fattah M., and Nurjannati T. (2018) Institution's Business Role To Improve Smallscale Fisherman's Household Income 12(20): 81–85. Available at: https://doi.org/10.18551/rjoas.2018-12.10

Intyas C. A., Koestiono D., and Tjahjono A. (2017) Business Analysis of Smoked Fish To Increase Small-Scale Fishers's Household Income. Russian Journal of Agricultural and Socio-Economic Sciences 62(2): 250–254. Available at: https://doi.org/10.18551/rjoas.2017-02.29

Intyas C. A., Koestiono D., Tjahjono A., Suhartini S., and Riana F. D. (2023) Management of the Sustainable Utilization of Ornamental Coral Wildlife in Pulau Kaung Village As Hobbyist Tourism. Geojournal of Tourism and Geosites 47(2): 523–530. Available at: https://doi.org/10.30892/gtg.47220-1052

Intyas C. A., Putritamara J. A., and Haryati N. (2022) Dinamika Agrobisnis Era VUCA (Volatility, Uncertainty, Complexity, Ambiguity) [Agribusiness Dynamics in the VUCA Era (Volatility, Uncertainty, Complexity, Ambiguity)]. Universitas Brawijaya Press *(in Indonesian*).

Intyas C. A., Tjahjono A., Koestiono D., Riana F. D., and Suhartini. (2023) Value Chain Analysis of the Marine Ornamental Reef: A Case Study in Banyuwangi, East Java, Indonesia. Environmental Research, Engineering and Management 79(2): 21–31. Available at: https://doi.org/10.5755/j01.erem.79.2.32951

Isdianto A., Intyas C. A., Asadi M. A., Haykal M. F., and Putri B. M. (2022) Pengelolaan Berkelanjutan Pada Kawasan Konservasi Penyu Hijau [Sustainable Management of the Green Turtle Conservation Area]. Universitas Brawijaya Press *(in Indonesian*).

Joshi S. (2022) A Review on Sustainable Supply Chain Network Design: Dimensions, Paradigms, Concepts, Framework and Future Directions. Sustainable Operations and Computers 3: 136–148. Available at: https://doi.org/10.1016/j.susoc.2022.01.001

Karim I., Wulandari E., Arsal A., and Mandasari N. F. (2021) The Causality Model of Maize Farmers' Income: Integrating Social Capital, Supply Chain, and Competitive Advantage. International Journal on Advanced Science, Engineering and Information Technology 11(1): 252–258. Available at: https://doi.org/10.18517/ijaseit.11.1.8275

Kotler P., and Lee N. (2005) Corporate Social Responsibility. John Wiley and Sons, Inc.

Mahmudah S., Turisno B. E., Dewi I. G., and Soemarmi A. (2023) Partnership in the Utilization of Coral Reefs Area, which Increases Women's Economy and Sustainable Conservation (Issue ICoLGaS). Atlantis Press SARL. https://doi.org/10.2991/978-2-38476-164-7_38

Marshall D., McCarthy L., Heavey C., and McGrath P. (2015) Environmental and social supply chain management sustainability practices: Construct development and measurement. Production Planning and Control 26(8): 673–690. Available at: https://doi.org/10.1080/09537287.2014.963726

Mastos T., and Gotzamani K. (2022) Sustainable Supply Chain Management in the Food Industry: A Conceptual Model from a Literature Review and a Case Study. Foods 11(15). Available at: https://doi.org/10.3390/foods11152295

Nazir M. (2003) Metode Penelitian [Research Methods]. Penerbit Ghalia Indonesia.

O'Brien J. A. and M. Marakas G. (2007) Management Information Systems. In The McGraw Hill/Irwin. Available at: https://doi.org/10.4324/9781351255363-6

Pitcher T. J., and Preikshot D. (2001) RAPFish: A rapid appraisal technique to evaluate the sustainability status of fisheries. Fisheries Research 49(3): 255–270. Available at: https://doi.org/10.1016/S0165-7836(00)00205-8

Putri V. L., and Indriana I. (2017) Apakah Manajemen Lingkungan Perlu Diimplementasikan Dalam Menciptakan Kinerja Lingkungan Yang Baik Dan Kinerja Keuangan Yang Optimal? [Is Environmental Management Necessary to Implement in Creating Good Environmental Performance and Optimal Financial Performance?]. Tirtayasa Ekonomika 12(2): 232. Available at: https://doi.org/10.35448/jte.v12i2.4457 *(in Indonesian)*.

Rhyne A. L., Tlusty M. F., and Kaufman L. (2014) Is sustainable exploitation of coral reefs possible? A view from the standpoint of the marine aquarium trade. Current Opinion in Environmental Sustainability 7: 101–107. Available at: https://doi.org/10.1016/j.cosust.2013.12.001

Riadi S., Wahyudin Y., and Arkham M. N. (2018) Review Literature: Policy of Backing for Trading Ornament Corals and Coastal and Ocean Journal 4(2): 83–90. Available at: https://doi.org/10.29244/COJ.2.2.83-90

Shohibudi M. (2018) Perspektif Agraria Kritis "Teori, Kebijakan dan Kajian Empiris" [Critical Agrarian Perspective "Theory, Policy and Empirical Studies"]. STPN Press *(in Indonesian)*.

Suriyani L. De. (2020) Perdagangan Koral dan Karang Hias Kembali Dibuka, Jangan Ada Dusta di Antara Kita [Coral and Ornamental Coral Trade Reopens, Let There Be No Lies Between Us]. Mongabay. Available at: https://www.mongabay.co.id/2020/01/21/perdagangan-koral-dan-karang-hias-kembali-dibuka-jangan-ada-dusta-di-antara-kita/ *(in Indonesian)*.

Susiloningtyas D., Handayani T., and Amalia A. N. (2018) IOP Conference Series: Earth and Environmental Science the Impact of Coral Reefs Destruction and Climate Change in Nusa Dua and Nusa Penida, Bali, Indonesia the Impact of Coral Reefs Destruction and Climate Change in Nusa Dua and Nusa Penida, Bali, Indonesia. IOP Conf. Series: Earth and Environmental Science 145: 12054. Available at: https://doi.org/10.1088/1755-1315/145/1/012054

Swara S. E., and Intyas C. A. (2021) Value Chain performance of the three developing Mangrove Ecotourism in East Java. Ecology, Environment and Conservation 27: 360–365.

Wahyunengseh R. D. (2011) Membangun Kepercayaan Publik Melalui Kebijakan Sosial Inklusif [Building Public Trust Through Inclusive Social Policies]. Jurnal Ilmu Sosial Dan Ilmu Politik 15(1): 29–40. Available at: https://journal.ugm.ac.id/jsp/article/view/10923/8164 *(in Indonesian)*.

Zailani S., Jeyaraman K., Vengadasan G., and Premkumar R. (2012) Sustainable supply chain management (SSCM) in Malaysia: A survey. International Journal of Production Economics 140(1): 330–340. Available at: https://doi.org/10.1016/j.ijpe.2012.02.008.