Incorporating the Ecological, Socio-economic and Institutional Conceptual Model Framework for Sustainable Management of Small-scale Mud Crab *(Scylla serrata)* Fishery in Western Seram Regency, Indonesia

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ABSTRACT

Mud crab *Scylla serrata* of Kotania Bay and Pelita Jaya Bay of Western Seram District, has been harvested by local fishermen for more than 25 years. The mud crab has high economic value, and there is always a market for this fishery. The economic dependence of the fishermen forces them to harvest this resource extensively. No existing management strategy and extensive exploitation leads to unsustainable conditions of this fishery. With inadequate data condition, the Driver-Pressure-State-Impact-Response (DPSIR) model constructs an ecological, social-economy, and institutional conceptual model framework for sustainable management of this fishery. The driving force (D) in this fishery comes from the local fishers harvesting the mud crab. The two most sensitive attributes that affected mud crab sustainability from Rapfish analysis were used as state-level of DPSIR methodology. The result shows that the most sensitive variables from ecological, socio-economy, and institution were: caught before maturity, mud crab size, consumer attitude towards sustainability, just management, government quality, and monitoring and reporting, respectively. It was concluded that this conceptual model allows a better understanding of how the mud crab *S. serrata* system works and management actions taken at different system components. This conceptual model framework can be a useful tool to incorporate the participation of stakeholders, managers, and scientists in the process of a sustainable management plan.

1. INTRODUCTION

The Bay of Kotania and Pelita Jaya of Western Seram Regency, Eastern Indonesia is a productive area with many fish resources like skipjack tuna, mackerel, anchovy, grouper, sea cucumber, and mud crab (Wouthuyzen and Sapulete, 1994; Siahainenia, 2016; Huliselan et al., 2017). The bay is considered as a semi enclosed estuary ecosystem covered with three important tropic ecosystems, mangrove, seagrass bed, and coral reef, among which mangrove ecosystem is the dominant one. Because of its productivity, in 1989 the Government of Indonesia designated this area as a part of the Seram Integrated Economic Development Area (KAPET Seram).

Among some economic fish resources, mud crab (*Scylla* spp.) is one of the most valuable crustacean species caught by local fishers in Western Seram Regency, Maluku Province. Three species of mud crab are commonly found in this area, *Scylla olivacea, S. paramamosain*, and *S. serrata* (Tetelepta and Makatita, 2012; Tetelepta et al., 2018), with *S. serrata* being the dominant species. The mud crab *S. serrata* which is generally known also as green crab or black crab is the crab from the genus of *Scylla* found living mostly in the mangrove ecosystem of tropical and subtropical waters of Indo Pacific region (Keenan, 1999; Jirapunpipat, 2008; Shelley, 2008).

The fishery in this area has been conducted for

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many years mostly by local fishers with most being artisanal fishermen. These fisheries represent an important socio-economic and cultural aspect of coastal communities, and their impact on coastal reefs and vulnerable mega-fauna may be significant. The ‘small’ in small-scale fisheries refers to the size of the fishing boat and the size of the crew on the boat. Small-scale can be misleading, however, since although the size of the fishing unit is small, the extent and prevalence of this type of fishery on a global scale is not. About 95% of fishers worldwide are small-scale fishers (Fujita et al., 2018; Smith and Basuro, 2019).

There are approximately 40 mud crab fishers in this rea, each having about 20 mud crab pots which operate every day, except Friday. Some mud crab fishermen from Wael Village have extended their fishing area to Manipa Island since the catch in this area has decreased (personal communication). Field observation also shows that the local people use hard coral for building material and mangrove trees for mud crab fences, burning fuel, and materials for floating cage mariculture. This condition if not managed properly will lead to more unsustainable fisheries management.

Interviews with local mud crab fishers indicate that the mud crab fishery in Western Seram, Maluku Province started from early 1980 with very few fishermen compared to recent years. According to the fishers, almost no fishery management has been applied to this crab fishery up to the present time. The study by Tetelepta and Makatita (2012), Tetelepta et al. (2017) at Pelita Jaya Village, Western Seram showed a sign of mud crab resource depletion. Both number and body size of mud crab harvested have decrease in the last 15-20 years. A recent study by Tetelepta et al. (2018) on *S. serrata* revealed that the overall sustainability of this species was 46.92% of 100% sustainable scale and was considered as less sustainable according to the Ecosystem Approach to Fisheries Management (EAFM) (Pitcher et al., 2013).

The core element in managing the fisheries is human behavior, meaning social and economic understanding are important considerations apart from the bio-ecology aspect of the resources. Incorporating the socio-economic aspect to the ecological aspect in fisheries management is important to understand the complexity of the fisheries system (Barclay et al., 2017; Sobocinski et al., 2017). Support for the implementation of EAFM has long been compelled through a range of global declarations and policy instruments, however, progress in the implementation of this approach at national and regional levels has been slow, partly due to fisheries managers lacking the relevant skills and experience to apply such an integrated and holistic approach (FAO, 2008; Staples et al., 2014; Voyer et al., 2017).

An ecosystem approach requires more parameters to be put into the system and most often there are fewer data available apart from imprecise parameter estimation and this produces noisy data which will later lead to an unsuitable model (Plaganyi, 2007; Staples et al., 2014; Voyer et al., 2017). Since its inception, EAFM has been evolving globally, and in the late 2000s, Indonesia adopted EAFM to guide national and regional fishery planning. For ground-level implementation, however, it will be within the remit of Fisheries Management Council (FMC) and the respective provinces to lead the way in EAFM planning and implementation in their regions. According for the Ministry of Marine Affairs and Fisheries (MMAF) Republic of Indonesia to achieve this, considerable capacity-building support will be necessary (MMAF et al., 2018). Maluku, in particular, is still in an infancy stage and still evolving, regardless of its complexity.

For the local mud crab fisher, the sustainability of the mud crab is important, however, information available for sustainable management of *S. serrata* in Western Seram, Maluku Province is considered very limited. The human system and ecosystems are linked by forming a socio-ecological system in which the social and biophysical interact on multiple spatial and temporal scales (Díaz et al., 2018). Fisheries management in the ecosystem approach should incorporate this relationship. The quantitative model for this relationship is scarce and difficult to model (Dambacher et al., 2009; Sobocinski et al., 2017; Barclay et al., 2017). Qualitative modeling, also known as loop analysis may be used when quantitative data is lacking, as it requires only the signs of interactions between model variables i.e., positive, negative or zero (Harvey et al., 2016; Sobocinski et al., 2017). This technique uses feedback to investigate the impacts of perturbation on system stability and produce predictions of change in ecological, socio-economic, and institutional aspects of systems. The qualitative modeling, therefore, can be useful to aid the development of a framework for EAFM (Smith et al., 2014; Barclay et al., 2017; Sobocinski et al., 2017; Rosellon-Druker et al., 2019).

An essential step of the integrated ecosystem assessment framework is the development of conceptual models. These models allow the integration of intrinsically linked social, environmental, and biological components of marine ecosystems that is pivotal to address unsolved questions in fisheries management (Rosellon-Druker et al., 2019). Conceptual models have become an essential tool for identifying knowledge gaps, informing research needs, and developing EAF objectives and strategies (Harvey et al., 2016, Zador et al., 2017). Conceptual models facilitate the selection of ecological and socio-economic ecosystem indicators, and they emerge as the basis for risk assessments and quantitative ecosystem models (Harvey et al., 2016, Ingram et al., 2018; Rosellon-Druker et al., 2019).

The Driver-Pressure-State-Impact-Response (DPSIR) framework has been indicated as a useful approach in analyzing problems concerning human and natural systems by the European Environment Agency because it provides a relatively simple and generic structure for linking cause-effect relationships (Martin et al., 2018). DPSIR is valuable in identifying cause-and-effect relationships between society and the ecosystem and joining scientific and place-based knowledge. DPSIR can also integrate information regarding intensities of identified relationships (Ingram et al., 2018). DPSIR framework is also seen as a useful adaptive management tool for analyzing and identifying solutions to environmental problems (Gari et al., 2015). DPSIR has found broad application in environmental assessments of terrestrial and aquatic ecosystems due to its ability to improve communication between policymakers, stakeholders, and scientists facilitating collaborative model development (Kelble et al., 2013; Zador et al., 2017; Díaz et al., 2018; Balzan et al., 2019; Mozumder et al., 2019).

The conceptual model framework developed through the DPSIR approach can be used as a tool in developing the sustainable management of mud crab fishery. With the condition and management practices on mud crab fishery in Kotania Bay and Pelita Jaya Bay, the DPSIR conceptual model framework can be a very suitable approach in addressing the conditions and problems of mud crab fishery and proposing a sustainable management strategy for mud crab fishery. The economic dependence of the local mud crab fishers from this area on the mud crab causes the mud crab fishery to become a driving force in the DPSIR conceptual model framework. Therefore, the objectives of this research are to analyze variables that contribute most to mud crab fishery sustainability and to produce a conceptual model framework for the sustainable management of mud crab *S. serrata* fishery based on EAFM principles.

2. METHODOLOGY

2.1 Study site

This study was conducted at Kotania Bay and Pelita Jaya Bay of Western Seram Regency (Figure 1) from April to August 2019. These areas have unique and comparative characteristics in terms of ecology and economy. The three most important tropical ecosystems, namely mangrove, seagrass bed, and coral reef, are found in this area with mangrove ecosystem being the dominant one. Mangrove forest in the coastal waters of these areas mainly consists of *Rhizophora* spp. and *Sonneratia* spp. with the predominant substrates being fine sand, mud, and crushed shell (Siahainenia et al., 2016).

2.2 Data collection

Data for ecological, socio-economy, and institutional conceptual framework for sustainable management of the mud crab *S. serrata* was obtained through in-depth interviews with local mud crab fishermen from the study site. Interview topics focused on ecological, socio-economy, and institutional dimensions for sustainability analysis following Pitcher et al. (2013). A questionnaire with 35 closed questions concerning variables corresponding to each domain was also distributed to 30 local mud crab fisher to obtain their perceptions about the particular variables. The local fishermen's ages ranged from 28-53 years old with an average of 38 years. Their experience on mud crab fishery varied but was on average above 15 years.

All the data collected were then tabulated and pooled for leverage analysis. A focus group discussion (FGD) with 10 mud crab fishermen was also conducted during the research to obtain their perception about the condition of mud crab fishery and other socio-economic issues.

2.3 Data analysis

Leverage analysis from the Rapfish method (Pitcher and Preikshot, 2001; Kavanagh and Pitcher, 2004) was used to determine the most sensitive variables that contribute to mud crab sustainability. To simplify the interaction and connectivity among variables in the conceptual model framework, only two variables from each dimension with high sensitivity

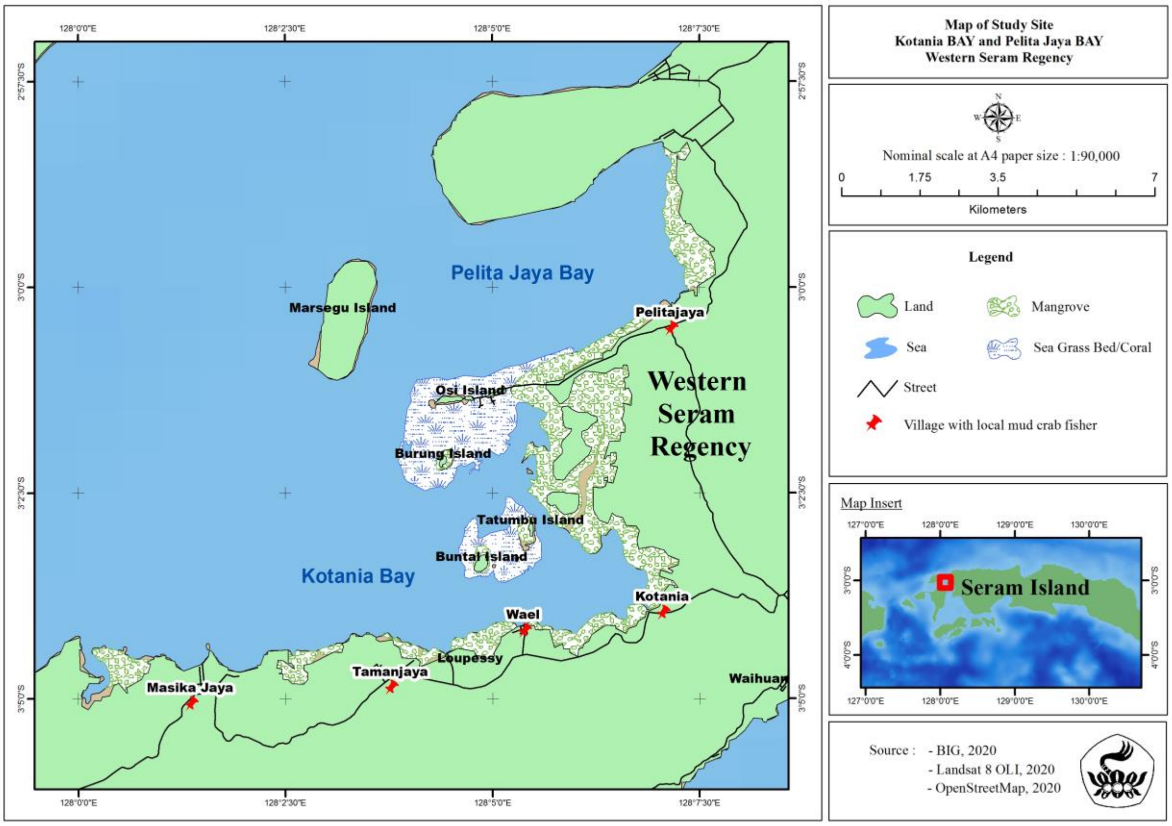

Figure 1. Map of Kotania and Pelita Jaya Bay showing study site

were used to construct the model. Two variables with the highest Root Mean Square (RMS) values from ecology, social-economy, and institutional dimension were then used as State variables of DPSIR to construct a conceptual model framework for the management instruments (Díaz et al., 2018; Balzan et al., 2019). Driving forces (D) can be a physical, chemical, or biological factor that causes a change in the system which in this study is the mud crab fishery. Pressure (P) which cascades from D in this study is the fishing gear, a traditional mud crab pot called *bubu* that affects the integrity of the system (ecology, socio-economic, and institutional). State (S) is the existing condition of the component of an ecosystem which results from the P. In this study the S is the most sensitive attribute affect the sustainability of mud crab. The impact (I) component is the condition of the organism and/or the system trigger by the pressure and can be in the form of population decline, a decrease of economy revenue, social conflict, etc (Kell and Luckhurst, 2018; Mozumder et al., 2019; Balzan et al., 2019). The response (R) component is the attempt conducted by the community in the form of a program or strategy to overcome the impact and it can be at the level of D, P, or S.

Cause-effect diagrams were developed and broken down into the different elements within the DPSIR framework. Each element was studied in detail, based on the finding and deep search in the literature, including every cause or factors that interacted with the element (Zador et al., 2017; Elliott et al., 2017; Mozumder et al., 2019). Identification according to the DPSIR framework was done to establish at which level of the framework the elements were found (driving forces, pressures, states, or impacts). Every management action associated with mud crab fishery was identified and broken down into different parts, introducing them in the conceptual framework and connecting as responses to the driving forces, pressures, states, or impacts (Zador et al., 2017; Elliott et al., 2017).

3. RESULTS AND DISCUSSION

3.1 Sensitive atribute

Sustainability analysis of mud crab *S. Serrata* of the ecology, social-economy, and institutional dimension incorporates 34 variables that form the system of this fishery. All variables interact with one another and have an impact on the sustainability of this fishery with different degrees of sensitivity. Table 1 shows all variables from the three dimensions analyzed with its sensitivity level measured by the RMS. This table shows the two most sensitive variables from the ecology dimension was 'catch before maturity' and 'mud crab size.' The study by Tetelepta and Makatita (2012) shows that the majority (70-80%) of the female mud crab harvested was in their reproductive status with different gonad maturity index. The average carapace width of mud crab harvested in 2012 was 14.79 cm and declined to 13.68 cm in 2018, the average weight also decreased from 575.52 g in 2012 to 477.72 g in 2018 (Tetelepta and Makatita, 2012; Tetelepta et al., 2019).

Table 1. Variables of each dimension with its sensitivity value, RMS (Root Mean Square)

Ecology	RMS	Socio-Economy	RMS	Institutional	RMS
Catch before maturity	4.80	Consumer attitude towards sustainability	3.86	Government quality	3.78
Mud crab size	3.80	Just management	3.33	Monitoring and reporting	3.64
Discard	3.72	Change in fishing practices	2.19	Management plan	3.08
By catch	3.40	Equity of fishing benefit	1.93	Protection	2.99
Change in size	2.30	Other source of income	0.89	Village by law	2.48
Migratory range	2.25	Strength of social network	0.88	Legality	2.37
Sex ratio	2.23	Marketing system	0.84	Regulation	2.16
Exploiation status	1.50	Subsides	0.83	Regulation implemented	1.98
Vulneralbility index	0.66	Local environment knowledge	0.56		
Range of collapse	0.45	Commoditization	0.39		
Species change	0.37	Socialization in fishing	0.38		
		Benefit transfer	0.19		
		Change in fishing benefit	0.16		
		Equity of economic benefit	0.12		
		Poverty index	0.12		

Leverage analysis for sensitivity variable of socio-economy dimension shows that of 15 attributes of this dimension, 2 attributes, 'consumer attitude towards sustainability' and 'just management,' were the most sensitive attribute towards mud crab sustainability (Table 1). This study shows that consumers, mud crab fishers, and local trade collectors have not considered sustainable fisheries principles whatsoever. Mud crab of small sizes and berried females trapped inside the mud crab pot were taken and sold to local mud crab collectors.

EAFM emphasizes the need for effective participation of all stakeholders in the management system. Objectives and targets in the management system should be agreed upon by all stakeholders (Pitcher et al., 2009; Staples et al., 2014; Fortnam, 2019). This study reveals that there was favoritism in the fishery where mud crab fishers having a close relationship with the chief of the village and/or government personnel will more likely get support compared to other fishermen. This condition could produce a conflict in the fishery which will lead to unsustainable management. A study on EAFM in the small-scale fishery in Indonesia reveals the need to increase co-management substantially among all stakeholders for better EAFM management (Courtney et al., 2017).

From eight attributes analyzed, the two most sensitive attributes from institutional dimensions were government quality and monitoring and reporting (Table 1). Government quality assesses the overall quality or capacity enabling conditions for legal, regulated, reported, and protected fisheries as indicated by the government. Monitoring is connected to reporting which assesses accurate, transparent reporting of fisheries activity and extraction of fish to government board either at local, regional, or national levels (Pitcher et al., 2009; Pitcher et al., 2013; Angel et al., 2019). The fish resources management system is comprehensive and inclusive, based on reliable data and knowledge and uses for the adaptive management approach (Pitcher et al., 2009). This study shows that government quality is very poor and no data is collected on monitoring and reporting for this fishery.

3.2 Ecological DPSIR framework for mud crab fishery

Fishing activities and gear types affect the marine environment and target species in many different ways. This study shows that the two most sensitive attributes towards the ecological sustainability of mud crab arise from mud crab pot use were catch before maturity and mud crab size (Table 1). Approximately 68.42% of female mud crabs caught were in their reproductive status with various levels of gonad maturity index. The study of Tetelepta et al. (2017) at Pelita Jaya shows that the majority (53.20%) of mud crabs caught ranged between 12-14 cm carapace widths. Furthermore, Tetelepta et al. (2019) in their study at Kotania Bay showed the same result with an average carapace width of mud crabs caught of 13.68 cm, a size prohibited by the Ministry of Marine and Fisheries Affairs of the Republic of Indonesia directive Nr. 1/2015 and Nr. 56/2016.

In practice, three processes link a stock at a given time to the stock at a future date: recruitment, growth, and mortality. These processes are interconnected to one another and not isolated (Diekert, 2012). The fish stock even in a manageable state can also be depleted. Ample evidence has shown that global fisheries and natural resources are depleting much faster than those that can replenish themselves (Froese, 2004; Thorpe et al., 2019; Pauly and Zeller, 2017; Gough et al., 2020). This depleting process is called overfishing and usually consists of two components: (i) diminishing the ability of fish to reproduce, called recruitment overfishing; and (ii) catching them before they can fully realize their growth potential, called growth overfishing (Froese, 2004; Diekert, 2012; Ordines et al., 2019). Some variables related to overfishing either growth overfishing or recruitment overfishing are high fishing mortality, low spawning stock, and environmental variability. The exact causes and mechanisms of recruitment collapse are poorly known, although often a combination of those three variables is indicated and ecological interactions are suspected (Pauly, 1994; Froese, 2004; Diekert, 2012).

This study has revealed that the two most sensitive variables contributing to the ecological sustainability of mud crab are catch before maturity and catch size which refers to body size. The ecological conceptual model (Figure 2) shows the DPSIR, a causal loop diagram, describing the existing condition of mud crab fishery at the study site and management actions that should be taken for sustainable management of this fishery. An example of management action taken at different levels of this system are fattening and grow out of small mud crab size caught (Aquino, 2018; Khoa and Harrison, 2019), mud crab bank (Thiammueang et al., 2012; Chap et al., 2012; Jöhl, 2013), and harvest control rules (HCR) (Kvamsdal et al., 2016; PEW, 2016). In HCR, the manager (government) can impose either input control on gear use, size harvested, season, etc. or output control on the number and size of resources taken (Tetelepta et al., 2018; Grubert et al., 2019). Crab fattening and grow out has the potential to be developed because it only requires small capital, short cultivation time, and simple technology (Karim et al., 2017). A study by Natan (2014) on this species has shown an increase in biomass from average biomass of 100-325 g/individual to 499-523.3 g/individual within 4 months grow out.

3.3 Social-economy DPSIR framework for mud crab fishery

There are 15 socio-economy attributes used in the analysis of mud crab sustainability. This socio-economy attribute can foster or inhibit the biological sustainability of mud crab. From leverage analysis, it was found that the two most sensitive attributes (attribute with the highest RMS) which affect the socio-economy sustainability of mud crab are consumer attitude towards sustainable management and just management (Table 1).

Consumer attitude towards sustainability assesses how a social attitude of consumers has an impact through a demand on what the fishing community delivers to the market and can foster sustainability (Pitcher et al., 2013). The attitude can be in the form of sustainable fishing practices, eco-labels, provenance information, sustainable sources of fish for restaurants, and fishery improvement plan. All of these attributes are not considered by the consumer in the study area and outside. Studies in Europe and South Korea showed a positive relationship between consumer attitude towards fishery products with certified eco-labels (Zander and Feucht, 2018; Yi, 2019). The mud crab fishers, mud crab brokers, and local consumers in the study site, for example, do not consider sustainable fisheries management principles. The second most sensitive attribute, just management, assess the inclusion of fishermen in the management

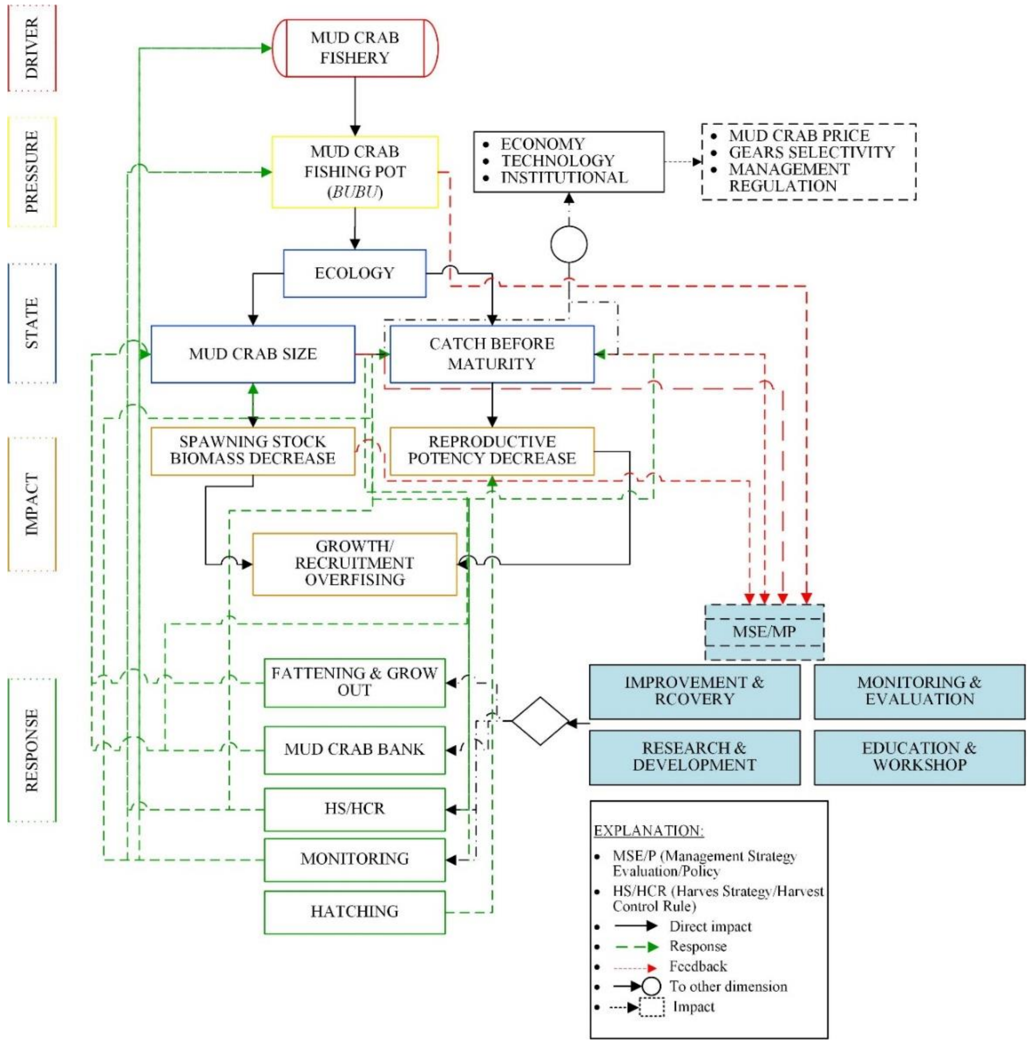

Figure 2. Ecological conceptual model framework for sustainable mud crab fishery management

and governance of the fishery. No inclusion of fishers in the management will lead to a bad impact on sustainability, while co-management with all parties having equal roles will have a good impact on sustainability (Rapfish Group, 2006; Pitcher et al., 2013).

With this kind of consumer attitude, the economic dependency of mud crab fishers on the mud crab, and continuous demand for this resource will lead to a high fishing intensity, and if not managed properly will lead to an overfishing situation. The fishery of mud crab in this area started in early 1980 and is still practiced up to the present time. Interviews with local fishers in FGD revealed that almost no fishery management is exercised towards this fishery. Production numbers and the individual size of mud crabs harvested have been decreasing recently (Tetelepta et al., 2019).

Fisheries co-management is defined as a relationship between a resource-user group (local fishers) and another entity (e.g., government agency or non-government organization) in which management responsibilities and authority are shared (Quimby and Levine, 2018; Tilley et al., 2019; Waithaka et al., 2020). This management concept has been considered as a good management approach in ensuring sustainable fisheries. With the involvement of local governance in Timor Leste, for example, the *tara bandu*, an indigenous knowledge co-management, has shown a positive impact on small-scale fisheries management (Tilley et al., 2019). Co-management in fisheries resources in the Naivasha Lake in Kenya has shown a positive impact on sustainable fisheries (Waithaka et al., 2020). Indigenous knowledge in fisheries management termed *sasi* in Maluku, Indonesia, has been considered as useful co-management (Warawarin et al., 2017; Persada et al., 2018; Soselisa, 2019). This co-management approach is not practiced in this site but could be an optional strategy management for this fishery.

In terms of just management, there should be an equal sharing of responsibility among stakeholders. There was some inclusion of fishers in the management but more on technical support and it went only to some fishers having a relation to the chief of the village. On one occasion there was a conflict between mud crab fishers from two different villages towards mud crab fishing ground. This poor quality of just management in the long term will affect mud crab sustainability. Figure 3 shows a socio-economy conceptual model framework describing the current situation of mud crab fishery and a series of management strategy which should be taken at a different level of the system to respond to the situation in this fishery which will lead to sustainable management.

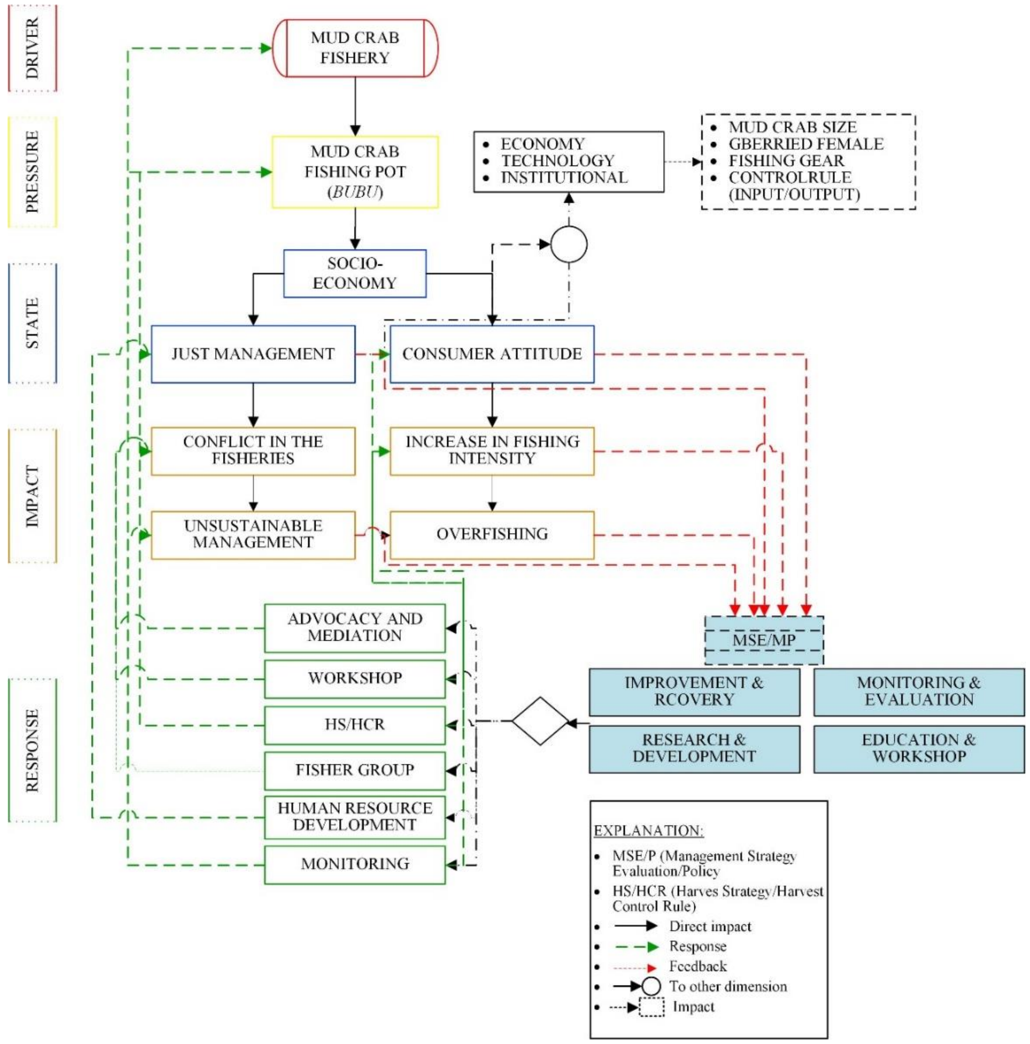

Figure 3. Socio-economy conceptual model framework for sustainable mud crab fishery management

3.4 Institutional DPSIR framework for mud crab fishery

In theory, sustainability should include social, cultural, institutional, and ethical dimensions of fisheries, but frequently the scope of sustainability in fisheries is limited to a small set of biological and economic considerations (Stephenson et al. 2018; Foley et al., 2018; Angel et al., 2019). The institutional field in sustainability analysis encompasses both governance (quality and legality) and management (regulation, reporting, monitoring, and protection) of fisheries. It focuses on organizational practices, established and enforced by formal rules of behavior, and their efficacy, as governed by both legal and cultural systems of accepted codes of conduct or norms (Pitcher et al., 2013; Stephenson et al., 2018). Fisheries Department of Queensland (DAF), for example, has been undertaking monitoring on fisheries for almost 30 years covering data on catch, size, effort, age, socio-economy indicators, legality (compliance), and used the data for the fisheries management plan (DAF, 2017). Marine Stewardship

Council (MSC) also develop monitoring and evaluation program to measure the achievement of MSC objectives through the assessment of results, effectiveness, improved processes, and performance within both MSC certified entities and the environments in which they operate (MSC, 2019).

Eleven attributes were used in the institutional sustainability analysis of mud crab *S. serrata* fishery. From these 11 attributes, the two most sensitive attributes towards mud crab sustainability are government quality and reporting and monitoring (Table 1). Monitoring assesses accurate, transparent reporting of fishing activities and fish extracted to national authority or local. This report then will be used in evaluation for the basis of the fisheries management plan. This study shows that there is no such monitoring and reporting taken in this fishery as a basis for the management plan. This will result in poor data situations which will lead to mismanagement and overfishing in the long run.

In sustainable fishery, management uses the best scientific evidence as a basis for management regulation. The regulation includes EAFM, multispecies attempts, precautionary approach, an ecosystem approach to management, monitoring and assessment, and adapting to change (Pitcher et al., 2013; Angel et al., 2019; Fortnam, 2019). In relation to EBFM/EAFM, the government of Indonesia already agrees to implement EAFM and there are also two specific regulations issued concerning the management of mud crab *Scylla* spp., but in the field, this is not the case. This study shows that none of these are implemented at the study site, hence will lead to unsustainable management. Figure 4 describes the conceptual model framework of the institutional domain of mud crab fisheries and series of responses which should be taken at a different level in this system in order to achieve sustainable mud crab fishery at the study site.

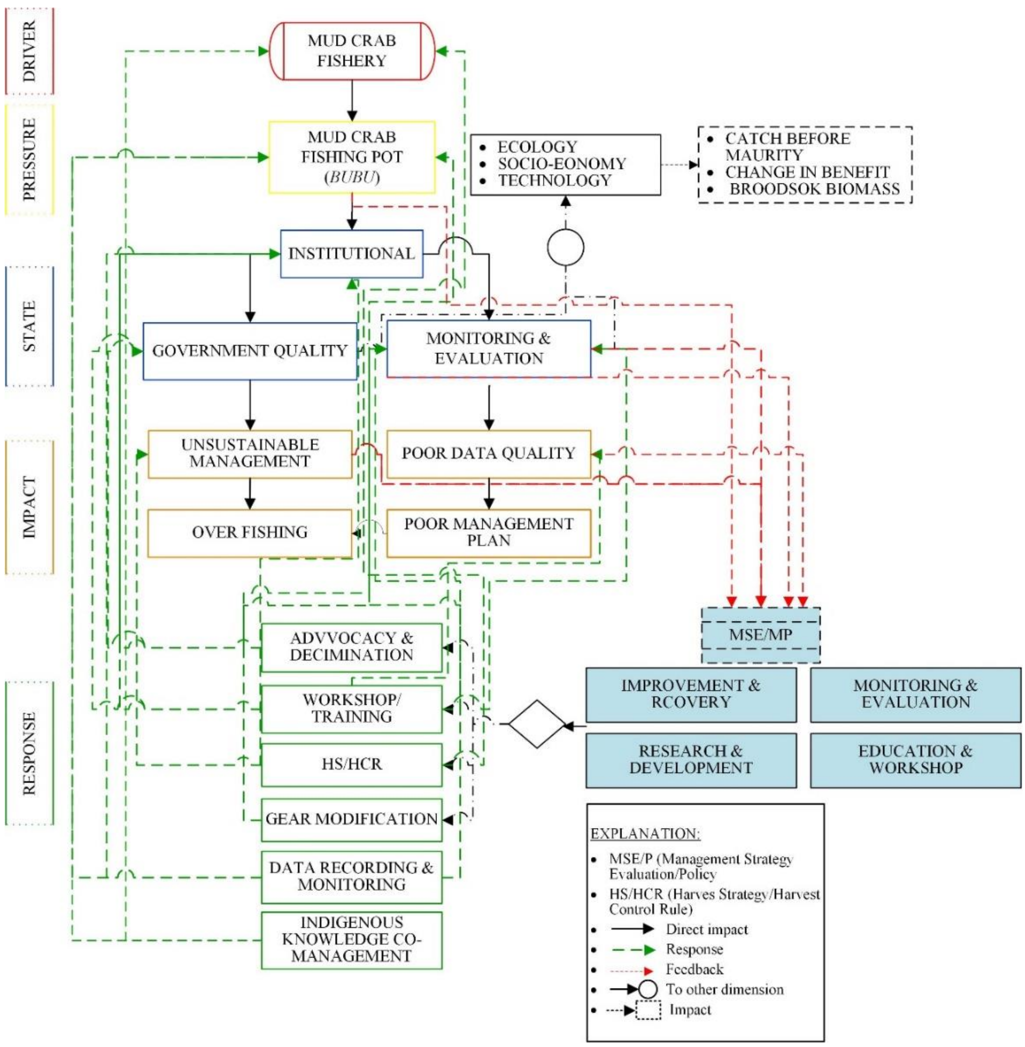

Figure 4. Institutional conceptual model framework for mud crab fishery management

The DPSIR is based on the idea that anthropogenic activities will impact the environment adversely and are considered as "Driving Forces" and "Impacts". Under DPSIR, environmental problems and solutions are simplified into variables that stress the cause-effect relationships between human activities that exert pressures on the environment, the condition of the environment and society's response to the condition. The DPSIR approach has been used in many different fields like an assessment of climate change (Salehi and Zebardast, 2016; Mozumder et al., 2019), the sustainability of fish in fisheries (Gebremedhin et al., 2018), environmental impacts will then drive humans to control the pressures. It introduces two new concepts: human welfare and environmental quality and societal behavior and economic pressures affecting the environment, incorporating assessing spatial-temporal differences of water quality, coastal management, marine protected area, and fisheries management (Patrício et al., 2016; Liu et al., 2019).

Conceptual models do not quantify restoration outcomes. This conceptual model framework summarizes the current understanding of how the ecosystem works, so they can assist in qualitative predictions and provide a key foundation for the development of benefits metrics, monitoring plans, and performance measures (Salehi and Zebardast, 2016; Elliott et al., 2017; Díaz et al., 2018). The conceptual model framework resulting from the DPSIR approach developed in this study was proposed as a first step to define the condition of the mud crab fishery of the study site, enabling the use of further and more accurate tools for the sustainable management of this fishery.

Information on mud crab fishery in Pelita Jaya and Kotania Bay for sustainable management is very scarce. The conceptual model framework combined with the DPSIR approach help to understand how the mud crab system works and its status. These three domains of the conceptual model framework in this study describe a series of responses that should be taken for sustainable management of mud crab *S. serrata* of Kotania Bay and Pelita Jaya Bay. Small size mud crab harvested could be improved through grow-out inside a fence to achieve more economical price and the berried female could be grown-out (Natan, 2014) as well to a mature stage and then transferred to a high salinity area to hatch. Harvest strategy through HCR can be imposed to manage the appropriate number of fishing units operated (input control) or amount of mud crab which could be taken (output control) for this fishery (Kvamsdal et al., 2016; Tetelepta et al., 2017).

In the ecosystem approach to fisheries management, these three domains do not stand separately, but they are connected as a system. Mud crab size at the ecological domain, for example, have a relation to the socio-economy domain in term of mud crab price, to the institutional domain in term of regulation, to technology domain in term of gear effect and gear modification and so forth. When management strategies have been taken according to responses shown by the conceptual model framework, monitoring, reporting, and evaluation should be followed afterward. The result of the evaluation will become a basis for new management strategies. Henceforth, the conceptual model framework will be changed or become adaptive management and this is a continuous process.

4. CONCLUSION

The DPSIR configuration of variables is a flexible framework that can be adapted to the necessities of specific programs to identify the different actors and processes affecting the system and in this case the mud crab *S. serrata* fishery at the study site. This conceptual model allows a better understanding of how the mud crab *S. serrata* system works and management actions taken at different system components (e.g., age at first maturity, spawning biomass, fishing intensity, etc.). Its structure can be used to select indicators as is being done in the implementation of, for example, Marine and Fishery Affairs of Republic Indonesia Directive on the mud crab fisheries management. Furthermore, it can be a very effective tool to incorporate the participation of stakeholders, managers, and scientists in the process of establishing a sustainable management plan.

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