Risk Management of Offshore Aquaculture Operations

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Abstract: Aquaculture method has been well known in Indonesia for a long time. Inland aquaculture, such as the brackish water pond, is a common practice for more than a couple of hundred of years. However, it is not the same case for marine aquaculture, especially offshore. Fish demand is continuously increasing following the growth of the world population. In spite of this, the number of wild captured marine fish is relatively stagnant for the last 30 years, and there is a need to ensure the sustainability of marine ecology. To deal with this challenge, the Indonesia Ministry of Marine Affairs and Fisheries (MMAF) has a pilot project to install and operate offshore aquaculture. Furthermore, this program is also aiming at providing more job opportunities for the community, ensuring food security, and increasing the contribution of the fisheries sector to the National GDP. To ensure the successfulness of this business, offshore aquaculture operational risk management is required. The purpose of this study is to identify, assess, evaluate, and propose treatment action for potential risks during offshore aquaculture operations by adopting the House of Risk method. This study identifies 47 risk events and 67 risk agents (source of risk events) of offshore aquaculture operations. Five risk agents are selected, and suitable treatment actions are proposed accordingly.

1 INTRODUCTION

With more than two-thirds of the Indonesia area is the ocean and approximately 7 million of its people involve in the fisheries sector, the Indonesian government sees that the future of the country depends heavily on sound maritime management. Indonesia is the second-largest fish producer in the world. Contribution of the Fisheries sector to national Gross Domestic Product is 2,56% in 2016, and the Indonesian government expects to increase it continuously (CEA, 2016).

Traditionally wild capture fisheries are the main source of fish; however, captured fish growth has been relatively stagnant in the last 30 years. On the other hand, aquaculture production showed rapid growth from only around 7% in 1974 to 42% in 2012. Moreover, in 2014, the contribution of aquaculture fish production for human consumption is higher than wild capture. Thus, aquaculture is expected to take on a greater role in the future, supplying the majority demand for increasing the world population (FAO, 2016b).

In Indonesia, total aquaculture production increases sharply from approximately five times between 2000 to 2016. The Ministry of Marine Affairs and Fisheries has set targets that total aquaculture production can reach 31.3 tons in 2019. However, it is not easy to achieve the target as the full potential of Indonesian aquaculture production has not yet employed. The potential area in Indonesia that is available to be utilized for marine, brackish, and freshwater aquaculture production is still very large (around 17.92 Million hectares), but only around 26% that has been employed. Furthermore, according to Slamet Soebjakto, Directorate General of Aquaculture - Ministry of Marine Affairs and Fisheries (MMAF), there are still 16.9 million hectares potential area that has not been utilized in 2015. Additionally, the knowledge and skill of Indonesia's fishermen are still limited (Soebjakto, 2015; Bappenas, 2018).

MMAF has put several programs to enhance aquaculture's production progress accordingly. Some examples of the programs are providing fish fingerlings/fry, broodstocks, fish foods, and biofloc systems (KKP, 2017). The president of Indonesia,

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likewise, suggests that education should be given for the fishermen to improve their understanding and knowledge of aquaculture or modern fisheries method. One of the MMAF special programs in 2018 is to install and operate Offshore Aquaculture in Aceh, West Java, and Central Java. Each of these offshore aquaculture units is targetted to produce more than 900 tons of Barramundi/Seabass annually as well as to provide jobs (income) for the surrounding community (Soebjakto and Pregiwati, 2018).

To enable the successful implementation of offshore aquaculture in Indonesia, it is important to understand and manage the risks associated with offshore aquaculture operations. Even though there are a lot of studies on risk management of aquaculture, specific research on offshore aquaculture risk management, specifically in Indonesia, is limited. Therefore, this study has five main objectives, they are: (1) to identify potential risks of Indonesia offshore aquaculture operations, (2) to determine potential risks and its drivers (causes), (3) to assess/measure risk magnitude, (4) to evaluate risks and (5) to recommend risk treatments plan.

To assist in the risk assessment process, the House of Risk matrix is utilized and modified on this study to correspond with offshore aquaculture operational risks. A more detail description of the House of Risk is presented in the next section. The method, results, and discussion are elaborated in the third and fourth sections, while section five presents the conclusion of this study.

2 LITERATURE REVIEWS

In this section, several works of literature related to aquaculture and risk management, including one of the tools, House of Risk, are presented.

2.1 Aquaculture

Indonesian waters that have stable temperature and levels of salinity provides a proper environment for aquaculture production. In addition, a potential area in Indonesia for aquaculture is still very huge. Up to now, less than 30% of the area (i.e., seawater, freshwater, brackish water) that has been utilized for aquaculture while the biggest potential area is seawater (around 12 million hectares). From 2000 to 2016, Indonesia's total aquaculture production increased sharply (up to five times) from 788.500 tons to 4.950.000 tons (FAO, 2016a).

In general, there are six methods of aquaculture that are commonly employed in Indonesia, and they are brackish water ponds, mariculture, freshwater ponds, cages, floating cage nets, and paddy fields. Brackish water ponds have been utilized in Indonesia for approximately 400 years and are considered the oldest method. Indonesia's major aquaculture commodities are Shrimp, Seaweed, Grouper, Patin, Tilapia, Goldfish, Catfish, Milkfish, and Gourami (German-Indonesian Chamber of Industry and Commerce, 2017). Mariculture is the cultivation of marine animals and plants in natural (i.e., open or enclosed section of the ocean) or controlled (i.e., tanks, ponds) marine waters (Deutsch et al., 2011). Bush et al. (2019) divide aquaculture operations scale into two levels, and they are: (1) small scale which mainly provides income and food security to households, (2) large scale that contributes more to national revenue as it is targetted for supplying export demand.

The terminology of "offshore Aquaculture," which is also known as "open ocean aquaculture," can be defined as "rearing of marine organisms under controlled conditions in the Exclusive Economic Zone—from the three-mile territorial limit of the coast to two hundred miles offshore. Facilities may be floating, submerged, or attached to fixed structures' (Upton and Buck, 2010). There are many mariculture (private) businesses that have been operated in several parts of Indonesia, for example, at the Buleleng area in Bali or Trenggalek area in East Java. However, these aquacultures are considered as coastal or off the coast aquaculture as these facilities are located less than 3 km from the shore. In addition, most of these aquaculture produces Grouper, Seabass, and Seaweed for the local and international markets.

In April 2018, the first pilot, Offshore aquaculture in Indonesia, was installed in Pangandaran, West Java. It consists of eight holes, with each of them has 25.5 meters diameter and 15 meters in depth. Moreover, it also includes one feeding system, maintenance (feed barge), and one transport vessel/transport boat. This offshore aquaculture is aimed to produce 946 tonnes of Barramundi and Seabass when it is fully operated. A similar offshore aquaculture system is planned to be installed in Jepara Central Java and Sabang Aceh. Moreover, these offshore aquacultures are also aimed to open new job opportunities to the nearby community as well as to fulfill market demand. Thus, it would support the MMAF program to enhance the contribution of the fisheries sector to national GDP as well as food security (Soebjakto and Pregiwati, 2018).

Jin, Kite-Powell, and Hoagland (2005) emphasize the importance of risk management in this business as it is in a high level of uncertainty regulation, technology, and many more. Thus, to ensure a successful business of offshore aquaculture, sound knowledge, and understanding of any potential risk that could impede this business should be well managed accordingly by taking appropriate actions.

2.2 Risk Management

Risk can be defined as "the possible occurrence of an event that produces adverse effects on man and his environment. The degree of risk is related to both the probability of the event's occurrence and also to the estimated outcome in terms of the nature, intensity, and duration of the adverse effects" (Wasserman and Wasserman's, 1979) in (Gratt, 1987). As risk could influence the goal of an activity/project and may lead to potential losses, managing risk is essential for any business. To manage risk, we should understand what, how, where, and when it could be happened and build an appropriate mitigation plan.

Risk management focuses on assessing most if not all potential and significant risks, then implementing effective risk response (Airmic, Alarm and Irm, 2010; Kayis and Karningsih, 2012). Several references have proposed a diverse risk management process/stages. Thomas, Kalidindi, and Ganesh (2006) suggest three steps in managing risk, and they are (1) risk identification, (2) risk assessment/measurement, (3) risk prioritization and response. Scavarda et al. (2006) suggest similar steps but with an additional one step that is communicating and consulting with stakeholders. International Organisation for Standardisation (ISO) provides a generic framework for risk management in 2009, which is called ISO 31000. It offers a common standard as well as a comprehensive guide that integrates risk management into an organization strategy with full support from senior management. It consists of five main processes, and they are: (1) establishing the context, (2) risk assessment (i.e., risk identification, analysis, and evaluation), (3) risk treatment, (4) communication and consultation, (5) monitoring and review.

The study of risk has been applied broadly in many areas, including aquaculture. According to Risk Management AS/NZS 4360 (1999) and Haring (2015), risks can be classified based on various attributes such as risk source, risk consequences, time, location, and related person/factor/activity. Arthur et al. (2009) examine potential risks in aquaculture that are categorized according to their source. This study shows that there are potential risks that originated from aquaculture operations in society. There are environmental, biological, financial, social, and human health risks. For example, environment risks could be occurred due to pollution from excess feeds and water flow changing or financial risks due to the bankruptcy of farming operations. On the contrary, this study also identifies that there are potential risks coming from society and environment to aquacultures, such as the environmental risk that is happened as a result of pollution from inland agriculture or sea transportation (ships) activities, or social risk which is due to lack of skilled human resource for aquaculture operators. While Jin, Kite-Powell, and Hoagland (2005) conduct a risk assessment study to assist the investor in making the decision in relation to aquaculture business. They propose a firm-level investment-production model. Moreover, as open water (offshore) aquaculture is operated under uncertainty from market demands, biological factors, and regulations, thus they suggest the traditional rule of Net Present Value should be altered.

There are some approaches/tools that could be utilized for supporting risk management process, to name a few: brainstorming, flow chart, structured interview and questionnaire, fault tree, structured interview, expert judgment, event tree, fault tree, statistical and numerical analysis, simulation and computer modeling (Ahmed, Kayis and Amornsawadwatana, 2007; Grimaldi, Rafele and Cagliano, 2012). Another tool, such as risk matrices, has broadly utilized to measure and rank risks according to its likelihood and consequences (Ristic, 2013).

Pujawan and Geraldin (2009) propose House of Risk (HOR), a tool for managing risks in the supply chain context, which is developed by integrating Failure Mode and Effect Analysis (FMEA) and House of Quality (HOQ). HOR consists of two main matrices. The first matrix, HOR stage 1 (table 1), for identifying and classifying risk events and their associated causes (risk agents) based on five SC processes of SCOR (i.e., Plan, Source, Make, Deliver, Return) framework.

Table 1: HOR 1 matrix

Bussiness process (Activity)	Risk event (Ei)	Risk agent (Aj)			*Severity of risk event* (S_i)
		A1	A2	A3	
Plan	E1	(R_{ij})	9		7
	E2			3	10
Occurance (O_j)			9	8	
ARP_j			567	240	
Priority of Rank of Agent j			1	2	

Aggregate Risk Potential (ARP) is calculated by using this formula (1) below:

$$ARP_j = O_j \sum_i S_i R_{ij} \quad (1)$$

ARPj = Aggregate Risk Potential of risk agent j
Oj = occurrence of risk agent j
Si = severity of risk event i
Rij = relation value of risk event i with risk agent j

Thus, from this matrix, the ARP value for each risk agent is calculated, and it could be ranked. The decision-maker then could select how many risk agents would be further analyzed for risk treatment. The selection could be based on Pareto Law or the top five or other particular criteria, depending on the organization's personal consideration. This step is generally called as risk analysis and evaluation. Then, the formulation of risk treatment (action) for each (selected) risk agent is conducted on the HOR stage 2 matrix. This matrix is aimed to measure and rank alternatives of risk treatments for each risk agent according to Effectiveness to Difficulty (EtD) Ratio. The total effectiveness of each action is calculated by using this formula (2) below:

$$TE_k = \sum_j ARP_j E_{jk} \quad (2)$$

Ejk = the degree of effectiveness of action k in reducing the likelihood of occurrence of risk agent j

Effectiveness to Difficulty (EtD) Ratio ratio is calculated by dividing the Total Effectiveness of each Action with Degree of Difficulty to perform this action. The highest rank (rank 1) is given to the preventive action with the highest ETD_k.

Prioritized Risk Agents (Aj)	Preventive Actions (PAk)			ARPj
	PA1	PA2	PA3	
A2	Ejk	9		567
A3		3	9	240
Total effectiveness of action k (TEk)	TE1	5823	2160	
Degree of difficulty performing Action k (Dk)	D1	5	3	
Effectiveness to difficulty (EtD) ratio	EtD1	1165	720	
Rank of priority for Preventive Action k	R1	1	2	

Table 2: HOR 2 matrix

As this HOR is developed specifically for managing risk in the Supply Chain Operations context; therefore, in this paper, the matrix is modified to suit the nature of this study that is offshore aquaculture operations.

3 RISK MANAGEMENT OF OFFSHORE AQUACULTURE OPERATIONS

In this part, assessing the risk of offshore aquaculture operations is conducted by following [14] steps, namely: (1) establish the context, (2) risk identification, (3) risk analysis, and (4) risk evaluation. Next, each step is elaborated further in the following subsections.

3.1 Establish the Context

This step is related to define external and internal parameters, including determining scope and risk criteria of offshore aquaculture operations. The selection of the location of installation, construction of the floating net cage (aquaculture structure), and fish distribution/marketing are not included in this study. In general, aquaculture operations could be divided into two main activities: they are:

a. Cultivating the fish, from stocking (fish seed/fingerling supply), feeding, nursing/monitoring, and harvesting

b. Maintaining the floating net cage

The type of fish that is selected in this study are Seabass, Barramundi, or Grouper, which are considered as a high-value fish, and they have been successfully grown in the current nearshore aquaculture practices in Indonesia. The floating net cage installation is located between three miles to two hundred miles of Indonesian offshore.

3.2 Identify Operations Risks

Identifying most (if not all) potential operations risks of offshore aquaculture is conducted, starting by gathering potential risks from literature studies. Then, these risks are validated by interviewing six experts from different field studies (i.e., Fisheries and Marine Sciences, Ocean Engineering, and Biology) as well as 12 practitioners (i.e., fishermen, aquaculture business owners and staffs). As a result, 47 risk events are identified, which consists of 21 risks related to floating cage maintenance and 26 risks related to fish cultivation. Next, the source of each risk event or risk agent also needs to recognize so effective risk treatment can be applied properly to reduce, transfer, or avoid these risk events. Risk agents (source of risk event) are obtained by using a similar method and conducted concurrently when identifying risk events. As a result, 67 risk agents (i.e., 35 risk agents related to floating cage maintenance and 32 risk agents related to fish cultivation) are then identified accordingly. Table 3 shows a partial list of risk events with their associated risk agents. These risk events are classified according to two main activities in aquaculture (i.e., maintaining floating net and cultivating fish).

Table 3: Partial list of a risk event and risk agent

Main Activities	Risk Events	Risk Agents
Maintain Net	Damaged / broken Nets (E1)	Lack of routine maintenance (A11) Close to Lifetime of the nets (A12) Marine animal bites the net (A13) Disproportion of fish density in the cages (A14) Do not use knotted nets or use a thin net (A15)
Cultivating Fish	Unavailable of seed (E2)	Late delivery/problem on Seed suppliers/ hatchery (A21)
	High mortality of seed (E3)	Improper handling during transport (A31)

3.3 Analyze and Evaluate Risks

Risk events and risk agents that have been identified in the previous step are then re-arranged into the HOR 1 matrix. Next, the severity of each risk event, the occurrence of each risk agent, and including relation level between risk events with its risk agent(s) are determined based on expert judgment. For this case study, the selected respondent is one of Aquaculture business practitioner that has operated his business for almost ten years. He is not only owned aquaculture business in several places in Indonesia but also several fishing vessels, hatchery, and a seafood restaurant. The respondent determines/measures the value of severity and probability based on scale 1 to 10. While scale 1 represents minor/insignificant consequences or very rarely to occur, scale 5 means medium consequences or possible to occur and scale 10 equal to major/very high consequences or highly frequent/almost certain to occur. While relation level between risk events and risk agents utilizes three-level value, they are 1, 3, and 9, which represent low, moderate, and high relations consecutively. Finally, Aggregate Risk Potential (ARP) of each risk agent is calculated by using formula (1). As a result, the partial calculation of HOR 1 for this case study can be seen in Table 4.

Risk agent with the highest top five of ARP (rank 1 to rank 5) are selected for further analyze, they are as follow: (1) Late delivery/problem of seed suppliers/hatchery, (2) Damaged net due to marine animals bites, (3) Low quality of fish feed, (4) Pollution from surrounding area of offshore aquaculture, (5) Lack of routine maintenance of net.

3.4 Formulate and Select Risk Treatment Action

Selected risk agent(s) from the previous stage are then analyzed by using the House of Risk (HOR) matrix stage 2 to formulate risk treatment as well as select the proper risk treatment. Table 5 shows the risk treatment action for each five risk agent. These risk treatment options are generated based on references as well as discussion with experts and practitioners (aquaculture owners).

Table 5: Risk treatment action for the top five risk agent

Risk agent	Risk treatment (RT)
A4. Late delivery/problem of seed suppliers/hatchery	RT1. Develop a partnership with more than one fish seed suppliers (multi suppliers and multi-locations) RT2. Manage inventory of fish seeds RT3. Manage/produce own fish seedling
A8.Damaged cage net due to marine animals bites	RT4. Improve cage net strength by combining with outer metal fence

A13. Low quality of fish feed	RT5. Develop procedure and run testing for incoming fish feed
A11. Pollution from the surrounding area of offshore aquaculture	RT6. Routine checking for the surrounding area while looking for the source of pollution and eliminate them
A18. Lack of routine maintenance of net cage	RT7. Develop a proper maintenance schedule for net cage

House of Risk (HOR) stage 2 is then utilized to determine which risk treatment action recommended based on difficulty and effectiveness. The level of difficulty and effectiveness is determined by judgment from several respondents, namely: aquaculture owner and aquaculture expert. Based on analysis of HOR stage 2 as can be seen in Table 6, the recommendation of selected risk treatment action for each prioritized risk agent are as follow:

(1) Develop partnerships with multiple fish seed suppliers located in different locations.
(2) Combining original cage net with an outer metal fence to increase its strength
(3) Develop a proper maintenance schedule for net cage
(4) Develop procedure and run testing for incoming fish feed
(5) Routine checking for the surrounding area while looking for the source of pollution and eliminate them

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4 CONCLUSIONS

Aquaculture, including offshore aquaculture operations, is considered a more environmentally friendly way of fulfilling the rising market demand of fish than traditional wild capture. Managing operations risks of offshore aquaculture is essential to ensure the successfulness of the MMAF program and any aquaculture operations.

This study has identified 47 risk events and 67 risk agents (source of risk events) of offshore aquaculture operations. By adopting the House of Risk stage 1 matrix, these risks are analyzed and evaluated by considering the expert's judgment. Five risk agents are selected or prioritized based on the highest-ranking (aggregate risk potential value) to further analysis. For each risk agent, the alternative of action for treating risk is determined and mapped into the House of Risk stage 2. As a result, five risk treatments are recommended to mitigate offshore aquaculture operations risks.

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APPENDIX

Table 6: House of Risk stage 1

Main Activity	Risk Event (Ei)	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	*Severity of risk event* (Si)
Floating cage net / aquaculture structure maintenance	E1	3	0	3	9	9	3	1	9													7
	E2				3					3	3	9										6
	E3									3			1									3
	E4				9							3										9
	E5				9																	9
	E6													9	3	3						10
	E7				9			1									3					5
	E8																	3	9			10
	E9																			9		10
	E10				9																	10
	E11								9												3	10
	E12								9													8
	E13																					4
	E14				9																	2
	E15				9			3														5
	E16																					8
	E17																					3
	E18																					3
	E19																					3
	E20																					3
	E21																					3
Fish Cultivation	E22																					10
	E23																					8
	E24																					10
	E25																					10
	E26																					9
	E27																					8
	E28																					7
	E29				9																	10
	E30																					4
	E31																					6
	E32																					10
	E33																					10
	E34																					4
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	E36																					7
	E37																					8
	E38																					10
	E39																					8
	E40																					9
	E41																					10
	E42																					10
	E43																				3	10
	E44																					5
	E45																					10
	E46																					10
	E47																					9
Risk agent occurence (O_j)		2	1	4	10	7	9	3	7	8	7	9	5	9	8	9	2	4	7	2	9	
ARP_j		42	0	84	5310	441	189	81	1575	216	126	729	15	810	240	270	30	120	630	180	540	
Rank		17	20	15	1	7	11	16	2	10	13	4	19	3	9	8	18	14	5	12	6	

Table 7: House of Risk stage 2

Selected Risk agent (Aj)	Risk Treatment (RT_k)							ARP_j
	RT1	RT2	RT3	RT4	RT5	RT6	RT7	
A4. Late delivery / problem of seed suppliers/hatchery	9	3	9					**5310**
A8.Damaged cage net due to marine animals bites				9				**3150**
A13. Low quality of fish feed					9			**1800**
A11. Pollution from surrounding area of offshore aquaculture						9		**1620**
A18. Lack of routine maintenance of net cage							9	**1620**
Total effectiveness of risk treatment (TE_k)	47790	15930	47790	28350	16200	14580	14580	
Degree of Difficulty of risk treatment (D_k)	4	3	5	5	5	5	3	
Effectiveness to difficulty ratio (ETD_k)	11947,5	5310	9558	5670	3240	2916	4860	
Rank	1	4	2	3	6	7	5	

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