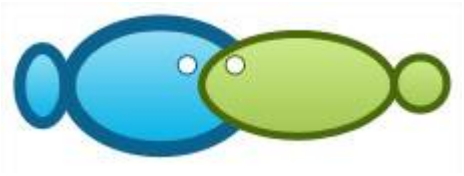

Mud crab fisheries management model to improve welfare of fishers: a study on outermost small island, Enggano

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Abstract. Fisheries management is conducted to attain sustainable productivity of aquatic resources, with a focus on enhancing the welfare of fishermen. The welfare of fishermen is influenced by a multitude of variables and indicators, constituting a complex interplay. Therefore, this study is significant in formulating a model for mud crab fisheries management, particularly in augmenting the welfare of fishermen residing in remote island regions. This model integrated variables, incorporating both ordinal and interval data, to include factors with direct and indirect impacts on welfare dynamics. Enggano Island is situated in Bengkulu Province, Indonesia, and classified as one of the outlying small islands. A sample of 42 respondents, constituting 84% of the total population, was used in this study. The analytical framework employed for data interpretation was structural equation modeling - partial least squares (SEM-PLS), including 21 latent and 70 observable variables. The welfare of mud crab fishermen was enhanced by improving food security and reducing poverty. Therefore, a comprehensive mud crab fisheries management model was implemented to improve the welfare of fishermen on the small outermost island, consisting of 14 latent variables and 21 indicators with a coefficient of 86.6%.
Key Words: EAFM, Enggano Island, fisheries management, mud crab, SEM PLS, welfare of fisher.

Introduction. Fisheries management is conducted to attain the sustainable productivity of the resources. An important facet pertains to the regulation of diminutive-scale fisheries, where fishing activities are shaped by social and institutional determinants (Apine et al 2019). Furthermore, the subsistence and food security of households engaged in fishing are intricately interwoven with the prosperity of diminutive-scale fisheries (Hanich et al 2018; Halim et al 2019; Dahlia et al 2022). The augmentation of diminutive-scale fishing operations stands as a central tenet within the ambit of management strategies aimed at enhancing operational efficiency (Sanon et al 2021).

Fisheries management can be conducted by building public awareness. Increasing this awareness can minimize the negative impacts of the resources exploitation (Hartono et al 2019). In addition, the awareness increases economic and social benefits (Marshall et al 2018) and also opens opportunities for adaptive capacity, institutional, knowledge, and technology (Jara et al 2020).

Fisheries management is related to the perception and participation of fishermen. Good perception positively impacts the environment (Henríquez-Antipa & Cárcamo 2019) and becomes a reference for stakeholders to make fisheries management policies more appropriate (De Keyzer et al 2020). Perception is influenced by participation (Cahyadinata et al 2019b), which is a manifestation of community involvement in maintaining their livelihoods (Kaewploy et al 2018).

Social and economic characteristics, education, and multidimensional poverty determine the participation of fishermen in fisheries management. Furthermore, the main characteristics of coastal communities are determined by the social and economic

conditions of the household (Lloret et al 2018). Multidimensional education and poverty further elaborate social and economic characteristics, including household expenditure (Masthalina et al 2021).

Sustainable fisheries management aims to improve the welfare of fishermen. Welfare is influenced by the efficiency of the business described by income level (Sukono et al 2021). The involvement in managing resources can be hindered by poverty (Miller et al 2020). Alternative livelihoods for fishermen can reduce dependence on fisheries resources and improve food security and welfare (Stacey et al 2019).

Many variables and indicators influence the welfare of fishermen and the study of welfare has been limited to the use of variables, constituting interval (Botha 2020) or ordinal data (Cahyadinata et al 2019a; Budiarti et al 2021). There have been no studies examining factors affecting welfare by using ordinal and interval data. Existing studies also discussed factors that directly affect the welfare of fishermen (Nguyen 2022). However, no studies examined the influence of variables directly and indirectly. Fisheries management models to improve welfare using complex variables and indicators are also minimal.

Studies using complex indicators and variables can be carried out through the structural equation model-partial least square (SEM-PLS) model. The current SEM-PLS model is widely used for non-fisheries analyses, including non-mud crab fisheries. Studies using SEM have been conducted for agriculture (Adiprasetyo et al 2019; Raza et al 2019; Yang et al 2019), health (Duff 2019), banking (George 2018), biology (Hassneen et al 2019), public transport policy (Ingvardson & Nielsen 2019), mining (Kursunoglu & Onder 2019), waters (Sun et al 2020), communication (Makiabadi et al 2019), gender (Seddig & Lomazzi 2019), forestry (Setiawan et al 2018) and education (Yi & Kim 2019).

This study is important to create a comprehensive model for the management of mud crab fisheries with complex variables. The resulting model uses the SEM-PLS approach with ordinal and interval data for variables that directly or indirectly affect welfare.

Material and Method

Study site. This study was conducted on Enggano Island, Bengkulu Province, one of the outermost small islands in May-September 2022. It is located between 102.05° to 102.25° (E) and 5.17° to 5.31° (S) (Statistics of North Bengkulu Regency 2022).

Data collection. The data in this study consisted of primary and secondary data. Secondary data were obtained from the available literature (from sources/agencies/ related institutions), while primary data were obtained directly in the field through interviews with questionnaires.

Sampling. The study method was descriptive with case studies and it examined the status of a group of human beings or objects to make a systematic, factual and accurate description of a specific or distinctive phase (Nazir 2014). The population of mud crab fishermen on Enggano Island was 50 respondents and a sample of 42 fishermen, constituting 84% of the total population, was used. The sampling method used was the census, in which eight fishermen were not selected as samples.

Data analysis. Data processing used SEM-PLS (Abdillah & Jogiyanto 2015) and the model used 21 latent and 70 measurable variables (Table 1).

Determination of the best model was conducted using validity and reliability tests. Convergent validity consists of 3 parameters, namely the loading factor, average variance extracted (AVE), and communality, with values > 0.5. The validity of the discriminant is indicated by the root value AVE > variable correlation. The reliability of the model is indicated by the value of composite reliability > 0.7.

Test significance between variables used a t-test (comparison value of t-count and t-table) at the level of trust 95%. A variable significantly affects others when t-count > t-table. For example, the model is evaluated using Q square predictive relevance (Q^2), with equation (Abdillah & Jogiyanto 2015):

$$Q^2 = 1 - (1 - R_1^2)(1 - R_2^2) \ldots (1 - R_i^2) \quad \ldots\ldots (1)$$

where: R_1^2, R_2^2…… R_i^2 is the R square variable, Q2 is interpreted as the value of the coefficient of total determination (R^2 total). R^2 total 0.19, R^2 total 0.33, R^2 total 0.67, R^2 total > 0.7 are categorized as weak, moderate, substantial, and strong, respectively.

Table 1

Study variables

Latent variables		*Measured variables*	
Constructs	*Dimension*	*Indicators*	*Code*
Perception	-	Perception of mud crabs	I
		Perceptions of the mangrove ecosystem	F
Participation	-	Participation in mud crab management	D
		Participation in the management of the mangrove ecosystem	G
Characteristics of fishermen	-	Number of dependents	R
		Age	E
		Fisherman's experience	K
		Formal education	H
		Length of domicile in Enggano	O
		Enggano exit frequency	J
Poverty	-	Status of household poverty	Y
Status of EAFM	Fisheries resources	CPUE (catch per unit effort)	V1
		Fish size trend	V2
		Proportion of yuwana (juvenile) fish caught	V3
		Species composition of the catch	V4
		Range collapse of fisheries resource	V5
		ETP species (endangered threatened protected)	V6
	Habitat and ecosystem	Water quality	Q1
		Mangrove ecosystem status	Q2
		Unique/special habitat	Q3
		Climate change to water and habitat conditions	Q4
	Fishing model	Destructive fishing	T1
		Modifications of fishing gear	T2
		Fisheries capacity and fishing efforts	T3
		Selectivity of fishing gear	T4
		The legality of suitability of the function and size of fishing gear	T5
	Economics	Asset ownership	P1
		Household income	P2
		Savings ratio	P3
	Social	Stakeholder participation	U1
		Fisheries conflicts	U2
		Use of local knowledge	U3
	Institutional	Compliance with fisheries principles	Z1
		Completeness of the rules of the game in fisheries management	Z2
		Decision-making mechanism	Z3
		Fisheries management plan	Z4
		Level of policy and institutional synergy	Z5
		Stakeholder capacity	Z6
Business efficiency	-	Income as a fisherman	S1
		Capital	S2
		Frequency of going to sea	S3
		Distance of the house to the scene of an arrest	S4

Multidimensional poverty	Education	Family members have completed junior high school	W1
		At least one child dropped out of school before grade 9	W2
	Health	At least one family member is malnourished	O1
		One or more children died	O2
	Standard of living	Electricity	C1
		Access to clean drinking water	C2
		Access to sanitation	C3
		Cooking fuel from charcoal, coal, firewood fuel	C4
		House with a dirt floor	C5
		Motor vehicle	C6
Food security	-	Food security status	N
	Food availability	Food supply	L1
		Food shortages	L2
		Fear of food shortages	L3
	Food access	Food production	M1
		Location difficulties	M2
		Purchase price	M3
	Food use	Low weight	B1
		Toddler dies of illness	B2
		Sources of drinking water	B3
		Sources of the cooking water	B4
Welfare	-	Education of the head of the family	A1
		The proportion of working household members	A2
		Walls of the house	A3
		Floor area	A4
		Access to sanitation	A5
		Main lighting	A6
		Ownership of goods	A7

Results. The variability consisting of 21 latent and 70 measurable variables produced a mud crab fisheries management model of 14 latent and 21 measurable variables stated to have convergent validity and reliability (Table 2). Based on the t-test, nine relationships between latent variables had a significant effect unlike the other five (Table 3).

Table 2

Convergent validity test and reliability test

No	*Latent variables*	*Indicators*	*Factor loading*	*AVE*	*Communality*	*Composite reliability*
1	Welfare	A1	0.628	0.555	0.555	0.709
		A2	0.845	0.555	0.555	0.709
2	Food security	N	1.000	-	1.000	-
3	Food availability	L2	0.946	0.917	0.917	0.957
		L3	0.969	0.917	0.917	0.957
4	Food access	M2	0.737	0.694	0.694	0.818
		M3	0.920	0.694	0.694	0.818
5	Education	W1	1.000	1.000	1.000	1.000
6	Status of EAFM	-	-	0.502	0.502	0.795
7	Fishing model	T1	0.666	0.576	0.576	0.728
		T3	0.842	0.576	0.576	0.728
8	Institutional	Z2	0.890	0.819	0.819	0.901
		Z3	0.921	0.819	0.819	0.901
9	Efficiency	S1	1.000	1.000	1.000	1.000

10	Poverty	Y	1.000	-	1.000	-
11	Perception	F	0.911	0.808	0.808	0.894
		I	0.887	0.808	0.808	0.894
12	Participation	D	0.907	0.730	0.730	0.843
		G	0.798	0.730	0.730	0.843
13	Characteristics	K	0.662	0.575	0.575	0.801
	of fishermen	O	0.791	0.575	0.575	0.801
		R	0.813	0.575	0.575	0.801
14	Multidimensional poverty	-	1.000	-	1.000	-

Table 3

t-test between latent variables

No	*Influence between variables*	*t-test*
1	Characteristics of fishermen → Perception	4.343*
2	Perception → Participation	5.150*
3	Participation → Poverty	1.799
4	Participation → Status_EAFM	2.546*
5	Status_EAFM → Fishing model	25.911*
6	Status_EAFM → Institutional	83.716*
7	Status_EAFM → Efficiency	0.697
8	Efficiency → Food security	0.654
9	Food access → Food security	3.155*
10	Food availability → Food security	14.807*
11	Poverty → Multidimensional Poverty	1.134
12	Multidimensional poverty → Education	1.000
13	Food security → Welfare	2.625*
14	Multidimensional poverty → Welfare	3.751*

*: significant at the level of trust 95% (α = 5% and t table = 2.020).

The model coefficient of determination (R^2 total) was 86.6% and variables with direct effect on welfare were poverty and food security. The variables with indirect influences were fishermen characteristics, perceptions, ecological approach for fisheries management (EAFM) status, multidimensional poverty, education, participation, and efficiency (Figure 1).

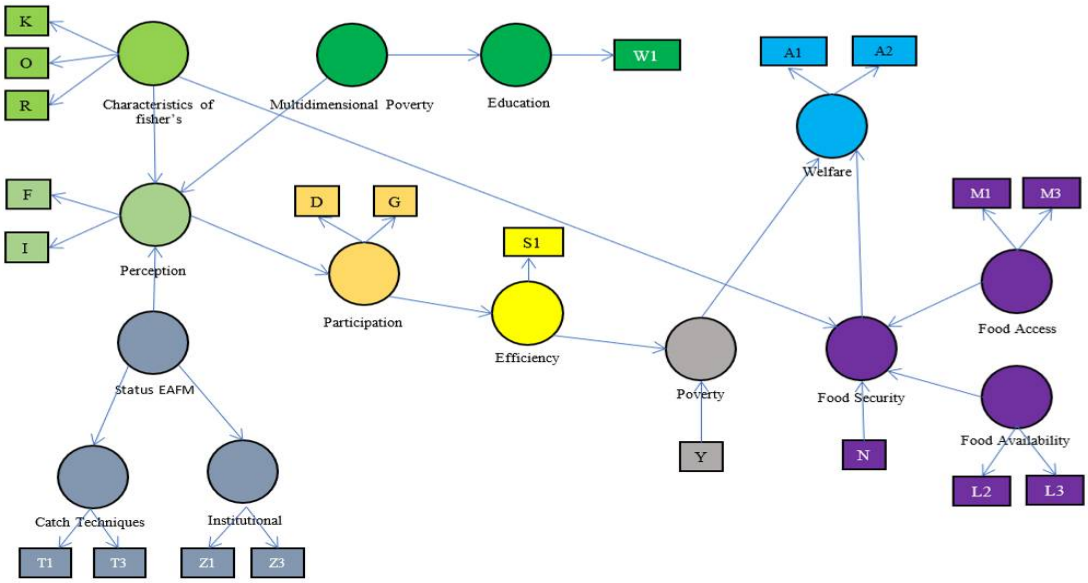

Figure 1. Model of mud crab fisheries management on the outermost small island.

Discussion. The influence of food access, food availability, and the attribute of fishermen exhibited a favorable correlation with security. The persuit of augmenting the accessibility and availability of sustenance is consistent with the objectives of the sustainable development goals (SDGs) program (FAO 2017). Enhanced accessibility and greater availability of food constituents, coupled with favorable attributes characterizing fishermen, collectively contribute to an amplified level of household food security. The constructive attributes of fishermen also have a positive impact on perceptual acuity. Consequently, an enhancement in attributes can potentially elevate their perceptions of mud crabs and mangrove ecosystems. This elevated perception holds the potential to increase the efficacy of fisheries management to be relatively good (Ditya et al 2022).

Food security has a real positive and direct effect on welfare. Sustainable and diverse food security contributes to minimizing the impact of activities on the environment (Stevens et al 2018). The perception and the participation of fishermen in managing mud crabs and mangrove ecosystems are directly related. A good mangrove ecosystem is also an excellent place to live for mud crabs (Putri et al 2022). Participation is indirectly influenced by the characteristics of fishermen, such as age, education, and household wealth (Rahman et al 2020).

Institutional fishing model of fisheries management is directly proportional to the status or application of EAFM. The EAFM model raises awareness of the importance of maintaining the biodiversity of ecosystems (Kenny et al 2018; Escalle et al 2019). Furthermore, multidimensional poverty has a significant positive effect on perception; the lower the multidimensional poverty, the better the perception of mud crabs and mangrove ecosystems.

Business efficiency has a negative impact on poverty and efficiency can be improved by optimizing the use of fishery resources (Sujan et al 2021). An inverse relationship exists between the efficiency of mud crab fishing enterprises and the incidence of household poverty. The reduction on poverty leads to a subsequent elevation in the welfare of households engaged in mud crab fishing.

The characteristics of fishermen consist of the number of household dependents (R), length of domicile in Enggano (O), and experience working as a fisherman (K). The dependents of fishermen in a family are between 0 to 6 people, with an average of 3. The length of fishermen domicile in Enggano ranges from 2 to 50 years, with an average of 20 years. The range of experience is 1 to 25 years with an average of 11 years.

Perception of fishermen entails mud crabs (I) and mangrove ecosystems (F) in the good category. Furthermore, the perception of excellent, good, enough and bad is 2%, 60%, 31%, and 7% respectively. The mangrove ecosystem shows a level of quality, including an outstanding component comprising 50% and a favorable component constituting an additional 50%. Good perception increases participation in maintaining mangrove ecosystems (Febrianessa et al 2020).

The educational dimension reflects multidimensional poverty by the number of family members who have completed junior high school. For every family, 64.28% of fishing household members still have a primary school education. A total of 35.72% (15 of 42 respondents) graduate from junior high school or above.

Fisheries management status (EAFM) consists of two latent variables, namely the fishing engineering and the institutional domain. Fishing model is reflected by destructive fishing (T1), fisheries capacity and fishing efforts (T3). Destructive fishing is seen by using tools or methods that are toxic or not consistent with applicable regulations. For example, bubu fishing gear used by fishermen produces mud crabs of various sizes, including those with a carapace width of less than 15 cm or weighing less than 200 grams. A total of 4.76%, 2.38% and 92.86% of respondents committed violations in more than 10 cases, 5-10 cases and less than 5 cases, respectively. Every bubu, catch per unit effort (CPUE) is about 12.5 kg per year and the maximum capture capacity is 15 kg per year. The ratio of catch and capacity was 83.33% and a total of 71.4% had a ratio smaller than one, where 23.8% was equal to one, and 4.8% with a ratio of more than one.

The institutional domain consists of two indicators, namely the completeness of the rules of the game in fisheries management (Z2) and the decision-making mechanism (Z3). There are no rules of the game in the management of mud crab fisheries, except for the ministerial regulation on banning the capture of mud crabs, which has not been implemented. According to 95.2% of respondents, there were no complete rules of the game, and 4.8% stated that the current ministerial regulations were quite adequate as the completeness of the game rules. There was no regulation regarding the mechanisms for deciding fisheries management, such as standard operating procedures (SOP), no recording and sanctions for violations. According to 73.8% of respondents, there was no decision-making mechanism, and 26.2% stated that there was a mechanism for collecting traders to provide low prices for crabs with small sizes.

Fishermen participation is reflected in mud crab (D) and mangrove ecosystem management (G). The variables are classified as a high category (where very high, high, and enough is 17%, 74% and 9% respectively). Similarly, the engagement of fishermen is categorized as extensive, with 67% falling within the classification of very high, and the remaining 33% categorized as high.

The efficiency of crab fishing efforts carried out by fishermen is included in the efficient category. The business efficiency of mud crab fishermen in Enggano Island indicated by a revenue-cost ratio (RC ratio) is 3.08 (Cahyadinata et al 2020). A total of 88.1% of fishing businesses are in the efficient category, while 11.9% are inefficient, with an R/C value of less than one. Business efficiency is influenced by income as a fisherman (S1). The average income of respondents from catching mud crabs is Rp 1 380 952 per month. The categories of income are low (less than IDR 1 000 000 per month), medium (IDR 1 000 000 to Rp 2 000 000 per month) and high (more than IDR 2 000 000 per month), which percentages are 30.95%, 57.14%, and is 11.9% respectively (Cahyadinata et al 2020).

Fishermen poverty is calculated based on per capita income. The per capita income of members of fishing households ranges from Rp 120 000 to Rp 2 166 667 with an average of Rp 716 553 per month. Based on this value, the household poverty status (Y) is classified as poor for 31% and not poor for 69%.

Food security of fishing households is classified as resistant at 19%, moderately resistant at 74%, and less resistant at 7% (Cahyadinata et al 2019c). Food availability is reflected by shortage (L2) indicators and fear of shortage (L3). Meanwhile, 73.8% of fishermen experienced food shortages, unlike 26.2%. A total of 83.3% of fishermen feel frightened or worried about food shortages, and only 16.7% do not worry about food shortages. It means that 9.5% of fishermen have not experienced food shortages in the past but have concerns about future food shortages.

Food access is reflected by indicators of difficulty reaching the location (M2) and price of purchase (M3). The foodstuffs in Enggano are mostly produced or imported from Bengkulu City and sold at many stalls. A total of 81.0% of respondents stated the location to buy food was easy, while 19.0% reported the purchase location was difficult to reach. Although the purchase location is accessible, 45.2% and 54.8% stated the price is relatively expensive and quite affordable respectively.

The welfare of fishing households is classified as moderate welfare (where high, moderate and low welfare is 36%, 62%, and 2% respectively). Indicators of welfare are the level of education of the head of the household (A1) and the proportion of working household members (A2). The average level of education for the head of the family is grade 8 of the first level advanced school with the category of high, junior high, and elementary school at 28.57%, 23.81% and 40.48% respectively as well as not finishing elementary school 7.14%. The average number of working household members in a family is 1 to 3, with an average of one person. The proportion is 2.38%, 0.5 to 0.99 is 21.43%, 0.25 to 0.49 is 66.67%, and less than 0.25 is 9.52%.

The efficiency of determination of 86.6% means that the indicator explains the latent variable by the percentage. Therefore, only 13.4% were not included in the mud

crab fisheries management model to improve the welfare of fishermen on the small outermost island.

Conclusions. A comprehensive mud crab fisheries management model was implemented to enhance the welfare of mud crab fishermen on Enggano Island, given its status as a small outermost island. The resulting model using SEM-PLS, consisting of 14 latent variables and 21 indicators, was a valid and reliable model with a coefficient of 86.6%.

Variables that directly affected welfare were poverty and food security. Indirect influences were fishermen characteristics, perceptions, EAFM status, multidimensional poverty, education, participation, and efficiency. Food security was enhanced by improving food access, availability, and fishermen characteristics. The welfare of mud crab fishermen on the small outermost island was also improved by increasing food security and reducing poverty.

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Conflict of interest. The authors declare that there is no conflict of interest.

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