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KEY FACTORS OF SUSTAINABLE MARICULTURE ENTERPRISES IN INDONESIA: FINFISH MARICULTURE CASES FROM STAKEHOLDER PERSPECTIVE

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Abstract

Mariculture is a profitable industry in Indonesia and other countries in Southeast Asia in general. The annual outputs of Indonesia's mariculture have been ranked among the tops worldwide. However, unsustainable issues are the main challenges to developing mariculture enterprises in Indonesia. This paper describes potential factors for realising sustainable mariculture enterprises. It then proposes the potential key factors sought by stakeholders in mariculture industries, including those involved in the input, production, and marketing stages, as well as experts (academics, researchers, and policymakers). To determine the key factors of sustainability, some gradual processes were conducted: (1) self-validation; (2) scientific validation; and (3) social validation. A total of 141 respondents (the stakeholders) were involved in this study. A principal component analysis was used to identify the critical key factors within the scales used. The Matrix of Crossed Impact Multiplications Applied to a Classification (MICMAC) was used to map the key factors and their relationships. This paper identifies and proposes key factors as references for policy formulation and decision-making to improve mariculture management. Further, influence, relationship, and dependence among the key factors and societal implications of this study are discussed.

***Keywords**: Key factors; Mariculture Management; Stakeholder Perspective; Sustainable*

Introduction

Sustainable development is one of the nation's concerns. Sustainability is a term used in industry operations, including mariculture, and it is a component of the Sustainable Development Goals (SDGs) [1]. Mariculture is anticipated to be a new frontier in the sustainable economic development of the islands and coastal states [2]. In this study, mariculture is defined as one of the aquaculture activities or an aquatic culture activity conducted on the sea and known as eco-friendly aquaculture [3, 4]. The sustainability of mariculture has currently been threatened by environmental, socio-economic conditions, institutional, and cultural aspects [5-7]. A widespread concern about the sustainability of

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mariculture has come to focus mainly on production methods, economic feasibility, and the environment [8].

Mariculture operations require natural and human resources to generate outputs and services; their success must be financially profitable for mariculture producers and have benign social and environmental impacts [9]. This statement emphasises that social and environmental factors affect the sustainability of mariculture. The social acceptability of mariculture is linked to its perceived environmental impacts [10]. Mariculture is deemed to have negative effects associated with environmental degradation. Some aspects that must be carried out comprehensively in sustainable fishery (including mariculture) development include ecological, technological, economic, sociological, and ethical aspects [11]. Aquaculture development policies must be designed according to an ecosystem approach, which promotes the integration of social, economic, and ecological aspects [12]. Thus, it is recognised that social and environmental aspects of mariculture companies play a key role in the sustainable development of the organisations, and thus these should be investigated more in depth [13].

Sustainability is an issue in fishery development around the world. However, it is difficult to analyse, especially due to the multiple relationships among ecological, social, and economic aspects [14]. These components needed for sustainable fishery development were mandated in the code of conduct for responsible fisheries by the Food and Agriculture Organisation (FAO) of the United Nations Conference in October 1995. The FAO promotes Blue Growth as a coherent approach for the sustainable, integrated, and socio-economically sensitive management of oceans and wetlands, focusing on aquaculture and the social protection of coastal communities. The Blue Growth framework promotes sustainable aquaculture through an integrated approach involving all stakeholders. Capacity development has the potential to strengthen the policy environment, institutional arrangements, and collaborative processes that empower fishing and fish-farming communities, civil society organisations, and public entities [15].

Research on environmental issues and knowledge management is urgently needed to develop the mariculture industries to become profitable and sustainable. Mariculture development is influenced by natural and physical conditions and inherently economic and social conditions in nature [16]. Research has proven that there may be positive effects of mariculture or no impact on the economy, such as increased income or job creation [17-19]. To ensure sustainable mariculture, it is necessary to identify key factors that contribute to sustainable mariculture. There are a small but increasing number of social science studies, especially on sustainable mariculture enterprises. However, most of them focus on stakeholder perceptions of fish farming management, consumer perceptions, or public perceptions of mariculture [20-22]. Developing an overview of the stakeholder perspectives may result in a better understanding of the sustainability issues in mariculture enterprises. Stakeholder engagement is essential for reaching consensus on effective policy development and implementation, and the process requires the sharing and understanding of various stakeholder perspectives to minimise conflict and ensure equitable and sustainable outcomes [23, 24]. The stakeholder perspectives are likely to differ from each other when looking at the key factors of sustainable mariculture enterprises. It is critical to investigate stakeholder views of sustainable mariculture since mariculture has the potential to raise the risk of conflict because several parties carry out activities in the same area for their own purposes [17, 25].

Historically, mariculture has been carried out with prior systematic planning or other zoning frameworks [26]. However, government policies do not involve multiple stakeholders, even though mariculture is held in open access areas prone to potential conflicts due to multiple uses of a space. Mariculture friendly to the environment likely gains social acceptance from the local community; hence, it is a significant consideration taken by stakeholders for sustainable mariculture [24]. Despite vast literature on the issues, farmers developing a sustainable mariculture enterprise have drawn no significant conclusions on specific factors from a stakeholder perspective to determine its sustainability. The expanding popularity of stakeholder perspective analysis reflects a greater need to discern how stakeholders' characteristics—individuals, groups, and organisations—influence decision-making processes [25]. This study aimed to determine key factors significantly contributing to sustainable mariculture enterprises. The results of this study can help governments and mariculture industries develop a sustainable mariculture sector. To identify the influence of key factors on its sustainability, previous studies [26-29] have predominantly discussed some biological aspects such as the suitability of feed nutrition, environmental issues, and management. Little research is conducted to address stakeholder perspectives on mariculture status and its management [20, 22, 30]. Considering stakeholder views and perspectives is a fundamental precept for developing the mariculture sector [31, 32]. This current study fills the gap in the previous study by identifying key factors that contribute to sustainable mariculture enterprises. Meanwhile, previous studies were commonly explored from a biological perspective [33, 34]. Stakeholder perspectives involved in the identification of key factors in sustainable mariculture enterprises were analysed quantitatively and qualitatively in this study.

Material and Methods

Study area

Field surveys were conducted in Lampung Province and Bali Province, Indonesia. Lampung Province is central to mariculture in western Indonesia, and Bali Province is one of the primary mariculture industries in eastern Indonesia (Fig 1.).

Fig. 1. Indonesia map illustrating target areas and distribution of the online survey. (Source: modified from https://pngimage.net/peta-indonesia-hijau-png-3/)

Mariculture in these two locations is almost identical, as both have faced a decline in production during the last ten years. In Lampung Province, the highest mariculture (finfish) production was 11,484 tonnes in 2011 and 476 tonnes in 2018. Meanwhile, the maximum mariculture production in Bali Province was 146,192 tonnes in 2013 and 857 tonnes in 2018 [28]. It indicates that problems in the mariculture sector likely occur due to unsustainable practises [35], environmental quality, easy access to markets, business capacity, competition or conflict in areas, and institutional frameworks [36, 37]. With this background, the two locations chosen were explored for their finfish mariculture enterprises. To get a comprehensive picture of stakeholder perspective in Indonesia, an online survey was also conducted using Google Forms and distributed to stakeholders (e.g., fish farmers, fish traders, input providers, and policymakers) in several other mariculture centres in Indonesia, such as the island of Sumatra, Kalimantan, Sulawesi, Nusa Tenggara, Maluku, and Java (Fig. 1), involving 141 participants. The survey was conducted from May to October 2020.

The primary data were also collected through in-depth interviews with fish farmers, fish traders, and local policymakers in Lampung and Bali Provinces to obtain complete information regarding key factors of sustainable mariculture enterprises. Secondary data, such as scientific journals or publications, articles, and reports, were also used in this study. Data were analysed using a mixed-methods design as per the initial identification of key factors through a literature review and stakeholder perspectives. Factor analysis and the MIC-MAC (Cross-Impact Matrix - Multiplication Applied to Classification) method were used as well.

Study design

This study used primary and secondary data, which were obtained in steps. Primary data were obtained from field surveys, online forms, independent interviews, and focus group discussions with stakeholders involved with mariculture enterprises. Stakeholders consist of four groups: Group 1 that are directly related to the mariculture enterprise, e.g., farmers, fish traders, input suppliers (e.g., feed, fingerlings); Group 2 including policymakers at the national and local levels, e.g., the Ministry of Marine Affairs and Fisheries, National Development Planning Agency, Provincial Marine Affairs and Fisheries Local Office; Group 3 consisting of mariculture expert groups, e.g., aquaculture-mariculture organisations, researchers, academics, and extension workers; and Group 4 including mariculture supporting groups, e.g., financial institutions, fisheries entrepreneurs, and NGOs. In contrast, secondary data were collected through a desk study and some related literature. The determination of the key factors in sustainable mariculture enterprises is carried out in three stages [38]: (i) self-validation (the researchers conducted literature reviews and first stage focus group discussion (FGD); (ii) scientific validation (independent expert judgement and statistical analysis); (iii) social validation (public webinar participation and second stage FGD). The first FGD was conducted face-to-face in Jakarta in February 2020 (before the restriction policy was enacted during the coronavirus pandemic), and the second FDG was conducted through Zoom to avoid long-distance trips in January 2021. Key factors were identified based on several previous studies.

Identified factors and verification of validity

The first step is to identify potential key factors in sustainable mariculture. Based on the literature reviews, 40 factors were identified to have contributed to sustainable mariculture enterprises (Table 1). Furthermore, for easier analysis, the potential key factors from the literature reviews were then grouped into five dimensions (economic, social, institutional, technological, and ecological) as determined in the first FGD.

Table 1. Potential key factors of sustainable mariculture enterprises in Indonesia

No	Dimension	Factor	Code	References
1	Economic dimension	Investment	E1	[39, 37]
2		Feed price	E2	[40, 41]
3		Fingerlings price	E3	[41]
4		Electricity, fuel, labor cost (operational cost)	E4	[42]
5		Fish price at the farm level	E5	[43]
6		Export demand	E6	[42]
7		Local demand	E7	[42]
8		Fish price at the export market	E8	[39, 43]
9		Fish price at the local level	E9	[43]
10		Marketing cost	E10	[39]
11	Social dimension	Poverty at the target areas/social security	S1	[39, 44]
12		Gender	S2	[44]
13		Experience	S3	[39, 45]
14		Conflict due to land use disputes	S4	[39, 45]

No	Dimension	Factor	Code	References
15		Labor incentives	S5	[46]
16	Institutional dimension	Number of feed sellers	I1	[47]
17		Number of fingerlings producers	I2	[47]
18		Number of middlemen	I3	[47]
19		Financial institutions	I4	[48]
20		Microfinance	I5	[49]
21		Number of mariculture policy	I6	[46, 39]
22		Number of farmer groups	I7	[50]
23		Contract between farmers and traders	I8	[46]
24		Credit accessibility	I9	[48]
25		Infrastructure accessibility	I10	[39]
26	Technology	Feed quality	T1	[44, 47]
27		Fingerlings quality	T2	[47]
28		Equipment quality	T3	[51]
29		Smartphone controlled	T4	[52]
30		Mariculture technique	T5	[39, 47]
31		Structure of facilities	T6	[28]
32		Number of cages	T7	[53]
33		Technology and information availability	T8	[51]
34	Ecological dimension	Utilization of marine areas	L1	[39]
35		Mangrove forest degradation	L2	[28]
36		Household waste	L3	[54, 43]
37		Shrimp ponds and industrial waste	L4	[54, 43]
38		Water quality	L5	[39, 55]
39		Climate change	L6	[34, 56, 57
40		Virus and bacteria	L7	[58]

Moreover, scientific confirmation of possible key factors was conducted using a validity test [59]. Before performing the validity test, each factor was assigned a score. The evaluation form was distributed online to 141 participants. Stakeholders explained their viewpoints on how these factors impact the sustainability of mariculture enterprises. Each participant assessed 40 factors with a score range of 1-5. Score 1 indicates the weakest influence, and higher scores indicate more robust influences (5=the strongest influence). The validity of the Jamovi programme was assessed with the Pearson Bivariate correlation test (with a significance value of 0.01), and factors are considered valid if the Pearson correlation value is equal to or the same as the r table. The analysis results showed that all the potential key factors tested were valid (Table 2).

Table 2. Validity test on potential key factors of sustainable mariculture enterprises in Indonesia

Factors		Sig (Pearson correlation)	r table (0.01)	Description
Investment	(E1)	0.734	0.1944	valid
Feed price	(E2)	0.663	0.1944	valid
Fingerling price	(E3)	0.716	0.1944	valid
Electricity, fuel, labor cost (Operating cost)	(E4)	0.663	0.1944	valid
Fish price at the farm level	(E5)	0.768	0.1944	valid
Export demand	(E6)	0.758	0.1944	valid
Local demand	(E7)	0.805	0.1944	valid
Fish price at the export market	(E8)	0.726	0.1944	valid
Fish price at local level	(E9)	0.783	0.1944	valid
Marketing cost	(E10)	0.737	0.1944	valid
Poverty conditions	(S1)	0.678	0.1944	valid
Gender	(S2)	0.521	0.1944	valid
Experience	(S3)	0.718	0.1944	valid
Conflict due to land use disputes	(S4)	0.690	0.1944	valid
Labor incentives	(S5)	0.780	0.1944	valid
Number of feed sellers	(I1)	0.772	0.1944	valid
Number of fingerlings producers	(I2)	0.825	0.1944	valid
Number of middlemen	(I3)	0.791	0.1944	valid
Financial institutions	(I4)	0.707	0.1944	valid
Microfinance	(I5)	0.758	0.1944	valid

Factors		Sig (Pearson correlation)	r table (0.01)	Description
Number of mariculture policies	(I6)	0.846	0.1944	valid
Number of farmer groups	(I7)	0.793	0.1944	valid
Contract between farmers and traders	(I8)	0.801	0.1944	valid
Credit accessibility	(I9)	0.794	0.1944	valid
Infrastructure accessibility	(I10)	0.844	0.1944	valid
Feed quality	(T1)	0.808	0.1944	valid
Fingerling quality	(T2)	0.856	0.1944	valid
Equipment quality	(T3)	0.802	0.1944	valid
Smartphone controlled	(T4)	0.707	0.1944	valid
Mariculture technique	(T5)	0.837	0.1944	valid
Structure of facilities	(T6)	0.820	0.1944	valid
Number of cages	(T7)	0.820	0.1944	valid
Technology and information availability	(T8)	0.863	0.1944	valid
Marine utilization area	(L1)	0.827	0.1944	valid
Mangrove forest degradation	(L2)	0.730	0.1944	valid
Household waste	(L3)	0.748	0.1944	valid
Shrimp ponds and industrial waste	(L4)	0.788	0.1944	valid
Water quality	(L5)	0.784	0.1944	valid
Stability of climate condition	(L6)	0.814	0.1944	valid
Virus and bacteria	(L7)	0.817	0.1944	valid

Data analysis

Key factors identified using a hybrid method combined the principal component analysis with the prospective analysis approach and MICMAC approaches [60]. This hybrid approach combined quantitative and qualitative analyses of the data.

First, within the scales used, the data were analysed using a principal component analysis (PCA) with varimax rotation to find the best solution maximising variances. The PCA analysis was conducted using Jamovi software and used to reduce redundant original factors to some specific new factors that can represent critical factors of sustainable mariculture enterprises. The number of factors was determined by selecting factors with eigenvalues (scores greater than two) and factor loading around ±0.5 or above with a p value of < 0.01 (see Ang, 2016). The final sort for each factor was then subject to interpretation.

Second, during interpretation, the most potential "key factors" from the PCA analysis were determined and mapped based on their influences and dependent components within a system. To conduct this analysis, the Matrix of Crossed Impact Multiplications Applied to a Classification (MICMAC) was developed by Godet [60] and was used due to its ability for a sustainable analysis in a lot of scenarios [15, 61-63]. The MICMAC has three basic steps: (1) identifying the elements (factors); (2) describing the relationship between the variables; and (3) identifying the key variables. The first step was carried out by identifying key factors for sustainable mariculture enterprises from the first FGD and PCA. The second and third steps were carried out once the data was inserted into the MICMAC computer programme developed by Lipsor. The MICMAC analysis, which has been widely used in previous research, determines the structural relationships of variables and provides a realistic picture of the variables [64].

Finally, with the MICMAC approach, problems were described, and a set of internal and external factors were identified. The relationship between the system factors is determined based on the degree of mobility and dependence between the existing factors. These factors are weighted according to certain qualifications. If the degree of influence is non-existent, low, medium, or high, a range of scales will be 0, 1, 2, and 3 or 0, 1, 3, and 5. In this case, this matrix entry is generally qualitative, and thus it is possible to adjust the strength of the relationships (0=non-existent, 1=weak, 2=medium, 3=strong, P=potential). The qualified results are the important factors that contribute to direct and indirect classifications. The analysis of mobility (influence) and dependency obtained by positioning the factor predictors in the quadrant may result in power variables, autonomous and conflict factors, or output factors according to their degree of influence and dependence (relationship).

Results and discussion

Identification of key factors of sustainable mariculture

Key factors of the sustainable mariculture enterprise investigated were selected using the PCA analysis according to priority. The basic idea of the selection priority is to identify a relatively small number of factors that are likely to be used to represent the relationships among sets of many interrelated variables. The PCA was conducted on 40 initial factors for the scales with orthogonal rotation (varimax). The Kaiser-Meyer-Olkin measure (KMO = 0.939) determines the sampling adequacy for further analysis if it has significant values above 0.9 [98]. This current study showed Bartlett's test of sphericity was statistically significant ($p < 0.001$), supporting the factorability of the correlation matrix. The analysis was carried out to obtain eigenvalues for each component in the data. Five principal components were retained in the analysis.

All of the components had eigenvalues of more than one and, in combination, explained 75.3% of the variance, indicating a high effect on sustainable mariculture enterprises. These results reveal the factors affecting sustainable mariculture enterprises (Table 3). This matrix contains the loadings of each variable onto each factor. By default, the statistics software displays all loadings, although those requested less than 0.5 were suppressed in the outputs, thereby leaving blank spaces for many of the loadings. Table 3 shows the factor loadings after rotation for the scales. The respective components were then named based on the same component classifications. This study is limited to choosing three factors with the highest loading factor values as components. The key factors with the three highest loading factor values (red box) for each component primarily form each component (Table 3). The five components named include Component 1: environmental quality and climate change (EQC); Component 2: international trade and marketing costs (ITM); Component 3: financial institutions and access credits (FAC); Component 4: operational costs for mariculture (OCM); and Component 5: farmers' characteristics and poverty conditions (FCP).

Table 3. Summary of exploratory analysis results of key factors in sustainable mariculture enterprises

Factors	EQC	ITM	FAC	OCM	FCP
Investment (E1)				0.536	
[1]**Feed price (E2)**				**0.793**	
[2]**Fingerlings price (E3)**				**0.752**	
[3]**Electricity, labor, fuel-Operational cost**				**0.702**	
Fish price at the farm level (E5)				0.511	
[1]**Export demand (E6)**		**0.739**			
Local demand (E7)		0.503			
[2]**Fish price at the export market (E8)**		**0.701**			
Fish price at the local level (E9)		0.644			
[3]**Marketing cost (E10)**		**0.666**			
[2]**Poverty level in the targets area (S1)**					**0.718**
[1]**Gender (S2)**					**0.823**
[3]**Experience & skill (S3)**					**0.537**
Conflict because of land use dispute (S4)					
Sharing system and incentives (S5)					
Number of feed sellers (I1)		0.503	0.509		
Number of fingerlings producers (I2)		0.574	0.546		
Number of middlemen (I3)			0.575		
[1]**Financial institutions (I4)**			**0.783**		
[2]**Microfinance (I5)**			**0.760**		
Number of mariculture policies (I6)			0.604		
Number of farmer groups (I7)			0.596		
Contract between farmers and traders (I8)			0.669		

Factors	EQC	ITM	FAC	OCM	FCP
[3]Credit accessibility (I9)			**0.685**		
Infrastructure accessibility (I10)			0.625		
Feed quality (T1)			0.530		
Fingerling quality (T2)		0.519			
Equipment quality (T3)		0.660			
Smartphone controlled (T4)					
Mariculture technique (T5)	0.504	0.545			
Structure of facilities (T6)		0.501			
Number of cages (T7)		0.535			
Technology and information availability (T8)		0.551			
Marine utilization area (L1)	0.734				
[1]Mangrove forest degradation (L2)	**0.825**				
Household waste (L3)	0.667				
Shrimp ponds and industrial waste (L4)	0.719				
[2]Water quality (L5)	**0.767**				
[3]Climate Change (L6)	**0.744**				
Virus and bacteria (L7)	0.719				
% of Variance	**19.01**	**18.12**	**17.94**	**11.67**	**8.59**
Cumulative %	**19.0**	**37.1**	**55.1**	**66.7**	**75.3**

Note: 1. EQC is environmental quality and climate change; ITM is international trade and marketing costs; FAC is financial institutions and access to credit; OCM is the operational cost of mariculture; and FCP is farmers' characteristics and poverty conditions. The superscript number shows the ranking of each principal component.
2. [dashed box] : Top 3 factor with the highest loading value

Component 1 (EQC) includes various factors such as mangrove forest degradation (0.825); water quality (0.767); and climate change (0.744). Environmental quality is an important factor in mariculture influenced by mangrove forest degradation. Abundant mangrove forests have a positive impact on fisheries, especially fish and shrimp [28, 65]. The decline of the mangrove forests may cause irreparable harm to the ecosystem. Maintaining mangroves can create a stable and healthy coastal environment [66]. However, Indonesia apparently has a very high rate of mangrove forest deforestation. In the last three decades, 40% of mangrove forest degradation occurred due to logging as well as land conversion for agriculture, shrimp ponds, and salt areas [67-69]. The areas of mangroves in Indonesia were 7,758,410ha in 2007 and decreased by 43% in 2017 to 3,361,216ha [70]. In particular, the same situation also occurred in Lampung and Bali provinces, which are the current research sites. In Lampung Province, there were initially around 160,000 ha of mangrove areas, but they were then reduced by 85%, or to around 24,000 ha [71]. In Bali Province, mangrove areas were estimated to be 130,868.1ha in 2015, but more than 50% of areas were damaged [72, 73]. Mangrove deforestation harms mariculture enterprises in these two locations, resulting in declining profits. Hence, some mariculture enterprises have even experienced losses and closed [19]. Water quality is a potential factor limiting the development of the mariculture industry [23]. Poor water quality may cause crop failure due to fish mortality. Plankton and fish parasites are two bioindicators used to assess water quality [74-76]. In fact, fish parasites are convincing bioindicators to see an environmental change in tropical groupers in Indonesia [77]. Climate change in the fishery sector has a broad impact on capture fisheries and aquaculture. Climate change possibly affects the quantity and quality of mariculture production [56]. It may decrease the potential diversity of mariculture species by 10-40% on average; consequently, it impacts the selection of cultivable fish species according to location. Based on several studies, climate change has an impact on the availability of suitable mariculture areas [78, 79].

Component 2 (ITM) includes various factors such as export demand (0.739); fish price at the export market (0.701); and marketing cost (0.666). Farmers often export fish as their main target, either directly or through middlemen, because the export selling price is higher than the local price. At the time of the research, the export price of grouper (live fish) was 11-28.5USD/kg depending on the species, and the local price was 5.5-10.5USD/kg. Export demand is an important factor in grouper cultivation that determines the harvest time. When export demand is low and prices are low, farmers tend to delay harvest time until they have export demand at higher prices. The buyer determines the formation of grouper prices in the target areas. A similar rule was found in research conducted in Southeast Sulawesi, Indonesia, where the buyer decided on sale prices influenced by market demand for the commodity [80]. Marketing costs are a major concern in a mariculture enterprise, especially in the flow of goods (fish) from farmers to buyers, both at the local and export levels. The problem is not only due to the high cost of transportation but also to the risk of fish mortality. If the fish on sale dies, then farmers will face the risk of financial loss. However, three schemes are applied in the target areas to avoid financial losses due to fish mortality during the marketing process; the loss is fully covered by either the farmer, buyer, or both parties (farmer and buyer). For local marketing, each dead fish will be priced at half the price of the live fish, but for export marketing, each dead fish has no value (0 USD) and is a subtraction factor from the total selling value.

Component 3 (FAC) includes various factors such as financial institutions (0.783), microfinance (0.760), and credit accessibility (0.685). The existence of financial institutions is essential as a source of capital for mariculture enterprises. In general, mariculture facilities owned by companies or individuals have a high dependence on financial institutions to meet their operational needs. Mariculture entrepreneurs in the target areas had relationships with financial institutions to get some loans for mariculture enterprise needs. However, for farmers or small-scale mariculture owners who cannot get loans from formal financial institutions because they lack collateral, they borrow the cash from local lenders (e.g., savings and loan cooperatives or village credit agencies). For farmers in the small-scale category, loans were usually used not only for mariculture operations but also for the benefit of daily life as they did not make money from the harvest. Microfinance has an important role in rural development through financial support to alleviate poverty [81]. In addition, credit accessibility should be given more attention because some farmers in the target areas still find it difficult to access credit from financial institutions and microfinance. They did not have sufficient knowledge about how to access credits. They were often stuck with loans with high interest and easy terms, even without collateral. Limited access to finance has remained one of the fundamental problems that hamper agricultural production, productivity, and investment in rural communities and farm households [82].

Component 4 (OCM) includes various factors such as feed price (0.793); fingerling price (0.752); and electricity, labour, and fuel costs as operational costs (0.702). Operational cost is one of the major factors affecting the profitability of grouper farming. The fingerling price, feed, and labour account for 61% and 74% of the total operational costs in grouper mariculture [11]. In general, the cost component of feed contributes more than 50% of the total operational costs [19]. Variable costs in this study include costs for labour, electricity, fuel, and freshwater. The types of feed used in the mariculture grouper consist of fish diets (feed from industries) and trash fish. The average feed requirement for one production cycle reached 1,160kg/cage, with an average fish weight of 100heads/cage. Trash fish prices fluctuated between IDR 5,000/kg and IDR 5,500/kg, and the price of pellets at the time of the study was IDR 20,000/kg. The increase in the trash fish price will greatly affect profits because this cost contributes more than 50%. The fingerling price, feed price, and labour cost are identified as major productional costs, and their changes are susceptible to profitability [83]. Other variable costs (electricity, labour, fuel, and freshwater) also play a vital role in the mariculture industry, and thus the overall operational costs likely impact the sustainability of the mariculture enterprises.

Component 5 (FCP) consists of various factors such as poverty in the target areas (0.718); gender (0.823); and experience (0.537). It has three factors representing the individual characteristics of the business actor: social condition and environmental condition. The poverty condition is indicated by the poverty rate indicator (the number of people who fall into the poor category). The existence of mariculture facilities in the target areas may have a positive impact on the environment because it gives employment opportunities for people involved in the business, starting with input needs, processes, and marketing. However, based on the results of interviews with several owners, they found that some people stole fish from the cage, and this crime might be allegedly caused by poverty. However, there is no scientific analysis or proof of this statement, but it might be considered in mariculture management given the fact that several studies have found a correlation between poverty and crime [84, 85]. Generally, the 56 people involved in mariculture enterprise operations in the target areas consisted of 49 men and seven women. From a gender perspective, mariculture enterprises are dominated by men, who have more influence on decision-making about their management than women. Male workers had better experience and skills in the field of mariculture than women. This study found one female owner, one female chief technician, and five female cooks and waitresses for other worker.

Influence and dependence among key factors and their relationship

Based on the PCA findings, 15 potential key factors have been selected based on priority or loading factor values (the three largest) in each formed component. Furthermore, the MICMAC method was used to identify several important factors and analyse the influence and dependence between these key factors to realise a sustainable mariculture enterprise. The influence and dependence significance is represented in four quadrants: excluded factors (low influence and dependence); dependent factors (strong dependence but low influence); relay factors (high dependence but low influence); and influencing factors (strong influence but low dependence). The basis for such divisions is taken from the matrices' multiplication pattern [86]. Then, the potential key factors were scored based on a consensus valuation approach. Values are entered into columns and rows (Table 4) by considering the influence of each factor that was discussed and agreed upon by stakeholders in the second FGD. They were then outlined in the Matrix of Direct Influence (MDI) by filling in 0, 1, 2, 3, and P. Score 0 describes no direct influence; score 1 indicates a weak relationship between variables; score 2 indicates a moderate relationship between the variables; score 3 shows a very strong relationship between variables; and P is a sign for potential key factors. The MDI results of the influence between the factors are presented in Table 4. In Figure 2, 15 factors are grouped into the four quadrants.

The MDI estimates in Table 4 result from a consensus in the FGD attended by 18 participants representing various stakeholders involved and having a good awareness of issues in the mariculture sector. All the participants agreed to fill out the MDI survey and provide a general description of group variables related to the influence and strength of the factors. Figure 2 shows the relative dependence and influence of key factors; the x-axis is the "dependence" measure. The x value of a specific factor shows that the factor is dependent on the other factor. The higher the x value, the greater the dependence. The y-axis is the "influence" measure. The y value of a specific factor indicates how that factor influences the other factors. The higher the y value, the greater the influence. As seen in Figure 2, as many as seven factors from the components of EQC (climate change, water quality), ITM (export demand, fish price at the export level), FAC (microfinance, credit accessibility), and FCP (experience and skill) are in quadrant I, which becomes the category of influencing factors or key drivers. The map shows how stakeholders perceive the system and what they consider to be constraints, opportunities, and potentialities for change [87]. Key factors for sustainable mariculture enterprises were identified based on the four quadrants in the map (influencing, relaying, depending, and excluded factors).

Table 4. Matrices of Direct Influence of Key Factors of Sustainable Mariculture Enterprises

Key Factors	1. Mangrove degradation	2. Water quality	3. Climate change	4. Export demand	5. Fish price at the export level	6. Marketing cost	7. Financial institution	8. Microfinance	9. Credit accessibility	10. Feed price	11. Fingerling price	12. Operational cost	13. Gender	14. Poverty condition	15. Experience & skills
1. Mangrove degradation	0	3	1	P	0	0	0	0	0	0	0	0	0	P	0
2. Water quality	2	0	2	1	2	2	0	0	1	2	3	3	0	2	2
3. Climate change	2	3	0	P	P	P	P	P	1	1	2	3	1	2	P
4. Export demand	0	0	0	0	3	2	1	1	0	3	3	2	1	2	0
5. Fish price at the export level	1	2	0	3	0	3	1	1	1	3	3	3	0	2	1
6. Marketing cost	0	0	0	3	3	0	0	0	0	3	3	2	0	1	0
7. Financial institutions	0	0	0	0	0	2	0	2	3	0	0	0	0	2	0
8. Microfinance	0	0	0	0	1	2	3	0	3	2	2	3	1	2	1
9. Credit accessibility	0	0	0	0	0	2	3	3	0	1	1	3	0	3	2
10. Feed price	0	3	0	0	3	3	1	0	1	0	3	3	1	1	1
11. Fingerling price	0	0	0	0	0	2	0	0	0	1	0	3	0	P	0
12. Operational cost	0	0	0	1	3	3	1	0	0	3	3	0	0	2	2
13. Gender	1	1	0	0	0	0	0	1	1	0	1	2	0	1	3
14. Poverty condition	2	2	1	0	0	0	2	3	2	1	1	1	1	0	1
15. Experience & skills	1	2	0	0	0	0	0	0	3	2	2	2	3	3	0

Note: 0 = no influence; 1 = weak; 2 = moderate influence; 3 = strong influence; p = potential influence

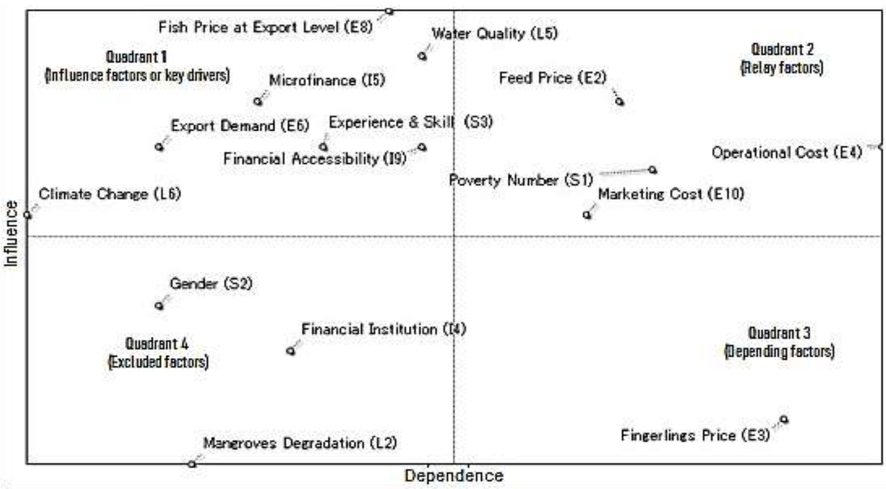

Fig. 2. MICMAC Analysis: Map of influencing and related key factors

The factors in quadrant I are referred to as driving or independent factors with strong influence but weak dependence [88]. Environmental conditions and climate change are external factors that are difficult to control for farmers. This result is in line with Brown et al.'s (2020) research stating that environmental quality, especially water quality, is a key issue for sustainable mariculture [23]. Climate change alters the abiotic properties of the oceans and, subsequently, the ecosystem for aquatic organisms [89]. Specifically, warming ocean temperatures combined with increased acidification and storm frequency may create new opportunities and threats for mariculture industries [57]. For example, changing sea surface temperatures (SST) cause observable effects on the distribution of economically important mariculture species (finfish, bivalve). Improved mariculture management becomes the main target. Impacts and mitigation of water quality impairment on coastal mariculture sites are potentially influenced by stakeholder involvement. Mariculture products in Indonesia, mostly targeted for the export market, affect price changes, and export demand indirectly affects mariculture operations. When demand and selling prices in the destination country are low, farmers tend to postpone harvesting, which increases operating costs. Limited capital is a common issue for small-scale (traditional) farming. Financial institutions near mariculture areas may provide farmers easy access to credit offers to tackle the financial constraints. In general, mariculture cases are often associated with labour, skills, finances, sales, and prices [18, 90].

In quadrant II (Figure 2), factors fall into the category of relay factors. These four factors include the ITM (marketing cost) component, the OCM (feed price, operational cost), and the FCP (poverty condition). These four factors are sensitive and volatile in the system and are affected by other variables. For example, in cases that often occur in target areas and Indonesia in general, especially in grouper aquaculture that rely on trash fish as the main feed, the availability of trash fish is significant for the sustainability of grouper fish farming. When the availability of trash fish around the mariculture facilities is low, the farmers will buy trash fish from other areas (outside the province) at a higher price. Thus, higher trash fish prices will increase production costs and result in inefficiency. In addition, to maintain their economic value, fish should be alive when traded in grouper exports. Fish mortality in the marketing process is a risk of value loss that the seller must bear. Factors in quadrant 3, such as fingerling price, have a low influence and a high reliance. Farmers in this situation typically have their own hatchery and supply it to satisfy their farm demands. According to the analysis results in Figure 2, current conditions in Lampung and Bali demonstrate fingerling prices did not have a substantial influence; nonetheless, producing excellent fingerlings is influenced by several factors, including tank colour, feeds, water condition, and brood stock [91-95]. Quadrant 4 is an autonomous or omitted element consisting of factors, i.e., gender, financial institutions, and mangrove forest deterioration, with a minor influence and dependence on the sustainability of mariculture in the target areas.

The influence or direct dependence between factors affecting the sustainability of mariculture can be seen in figure 3. Factors with a much stronger influence on other factors are indicated by a thick red line, while a blue line and others indicate a weaker relationship. In the EQC components, mangrove forest degradation and climate change had a strong ability to influence the water quality factor. Other than that, the feed price in the OCM components had a strong ability to influence water quality. In this case, the feed price has something to do with the amount of feed (trash fish) the farmers put into the marine cage. The farmers tend to buy more trash fish for feed when its price is cheaper. On the other hand, trash fish used as aquafeeds in mariculture sometimes induce environmental risk due to decreased water quality [96, 97]. In the OCM components, feed price, marketing cost, operational cost, export demand, fingerling price, and fish price at the export level likely had a solid ability to influence each other simultaneously in the system. It shows that the factors in the tested OCM components had a strong influence on the sustainability of mariculture enterprises. Changes in the OCM components will strongly influence other factors at the same time.

Additionally, figure 3 illustrates major relationships between factors in developing sustainable mariculture enterprises. The thick lines indicate a greater and stronger influence on other factors. In contrast, the more lines that go into a factor, the stronger its influence or dependence on other factors. The colour and thickness of the various lines connecting one variable to another show the strength of the influence. The red line represents the strongest influence, while the grey dotted line represents the lowest effect. The results showed climate change, export demand, financial accessibility, fish price at the export level, and water quality had a very strong direct influence on other factors (see Figs. 2 and 3 included in quadrant 1).

The factors in quadrant 2, such as feed price, operational costs, and marketing costs, influenced other factors the most. Interestingly, all cost-related factors in the mariculture enterprises were grouped as relay factors with high dependence and low influence. This indicates that costs in a mariculture enterprise will be greatly influenced by other factors. In this study, feed price was strongly influenced by water quality, operational cost, and fish price at the export level. In the target areas, both mariculture enterprises in Lampung and Bali mostly used trash fish as feed. In general, water quality will affect the availability of fish in the sea as a source of food. In addition, as conveyed in the FGD, the feed price (fish diet) likely increased as the selling price of fish increased. The findings of this study are generally able to describe existing phenomena. Factors in a quadrant influence other factors in the same quadrant and across quadrants. For example, mangrove forest degradation substantially influenced water quality but was relatively moderately influenced by climate change. The results indicated no difference in the findings of grouping variables between the analysis of relationships based on direct influence (Fig. 3) and the categorization of variables into four quadrants (Fig. 2), which indicates a stable system.

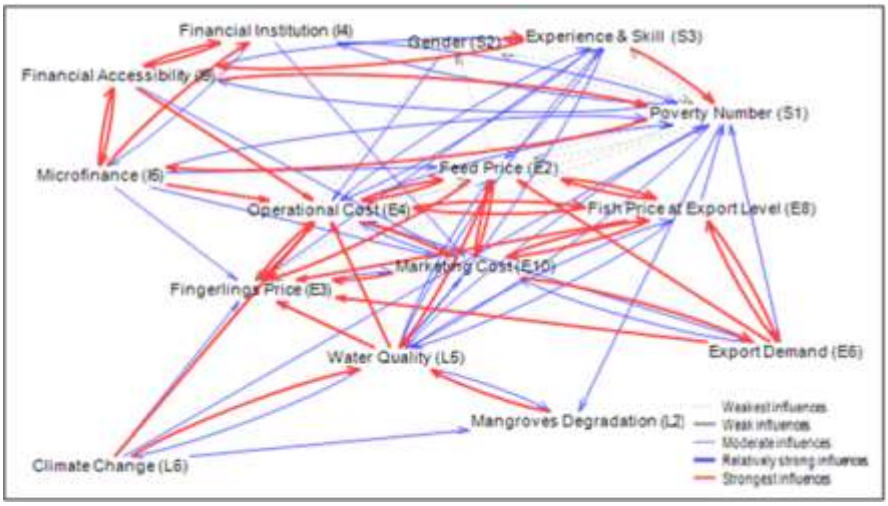

Fig. 3. Relationship among key factors

As shown in figure 3, several factors influence each other strongly. Each factor in the same component (Table 3) has a substantial influence on each other in a system. Water quality, feed price, and operational cost are the factors with the most extensive thick red line direction from other factors (Fig. 3). It indicates these three factors are susceptible and thus need more attention to avoid harm in a mariculture enterprise. Credit accessibility can be improved by increasing the knowledge of farmers regarding credit and banking. It lies in the finding stating that experience and skills influence credit accessibility. Credit access must also be possible through effective social networks among farmers and the availability of financial institutions (banks) and microfinance [10, 53] (Fig. 3). Therefore, capacity-building policies are required to promote quick credit access and support the establishment of sustainable mariculture.

Conclusions

This study filled the gap in sustainable mariculture research from stakeholder perspectives, providing input, production, and marketing stages. Out of 40 potential key factors, 15 main factors were selected with the most significant loading factor value from each dimension. The PCA results showed five components of potential key factors for sustainable mariculture enterprises: (1) environmental quality and climate change; (2) international trade and marketing costs; (3)

financial institutions and access credits; (4) operational costs for mariculture; and (5) farmer characteristics and poverty conditions. The combination of the components explained 75.3% of the variance. Environmental quality and climate change components had the highest average loading factor values compared to other components. The loading factor value shows a significant correlation between a factor and a construct in sustainable mariculture enterprises. In other words, from the current stakeholder perspective, environmental quality and the threat of climate change are likely to influence the sustainability of mariculture enterprises.

However, through the MICMAC analysis, some key factors based on their status and role were found. In quadrant 1 (influencing factors), fish price at the export level, water quality, microfinance, export demand, experience and skills, financial accessibility, and climate change had strong influences but weak dependence on the sustainability of mariculture enterprises. Besides, each key factor had a relationship with and influence on other factors in the same quadrant or in different quadrants. Key factors in the environmental quality and climate change components had a strong influence on the key factors in international trade, marketing costs, and operational costs. Alternatively, it can be concluded that all the key factors in the three components were strongly interrelated in establishing sustainable mariculture enterprises. The identified key factors of sustainable mariculture enterprises will help the government or policymakers map which factors could be used as input objects for engendering policies on mariculture management, especially in the target areas and Indonesia in general. Besides, those could serve as leverage variables, meaning changes could be detected earlier to anticipate and plan business in the future. The research findings could be references for better mariculture management in Southeast Asia in general and could be a source of academic knowledge for improving mariculture management. The selected key factors could be an entry point for discussion at the policymaker's level. Some limitations of the research lie on its application side. Some of the important factors or specific processes in mariculture operations may have been left out of the analysis. The current data did not contain further information, such as specific social issues and conflicts between users of the water (mariculture vs. captured fisheries or mariculture vs. marine tourism), which could be included in future research. Also, sustainable mariculture requires comprehensive implementation. Despite the limitations, this study contributes to identifying key factors that each policymaker needs to consider when making some decisions.

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References

[1] H. Eriksson, M. Troell, C. Brugere, M. Chadag, M. Phillips, N. Andrew, **Equitable Mariculture: A Diagnostic Framework for Equitable Mariculture Development in the Western Indian Ocean,** Australian Centre for International Agricultural Research (ACIAR), 2018. https://hdl.handle.net/20.500.12348/3203. [Accessed 2022 January 15].

[2] M.M. Islam, M.D. Shamsuddoha, *Coastal and marine conservation strategy for Bangladesh in the context of achieving blue growth and sustainable development goals (SDGs)*, **Environmental Science & Policy, 87**, 2018, pp. 45-54.

[3] Ministry of Marine Affairs and Fisheries. **Marine and Fisheries Information Statistics**, Pusat Data, Statistik dan Informasi, Jakarta, Kementerian Kelautan dan Perikanan, 2020, 590p.

[4] R.S.Pomeroy, J.E Parks, C.M. Balboa, *Farming the reef: is aquaculture a solution for reducing fishing pressure on coral reef?*, **Marine Policy, 30**(2), 2006, pp. 111-130.

[5] A. Fredheim, T. Reve, *Future prospects of marine aquaculture*, **OCEANS 2018 MTS/IEEE Charleston**, 2018, pp. 1-8. DOI:10.1109/OCEANS.2018.8604735

[6] M. Marzuki, I.W. Nurjaya, A. Purbayanto, S. Budiharso, E. Supriyono, *Sustainabiliy Analysis of Mariculture Management In Saleh Bay of Sumbawa District*, **Environmental Management and Sustainable Development, 3**(2), 2014, pp. 127-137.

[7] J. Yu, W. Yin, *Exploring stakeholder engagement in mariculture development: Challenges and prospects for China*, **Marine Policy, 103**, 2019, pp. 84-90.

[8] S. Mustafa, R.A. Rahman, **Sustainable Marine Aquaculture: Recent Developments with Special Reference to Southeast Asia,** Borneo Marine Research Institute, Universiti Malaysia, Sabah, Malaysia, 2000, pp. 3-6.

[9] Y. Liu, U.R. Sumaila, *Economic analysis of netcage versus sea-bag production systems for salmon aquaculture in British Columbia*, **Aquaculture Economics & Management, 11**(4), 2007, pp. 371-395.

[10] D. *Whitmarsh, M.G. Palmieri, Social acceptability of marine aquaculture: The use of survey-based methods for eliciting public and stakeholder preferences*, **Marine Policy, 33**(3), 2009, pp. 452-457.

[11] J. Alder, T.J. Pitcher, D. Preikshot, K. Kaschner, B. Ferriss, *How good is good? A rapid appraisal technique for evaluation of the sustainability status of fsheries of the North Atlantic*, **Fisheries Centre Research Reports, 8**(2), 2000, pp. 136–182.

[12] B. Costa-Pierce, *Sustainable ecological aquaculture systems: The need for a new social contract for aquaculture development*, **Marine Technology Society Journal, 44**(3), 2010, pp. 88-112.

[13] E. Bonsón, M. Bednárová, *CSR reporting practices of Eurozone companies*, **Revista de Contabilidad, 18**(2), 2015, pp. 182-193.

[14] S.M. Garcia, A.T. Charles, *Fishery systems and linkages: implications for science and governance*, **Ocean & Coastal Management, 51**(7), 2008, pp. 505-527.

[15] Fauzi, A., **Sustainability Technique Analysis**, Gramedia, Indonesia, 2019, 300p.

[16] C. Bailey, C. Pomeroy, *Resource dependency and development options in coastal Southeast Asia*, **Society & Natural Resources, 9**(2), 1996, pp. 191-199.

[17] C.R. Engle, J.J. Bohorquez, *Mariculture, economic and social impacts., a Derivative of Encyclopedia of Ocean Sciences, Porter Hoagland*, **Marine Policy, and Economics, 2**, 2010, pp. 236-244.

[18] M.E. Fachry, K. Sugama, M.A. Rimmer, *The role of small-holder seed supply in commercial mariculture in South-east Asia*, **Journal Aquaculture, 495**, 2018, pp. 912-918.

[19] M. Firdaus, K. Hatanaka, R. Saville, *Profitability analysis of mariculture as well as its impact on farmers' incomes and poverty alleviation: insights from Lampung and Bali Provinces, Indonesia*, **AACL, Bioflux, 13**(4), 2020, pp. 2396-2409.

[20] K. Bacher, A. Gordoa, E. Mikkelsen, *Stakeholders' perceptions of marine fi sh farming in Catalonia (Spain): A Q-methodology approach*, **Aquaculture, 424**, 2014, pp. 78-85.

[21] L.V. Essen, S.C.A. Ferse, M. Glaser, A. Kunzmann, *Ocean & Coastal Management Attitudes and perceptions of villagers toward community-based mariculture in Minahasa, North Sulawesi, Indonesia*, **Ocean & Coastal Management, 73**, 2013, pp 101–112.

[22] S. Freeman, E. Vigoda-Gadot, H. Sterr, M. Schultz, I. Korchenkov, P. Krost, D. Angel, *Public attitudes towards marine aquaculture: a comparative analysis of Germany and Israel*, **Environmental Science & Policy, 22**, 2012, pp. 60-72.

[23] A.R. Brown, J. Webber, S. Zonneveld, D. Carless, B. Jackson, Y. Artioli, I.J. Bateman, *Stakeholder perspectives on the importance of water quality and other constraints for sustainable mariculture*, **Environmental Science & Policy**, 114, 2020, pp. 506-518.
[24] C. Mather, L. Fanning, *Social licence and aquaculture: towards a research agenda*, **Marine Policy, 99**, 2019, pp. 275-282.
[25] L.C. Kluger, R. Filgueira, *Thinking outside the box: embracing social complexity in aquaculture carrying capacity estimations*, **ICES Journal of Marine Science, 78**(1), 2021, pp. 435-442.
[26] J.G. Ferreira, J. Grant, D.W. Verner-Jeffreys, N.G.H. Taylor, *Carrying capacity for aquaculture, modeling frameworks for determination of. In Sustainable Food Production*, **Science & Business Media** (Editors: P. Christou, R. Savin, B. Costa-Pierce, I. Misztal, and B. Whitelaw), Springer, New York, 2012, pp. 417-448.
[27] J.C. Navarro, Ó. Monroig, A.V. Sykes, *Nutrition as a Key Factor for Cephalopod Aquaculture*, **In Cephalopod Culture**, Springer, Dordrecht, 2014, pp. 77-95.
[28] A. Akber, A. Abdul, C. Lovelock, *Major drivers of coastal aquaculture expansion in Southeast Asia*, **Ocean & Coastal Mangement, 198**, 2020, Article Number 105364. https://doi.org/10.1016/j.ocecoaman.2020.105364
[29] T. Chopin, A.H. Buschmann, C. Halling, M. Troell, N. Kautsky, A. Neori, C. Neefus, *Integrating seaweeds into marine aquaculture systems: a key toward sustainability*, **Journal of Phycology, 37**(6), 2001, pp. 975-986.
[30] Y. Olsen, O. Otterstad, C.M. Duarte, *Status and Future Perspectives of Marine Aquaculture*, **Aquaculture in the Ecosystem**, Springer, Dordrecht, 2008, pp. 293-319.
[31] J. Memery, D. Birch, *Exploring Attitudes Toward Aquaculture Development in the United Kingdom: A Consultative Stakeholder Approach*, **Journal of International Food & Agribusiness Marketing, 28**(4), 2016, pp. 363-372.
[32] H. Salgado, J. Bailey, R. Tiller, J. Ellis, *Stakeholder perceptions of the impacts from salmon aquaculture in the Chilean Patagonia*, **Ocean & Coastal Management, 118**, 2015, pp. 189-204.
[33] R.L. Shelmerdine, B. Mouat, R. Shucksmith, *The most northerly record of feral Pacific oyster Crassostrea gigas (Thunberg, 1793) in the British Isles*, **BioInvasions Records, 6**, 2017, pp. 57-60.
[34] V. Montalto, B. Helmuth, P.M. Ruti, A. Dell'Aquila, A. Rinaldi, G. Sarà, *A mechanistic approach reveals nonlinear effects of climate warming on mussels throughout the Mediterranean Sea*, **Climatic Change, 139**(2), 2016, pp. 293-306.
[35] Y. Ye, M. Barange, M. Beveridge, L. Garibaldi, N. Gutierrez, A. Anganuzzi, M. Taconet, *FAO' s statistical databases and the sustainability of fisheries and aquaculture: Comments to Pauly and Zeller 2017*, **Marine Policy, 81**, 2017, pp. 401-405.
[36] M.D. Garzagil, M. Varela-lafuente, G. Caballero-miguez, *Price and production trends in the marine fish aquaculture in Spain*, **Aquaculture Research, 40**(3), 2009, pp. 274-281.
[37] I.P. Davies, V. Carranza, H.E. Froehlich, R.R. Gentry, P. Kareiva, B.S. Halpern, *Governance of marine aquaculture: Pitfalls, potential, and pathways forward*, **Marine Policy, 104**(2), 2019, pp. 29-36.
[38] T. Hak, B. Moldan, A.L. Dahl, **Sustainability Indicators: A Scientific Assessment**, Island press, Vol 67, 2007, 413p.
[39] P. Burbridge, V. Hendrick, E. Roth, H. Rosenthal, *Social and economic policy issues relevant to marine aquaculture*, **Journal of Applied Ichthyology, 17**(4), 2001, pp. 194-206.
[40] J.S. Diana, H.S. Egna, T. Chopin, M.S. Peterson, L. Cao, R. Pomeroy, M. Verdegem, W.T. Slack, M.G. Bondad-Reantaso, F. Cabello, F., *Responsible aquaculture in 2050: valuing local conditions and human innovations will be key to success*, **BioScience, 63**(4), 2013, pp. 255-262.

[41] M.J. Kaiser, Y. Yu, B. Snyder, *Economic feasibility of using offshore oil and gas structures in the Gulf of Mexico for platform-based aquaculture*, **Marine Policy, 34**(3), 2010, pp. 699-707.
[42] J.R. Barton, A. Floysand, *The political ecology of Chilean salmon aquaculture, 1982–2010: A trajectory from economic development to global sustainability*, **Global Environmental Change, 20**(4), 2010, pp. 739-752.
[43] A. Neori, T. Chopin, M. Troell, A.H. Buschmann, G.P. Kraemer, C. Halling, M. Shpigel, C. Yarish, *Integrated aquaculture: Rationale, evolution and state of the art emphasizing seaweed biofiltration in modern mariculture*, **Aquaculture, 231**(1), 2004, pp. 361–391.
[44] C. Béné, R. Arthur, H. Norbury, E.H. Allison, M. Beveridge, S. Bush, L. Campling, W. Leschen, D. Little, D. Squires, S.H. Thilsted, M. Troell, M. Williams, *Contribution of Fisheries and Aquaculture to Food Security and Poverty Reduction: Assessing the Current Evidence*, **World Development, 79**, 2016, pp. 177–196.
[45] T.R. Johnson, K. Beard, D.C. Brady, C.J. Byron, C. Cleaver, K. Du, N. Keeney, M. Kimble, M. Miller, S. Moeykens, M. Teisl, G.P.V. Walsum, J.A. Yuan, *Social-Ecological System Framework for Marine Aquaculture Research*, **Sustainability, 11**(9), 2019, Article Number 2522. doi:10.3390/su11092522.
[46] G. Knapp, M.C. Rubino, *The political economics of marine aquaculture in the United States*, **Reviews** in **Fisheries Science & Aquaculture, 24**(3), 2016, pp. 213-229.
[47] M. Shaalan, M. El-mahdy, M. Saleh, M. El-matbouli, *Reviews in Fisheries Science & Aquaculture Aquaculture in Egypt: Insights on the Current Trends and Future Perspectives for Sustainable Development*, **Reviews in Fisheries Science & Aquaculture, 26**(1), 2018, pp. 99-110.
[48] C. Knott, B. Neis, *Privatization, financialization and ocean grabbing in New Brunswick herring fi sheries and salmon aquaculture*, **Marine Policy, 80**, 2017, pp. 10-18.
[49] M.T. Kalhoro, Y. Mu, S.B.H. Shah, M. Noman, M.A. Kalhoro, T.R. Pavase, M.A. Soomro, *Microfinance for Fisheries and Aquaculture, Lessons for Pakistan from Regional Asian Countries*, **Lasbela, UJ Sci. Techl, VI,** 2017, pp. 312-222.
[50] G. Parkes, J.A. Young, S.F. Walmsley, R. Abel, J. Harman, P. Horvat, A. Lem, A. Macfarlane, M. Mens, C. Nolan, *Behind the signs—a global review of fish sustainability information schemes*, **Review in Fisheries Science, 18**(4), 2010, pp. 344-356.
[51] E.C. Lagares, F.G. Ordaz, J. José, *Innovation, environmental commitment, internationalization and sustainability: A survival analysis of Spanish marine aquaculture firms*, **Ocean & Coastal Management, 151**, 2018, pp. 61-88.
[52] W. Sung, J. Chen, H. Wang, Remote fish aquaculture monitoring system based on wireless transmission technology, **International Conference on Information Science, Electronics and Electrical Engineering, 1**, 2014, pp. 540-544.
[53] I. Olesen, A. Ingeborg, G.K. Rosendal, *Sustainable Aquaculture: Are We Getting There? Ethical Perspectives on Salmon Farming*, **Journal of Agricultural and Environmental Ethics, 24**(4), 2011, pp. 381-408.
[54] R. Lounas, H. Kasmi, S. Chernai, N. Amarni, L. Ghebriout, N. Meslem-haoui, *Towards Sustainable Mariculture: Some global trends,* **Thalassas: An International Journal of Marine Sciences 36**(2), 2020, pp. 447-456.
[55] T.K.N. Hong, T.T.H. Phan, T.N.T. Tran, L. Philippe, *Vietnam's Fisheries and Aquaculture Development's Policy:Are Exports Performance Targets Sustainable?*, **Oceanography and Fisheries Open Access Journal, 5(**4), 2017, Article Number. DOI: 10.19080/OFOAJ.2017.05.555667
[56] R.R. Gentry, H.E. Froehlich, D. Grimm, P. Kareiva, M. Parke, M. Rust, S.D. Gaines, B.S. Halpern, *Mapping the global potential for marine aquaculture*, **Nature Ecology & Evolution, 1**(9), 2017, pp. 1317-1324.

[57] S.S. De Silva, D. Soto, **Climate Change and Aquaculture: Potential Impacts, Adaptation and Mitigation. Climate Change Implications for fisheries and Aquaculture: Overview of Current Scientific Knowledge**, FAO Fisheries and Aquaculture Technical Paper, 530, 2009, pp. 151-212.

[58] K.D. Lafferty, C.D. Harvell, J.M. Conrad, C.S. Friedman, M.L. Kent, A.M. Kuris, E.N. Powell, D. Rondeau, S.M. Saksida, *Infectious Diseases Affect Marine Fisheries and Aquaculture Economics,* **Annual Review of Marine Science, 7**(1), 2015, pp. 471-496.

[59] L.L. Chan, N. Idris, *Validity and reliability of the instrument using exploratory factor analysis and Cronbach's alpha***, International Journal of Academic Research in Business and Social Sciences 7**(10), 2017, pp. 400-410.

[60] M. Godet, F. Roubelat, *Creating the future: The use and misuse of scenarios,* **Long Range Planning, 29**(2). 1996, pp. 164-171.

[61] M. Godet M, **From Anticipation to Action: A Handbook of Strategic Prospective**, UNESCO, Paris [FR], 1994.

[62] R. Dubey, A. Gunasekaran, T. Papadopoulos, S.J. Childe, K.T. Shibin, S.F. Wamba, *Sustainable supply chain management: framework and further research directions,* **Journal of Cleaner Production, 142**, 2017, pp. 1119-1130.

[63] E.R. Arozamena, A.D. Ibarbia, *Influential Aspects Modeling For the Development Of Sustainable Strategies In Industrial Areas,* **Proceedings from the 16th International Congress on Project Engineering**, 2012, pp. 85-93.

[64] R. Attri, N. Dev, V. Sharma, *Interpretive structural modelling (ISM) approach: An overview,* **Research Journal of Management Sciences, 2**(2), 2013, pp.3-8.

[65] S.Y. Lee, *Relationship between mangrove abundance and tropical prawn production: a re-evaluation*, **Marine Biology, 145**(5), 2004, pp. 943-949.

[66] S. Sandilyan, K. Kathiresan, *Mangrove conservation: a global perspective*, **Biodiversity and Conservastion, 21**(14), 2012, pp. 3523-3542.

[67] M. Firdaus, K. Hatanaka, R. Saville, *Mangrove Forest Restoration by Fisheries Communities in Lampung Bay: A study based on perceptions, willingness to pay, and management strategy*, **Forest and Society, 5**(2), 2021, pp. 224-244.

[68] A. Campbell, B. Brown, *Indonesia's vast mangroves are a treasure worth saving*. **The Conversation**. 2015, [Accessed 18 November 2020]. http://theconversation.com/indonesias-vast-mangroves-are-atreasure-worth-saving-39367/.

[69] FAO, The world's mangroves 1980-2005. Rome: Food and Agriculture Organization of the United Nations. 2007. [Accessed 20 April 2022]. http://www.fao.org/3/a1427e/a1427e00.htm

[70] A. Rahadian, L.B. Prasetyo, Y. Setiawan, K. Wikantika, *A historical review of data and information of Indonesian mangroves area,* **Media Konservasi, 24**(2), 2019, pp. 163-178.

[71] N. Damayanti, **Hutan Bakau di Pantai Timur Lampung Tersisa 10%. Tempo news 2007**, https://koran.tempo.co/read/nusa/110247/hutan-bakau-di-pantai-timurlampung-tersisa-10-persen. [Accessed 13 January 2021]

[72] M. Lugina, I. Alviya, I. Indartik, M.A. Pribadi, *Strategi keberlanjutan pengelolaan hutan mangrove di Tahura Ngurah Rai Bali*, **Jurnal Analisis Kebijakan Kehutanan. 14**(1), 2017, pp. 61-77.

[73] A. Redi, *Urgensi Pembentukan Peraturan Daerah Provinsi Bali Tentang Perlindungan dan Pengelolaan Hutan Mangrove Berlandaskan Kearifan Lokal,* **Jurnal Muara Ilmu Sosial, Humaniora, dan Seni, 3**(1), 2019, pp. 32-42.

[74] M. Casé, E.E. Leça, S.N. Leitão, E.E. Sant, R. Schwamborn, A.T. de Moraes Junior, *Plankton community as an indicator of water quality in tropical shrimp culture ponds,* **Marine Pollution Bulletin, 56**(7), 2008, pp. 1343-1352.

[75] B. Sures, M. Nachev, C. Selbach, D.J Marcogliese, *Parasite responses to pollution: what we know and where we go in 'Environmental Parasitology'*, **Parasites & Vectors, 10**(1), 2017, Article Number 65. DOI 10.1186/s13071-017-2001-3.
[76] V.M. Vidal-Martínez, M.L. Aguirre-Macedo, C.M. Vivas-Rodríguez, F. Moravec, The macroparasite communities of the red grouper, Epinephelus morio, from the Yucatan Peninsula, Mexico, **Proceedings of the 50th Annual Meeting of The Gulf and Caribbean Fisheries Institute**, 1998, pp. 9-14.
[77] H.W. Palm, S. Kleinertz, S. Rückert, *Parasite diversity as an indicator of environmental change? An example from tropical grouper (Epinephelus fuscoguttatus) mariculture in Indonesia*, **Parasitology, 138**(13), 2011, pp. 1793-1803.
[78] H.E. Froehlich, A.R. Claire, R.G. Rebecca, D.G. Steven, S.H. Benjamin, *Comparative Terrestrial Feed and Land Use of an Aquaculture-Dominant World*, **Proceedings of the National Academy of Sciences, 115**(20), 2018, pp. 5295–5300.
[79] D.H. Klinger, S.A. Levin, J.R. Watson, *The growth of finfish in global open-ocean aquaculture under climate change*, **Proceedings of the Royal Society B: Biological Sciences, 284**(1864), 2017, pp. 20170834.
[80] L.O.M. Aslan, W. Iba, B.A. Ingram, G.J. Gooley, S.S. de Silva, *Mariculture in SE Sulawesi, Indonesia: Culture practices and the socio-economic aspects of the major commodities*, **Ocean and Coastal Management, 116**, 2015, pp. 44-57.
[81] K. Gow, **Microfinance in Asia: Toward Economic Sustainable Development Policies and Strategies**. Public administration and public policy. New York. 118, 277.2010.
[82] I. Abunyuwah, J.K. Blay, A. Ghana, *Accessibility constraints of small-scale fish farmers to formal credit in the Nzema East Municipality*, **Journal of Economics and Sustainable Development, 4**(1), 2013, pp. 128-133.
[83] F. Afero, S. Miao, A.A. Perez, *Economic analysis of tiger grouper Epinephelus fuscoguttatus and humpback grouper Cromileptes altivelis commercial cage culture in Indonesia*, **Aquaculture International, 18**(5), 2010, pp. 725-739.
[84] S.B. Heller, B.A. Jacob, J. Ludwig, **Family Income, Neighborhood Poverty, and Crime. In Controlling Crime: Strategies and Tradeoffs,** University of Chicago Press, pp. 419-459, 2010.
[85] P.P. Pare, R. Felson, *Income inequality, poverty and crime across nations*, **The British Journal of Sociology, 65**(3), 2014, pp. 434-458.
[86] A. Mandal, S.G. Deshmukh, *Vendor selection using interpretive structural modelling (ISM)*, **International Journal of Operations Production Management, 14**(6), 1994, pp. 52–59.
[87] M. Delgado-Serrano, P. Vanwildemeersch, S. London, C.E. Ortiz-Guerrero, R.E. Semerena, M. Rojas, *Adapting prospective structural analysis to strengthen sustainable management and capacity building in community-based natural resource management contexts*, **Ecology and Society, 21**(2), 2016, Article Number 36. DOI: 10.5751/ES-08505-210236.
[88] G. Kannan, N.A. Haq, *Analysis of interactions of criteria and sub-criteria for the selection of supplier in the built-in-order supply chain environment*, **International Journal of Production Research, 45**(17), 2007, pp. 3831-3852. DOI: 10.1080/00207540600676676.
[89] M.L. Zippay, B. Helmuth, *Effects of temperature change on mussel, Mytilus*, **Integrative Zoology, 7**(3), 2012, pp. 312-327.
[90] M.A. La Ode, W. Iba, B.A. Ingram, G.J. Gooley, S.S. de Silva, *Mariculture in SE Sulawesi, Indonesia: Culture practices and the socio-economic aspects of the major commodities*, **Ocean and Coastal Management, 116**, 2015, pp. 44-57.
[91] S. Sim, H. Kongkeo, M. Rimmer, *Brief overview of recent grouper breeding developments in Thailand*, **Aquaculture Asia, 10**(3), 2005, Article Number: 24.

[92] R. Shapawi, S. Mustafa, W.K. Ng, *Effects of dietary fish oil replacement with vegetable oils on growth and tissue fatty acid composition of humpback grouper, Cromileptes altivelis (Valenciennes)*, **Aquaculture Research, 39**(3), 2008, pp. 315-323.
[93] S. Ghavidel, P. Kochanian, A.P. Salati, *The effects of the tank colour on growth performance and physiological responses in fingerling grouper, Epinephelus coioides*, **Aquaculture Research, 51**(1), 2020, pp. 276-281.
[94] E.R. Misailă, C. Misaila, G. Vasile, *Preliminary data on ecological plasticity in sturgeon fries*, **Analele Ştiinţifice ale Univ. „Alexandru Ioan Cuza" Iaşi, s. Biologie Animală**, **53**, 2007, pp. 269-275.
[95] G. Dumitru, E.Todirascu-Ciornea, L. Hritcu, I.G. Sandu, *Studies of some morphological and biochemical parameters concerning the health condition of some fish species from Prut River, Romania*, **Revista de Chimie, 69**(5), 2018, pp. 1194-1199.
[96] Z. Xu, X. Lin, Q. Lin, Y. Yang, Y. Wang, *Nitrogen, phosphorus, and energy waste outputs of four marine cage-cultured fish fed with trash fish*, **Aquaculture, 263**(1-4), 2007, pp. 130-141.
[97] D.K. Gomez, K.I. Mori, Y. Okinaka, T. Nakai, S.C. Park, *Trash fish can be a source of betanodaviruses for cultured marine fish*, **Aquaculture, 302**(3-4), 2010, pp. 158-163.
[98] A. Field, **Discovering Statistic Using SPSS (Third edition)**, London and New York: Sage, pp. 651-656, 2009.

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