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Influence of environmental parameters on the shrimp catch in Banyuasin Coastal Water, South Sumatra, Indonesia

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Abstract. Shrimps are species with short life cycle and particularly sensitive to environmental conditions since both marine and coastal habitat. However, changes in some environmental parameters were thought to be the most important which can affect the shrimp catch. This research aimed to determine the environmental parameters that most influence the shrimp catch in the Banyuasin Coastal Waters. Sampling for shrimp catch was conducted at 11 stations in Banyuasin Coastal Water used a trammel net. In situ environmental parameters such as water temperature, salinity, pH, current velocity, chlorophyll-a concentration, depth, substrate types, phosphates and nitrates concentrations were recorded during each sampling time. The influence of environmental parameters on the shrimp relative-abundance was analyzed by stepwise multiple regression and the significance level adopted was $p < 0.05$. The analysis results indicated that approximately 64.5% of the variation in the relative abundance of shrimp was explained by pH and substrate types. There were a strong correlation between the relative abundance of shrimp and in situ environmental parameters ($0.50 <$ adjusted $R^2 = 0.645 \leq 0.75$), particularly pH and substrate types. The shrimp relative-abundance was positively correlated with pH, but negatively with substrate types. Thus, pH and the substrate types were determinant factors to the shrimp relative-abundance in the study area.

1. Introduction

Banyuasin coastal waters are strongly influenced by the condition of the Musi River inflow. Sediment, carbon, nutrients and organic matter carried by the freshwater inflow have a major influence on bathymetry and primary productivity of coastal water. Changes in environmental conditions are suspected to affect the species abundance in the Banyuasin Coastal Waters. As one type of species that has a short life cycle, the shrimp abundance is often influenced by environmental factors even simultaneously increasing fishing effort and degradation of environmental factors have an impact on increasing their vulnerability [1].

The existence of the Musi River estuary on the Banyuasin coastalwas suspected to have a significant impact on shrimp habitat.As one of the largest rivers in South Sumatra Province, the communities have a very high dependence on the river. This can be seen from the variety of activities found along river, such as: settlements, industries and transportation [2]. This condition has the potential to reduce water quality and affect the ecosystem balance as well as affect the shrimp growth.

Some previous studies reported that several pollutant components had accumulated on the substrate and several fish that caught in the area [2, 3]. Estuaries are very important habitats for shrimp because

they serve as "nurseries" for juveniles, when growth rate has the greatest effect on overall mortality [4]. Paneaeid shrimp are particularly sensitive to environmental conditions since both marine and coastal habitat are exploted at different points in their life-hostory. Their distribution are thought to be influenced by various environmental conditions. Knowledge of the tolerance ranges and responses of estuarine fauna valuable to sport and commercial fishermen thus becomes increasingly important to advisors, decisionmakers, and scientists [5].

Some researchers have investigated the relationship between shrimp abundance and enveronmental variastion, particularly the sediment type, salinity, depth, organic matter content, dissolved oxygen, pH and temperature [5, 6, 7], the model to simulate environmental effect on brown shrimp production [8], relationships between the fluctuation of the environmental parameter (the NAO index) and red shrimp landings [9], relationships between catch per unit effort and environmental variables on the white shrimp fishery [10], and the influence of oceanographic factors such as physics, chemistry and biology of the existence of penaeid shrimp [11].

The study of the relationship between shrimp catches and environmental parameters has never been done in the Banyuasin coastal waters. Therefore, this research was needed to find out how the effect of variations in environmental conditions on shrimp catches. This research aimed to determine the environmental parameters that most influence the shrimp catch in the Banyuasin Coastal Waters. The study results are expected to be useful to determine the fishing ground andfishery management.

2. Materials and Methods
This research was conducted for 11 trip in September 2017 in the Banyuasin Coastal Water, South Sumatra, Indonesia (Fig. 1). Determining the sampling location was carried out in accordance with the fishing ground of shrimps (outside the estuary).
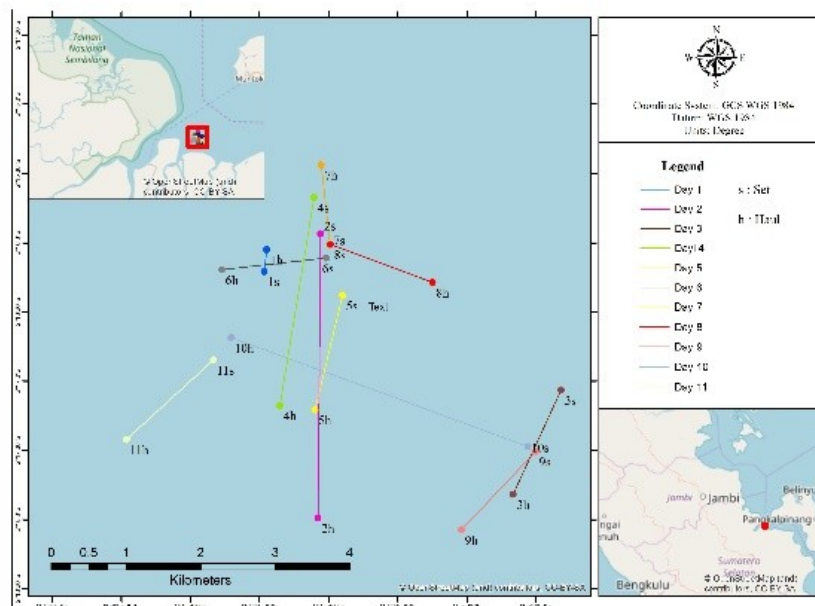
Figure 1. The map of sampling location in Banyuasin Coastal Water, South Sumatra, Indonesia.

The data needed included: shrimps catches and environmental variables at the sampling locations. The samples were analyzed in the Marine Laboratory, Faculty of Mathematics and Natural Sciences, UNSRI. The subtrate types were classified according to a triangular diagram (clay- silt-sand). The backscattering strength of substrate types from the smallest to the largest values were: 1) clay, 2) silty clay, 3) silt, 4) clayey sand, and 5) sand [12, 13, 14]. The values sequence were used as input data for a multiple regression analysis.

This research was conducted using experimental fishing methods. The sampling locations (11 stations) were determined purposively based on the fishing ground where fishermen usually fishing using trammel net. Environmental variables were measured and recorded at each operation of trammel net, included; temperature, salinity, pH, current velocity, chlorophyll-a, depth, type of substrate, phosphate, and nitrate. The trammel net catches were separated and weighed based on the main catches (shrimp), by-catches and the discard catch. The shrimp catch percentage also known as relative abundance (RA$_s$), was calculated using the following formula [15, 16, 17]:

$$RA_s = \frac{W_s}{W_c} \; x \; 100$$

Where: W_s = the weight of shrimp catch per trip

W_c = the total weight of trammelnet catch.

Correlation analysis (Pearson correlation) between the environmental variables and the shrimp relative-abundance (RA$_s$) were carried out at the initial stage then continued with stepwise multiple regression analysis to determine the most influential environmental variables [18]. The method was used to analyze the relationship between the dependent variable and two or more independent variables [19]. While the stepwise method was used to solve regression problems whose independent variables are correlated each others [20].

In this research, the response variable (dependent variable) was the RA$_s$ (Y) while temperature (X1), salinity (X2), pH (X3), current velocity (X4), chlorophyll-a concentration (X5), Depth (X6), substrate type (X7), phosphates concentrations (X8), and nitrates concentrations (X9) were predictor variables (independent variables). Statistical analysis were preformed with SPSS software package and a significant level of 0.05 was accepted.

3. Result

3.1. The shrimp relative abundance and environmental parameters

Table 1 presented the relative abundance of shrimp (RA$_s$) and environmental variables at 11 observation stations. The RA$_s$ value varied from 35.66% to 78.67% with an average value of 57.32%. The highest RA$_s$ was station 4 (78.67%) where the water temperature conditions of 29.98^{0}C, salinity of 30.00 ‰, pH of 8.34, current velocity of 0.16 m/sec, chlorophyll-a content of 3.80 mg/m^3, water depth of 6 meters, type substrate of silty clay, phosphate content of 0.020 mg/liter and nitrate content of 4.112 mg/liter. Conversely, the lowest RA$_s$ was station 8 (35.66%). At the station, the water temperature, salinity, pH, current velocity, chlorophyll-a content, waters depth, substrate types, phosphate and nitrates content were 30.13^{0}C, 30.00‰, 8.11, 0.05 m/sec, 6.92 mg/m^3, 7 meters, silty clay, 0.037 mg/liter and 2.888 mg/liter, respectively.

Table 1. The data of shrimp relative abundance and environmental variables at each station.

Station	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7 [*]	X_8	X_9
1	42.53	30.90	25.50	8.00	0.10	3.31	6	4	0.031	2.888
2	66.54	29.65	30.00	8.16	0.10	3.82	4	4	0.032	2.351
3	62.57	29.62	31.00	8.34	0.15	6.11	4	4	0.043	2.644
4	78.67	29.98	30.00	8.34	0.16	3.80	6	2	0.020	4.112
5	72.69	31.12	25.17	8.08	0.17	4.90	7	2	0.026	5.110
6	35.90	30.43	24.83	7.79	0.06	3.18	8,2	4	0.034	2.752
7	51.27	30.48	27.50	8.00	0.03	5.57	8,3	4	0.047	2.349
8	35.66	30.13	30.00	8.11	0.05	6.92	7	4	0.037	2.888
9	63.46	29.68	26.00	8.11	0.07	4.92	5,5	2	0.032	3.781
10	55.72	29.87	27.17	8.07	0.18	3.67	4	2	0.022	4.561
11	65.46	30.45	23.50	8.07	0.14	4.85	6	2	0.029	3.563
Rerata	57.32	30.21	27.33	8.10	0.11	4.64	6	2	0.032	3.364

Note: [*] 1 = clay   2 = silty clay   3 = silt   4 = clayey sand   5 = sand
Y = shrimp relative abundance (%) X_5 = chlorophyll-a concentration (mg/m^3)
X_1 = temperature (ºC) X_6 = depth (m)

X_2 = salinity (‰) X_7 = substrate type
X_3 = pH X_8 = phosphates concentrations (mg/liter)
X_4 = current velocity (m/s) X_9 = nitrates concentrations (mg/liter)

In addition, the waters environmental conditions at 11 stations also varied. Surface water temperature ranged from 29.62^0C - 31.12^0C, salinity ranged from 24.83 ‰ - 31.00 ‰, pH ranged from 7.79 - 8.34, current velocity ranged from 0.03 m/sec - 0.18 m/sec, chlorophyll-a content ranged from 3.18 mg m^3 - 6.92 mg/m^3, water depth ranged from 4 m - 8.3 m, substrate types ranged from silty clay to clayey sand, phosphates content ranged from 0.020 mg/liter - 0.047 mg/liter, and nitrates content ranged from 2,349 mg/liter - 5,11 mg/liter.

3.2. Correlation between variables

Table 2 presented the correlation between the RA_s and environmental parameters using Pearson's Correlation. The value of Pearson's Correlation between the RA_s (Y) and the environment variable (X_i) from the largest value to the smallest were pH (X_3 = 0.676), substrate type (X_7 = 0.654), current velocity (X_4 = 0.647), nitrate (X_9 = 0.509), phosphate (X_8 = -0.436), depth (X_6 = -0.425), temperature (X_1 = -0.202), salinity (X_2 = 0.135) and chlorophyll-a (X_5 = 0.076). The '-' mark on the variable value only indicated the direction of the opposite relationships. These results indicated that only the variables of pH, substrate and current velocity have a strong correlation (the value of pearson's correlation > 0.5) at a significant level of 5%.

Table 2. Pearson correlation coefficients between the shrimp relative abundances and environmental parameters.

	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
Y	1	-0.202	0.135	0.676*	0.647*	-0.076	-0.425	-0.654*	-0.436	0.509
X_1		1	-0.642*	-0.524*	-0.056	-0.149	0.654*	-0.018	-0.066	0.236
X_2			1	0.707*	0.032	0.378	-0.407	0.361	0.222	-0.322
X_3				1	0.515	0.337	-0.613*	-0.235	-0.131	0.156
X_4					1	-0.241	-0.611*	-0.616*	-0.670*	0.690*
X_5						1	0.104	0.170	0.599*	-0.170
X_6							1	0.184	0.274	-0.107
X_7								1	0.731*	-0.887
X_8									1	-0.759*
X_9										1

Note: * : Correlation significance (2-tailed) $p < 0.05$.
Y = shrimp relative abundance (%) X_5 = chlorophyll-a concentration (mg/m^3)
X_1 = temperature (°C) X_6 = depth (m)
X_2 = salinity (‰) X_7 = substrate types
X_3 = pH X_8 = phosphates concentrations (mg/liter)
X_4 = current velocity (m/s) X_9 = nitrates concentrationsmg/liter

In addition, there was a strong interrelationship between some environmental variables (occurred multicollinearity), such as: between currents velocity, depth, substrate types phosphate and nitrates as well as between depth, pH and temperature. This indicated that the relationship between the RA_s and the all environmental variables did not pass the classical assumption test for multiple regression due to the multicollinearity problem. Furthermore, a stepwise multiple regression analysis was needed to solve the problem.

3.3. Filtering environmental variables using stepwise method

In the stepwise method, the environmental variables (independent variables) were used in the regression model if α ≤ 0.05, otherwise the variables were excluded from the model if α ≤ 0.1. The

value of α was the probability value of the partial correlation test between the dependent variable and the independent variables. Filtering results of the environmental variables used the stepwise method was presented in Table 3. Based on the results, only 2 variables were used in the regression model, namely pH (X_3) and substrate (X_7). The following equation expressed this relationship:

$$Y = -341.845 + 52.083X_3 - 7.263X_7$$

where: Y = shrimp relative abundances; X_3 = pH; X_7 = subtrate types.

Table 3. Filtering results of the environmental variables used stepwise method

Model	b_i	Adjusted R^2	F-test		t-test	
			F	Sig.	t	Sig.
Regression (X_3,X_7)		0.645	10.103	0.006*		
a (constant)	-341.845				-2.280	0.052
X_3 (pH)	52.083				2.854	0.021*
X_7 (substrates)	-7.263				-2.706	0.027*

* : significant at 5%

The model indicated that the pH parameter had a positive influence to the RA, meaning that increasing the pH value in the waters (up to the tolerance limit for shrimp growth) will result in an increase in the RA_s value (the shrimp catches percentage used trammel net). Conversely, the substrate type had a negative effect to the RA_s, meaning that the smaller of the substrate fraction (the closer to the clay tipe) will result in an increase of the RA_s value.

The multiple coefficient of determination (adjusted R^2) was 0.645 (64.5%). This means that 64.5% of the RA_s can be explained by the pH and the substrate type variable while the remaining 35.5% is explained by other factors not examined in this study. R^2 describes the variance proportion of the measured data described by the model and usually the model can be accepted if R^2 is greater than 0.5 [21, 22]. Based on the R^2 value obtained ($0.50 < R^2 = 0.645 \leq 0.75$), indicated that there was a strong relationship between the RA with pH and substrate type [20]. The F value was 10.103 with a significance level of 0.006 (p value < 0.05) indicated that the pH and substrate types simultaneously had a significant effect on the RA_s. Based on the t-test results, it showed that the pH variable partially had a positive effect (b_3 = 52,083) and was significant to the RA_s (p value = 0.021 < 0.05). On the other hand, the substrate type partially had a negative effect (b_7 = -7,263) and was significant to the RA_s (p value = 0,027 < 0,05).

The result of multiple regression model using stepwise method must be tested using classical assumptions of multiple regression, included: normality, autocorrelation, multicollinearity, and heteroscedasticity test (Table 4). The results showed that the multiple regression results used the stepwise method (Table 3) were appropriate the classical assumption of multiple regression.

Table 4. The results of the classical assumption test for multiple regression between the shrimp relative abundances (Y) with pH (X_3) and substrate types (X_7)

The classical assumption	Method	Result	Conclusion
Normality Test	Skewness (S) and kurtosis (K) ratio. The value was between -2 to 2	S value = -0.7056 K value = 0.642 -2 < S=-0.701 < 2 -2 < K=0.642 < 2	Normal
Autocorrelation Test	du < DW < 4-du	DW= 2.22 DL = 0.82 DU = 1.32 1.32<DW=2.22<2.68	No autocorrelation

| Multicollinearity Test | VIF < 10 | VIF of pH = 1.07 VIF of subtrates = 1.06 Both VIF value < 10 | No multicollinearity |
| Heteroscedasticity Test | Glejser test: sig. > 0.05 | Sig. of pH = 0,952 Sig. of Subtrates = 0.53 Both sig. value > 0.05 | No heteroscedasticity |

4. Discussion

Shrimp have a short life cycle and are often influenced by environmental factors [1] even very sensitive to environmental conditions since being in coastal and marine [5]. The existence of estuaries and mangrove in the Banyuasin Coastal Waters certainly have an impact on changes in environmental parameters. Rivers, near shore habitats and straits have more variable water conditions, stronger currents and higher predation [24]. The existence of mangrove can affect environmental conditions, the content of chlorophyll-a relatively higher, stable pH, and DO relatively better [25].

The data of shrimp catches percentage (the relative abundance of shrimp) and environmental parameters in this study varied at each observation station. In the stepwise multiple regression analysis (Adjusted R^2 = 0,645; p < 0,05), approximately 64,5% of the variation in the shrimp relative abundance was explained by two predictor variables (pH and subtrate types). The shrimp relative abundance was positively correlated with pH, but negatively with subtrate types. In this study, variations in pH values from 7.79 to 8.34 were still in the optimal conditions range for shrimp growth. The optimal pH range that supports the penaeid shrimp growth ranges from pH 7.8 to 8.1 [9]. Waters which has a pH of more than 9 or less than 4.5 becomes unsuitable for most life forms and also for most other uses [28].

Substrate variations in this study ranged from the silty clay to the clayey sand were thought to be suitable for the shrimp growth. The substrate types had a negative correlation indicated that the closer to the type of clay substrate, the relative abundance of shrimp increased. This results in line with the resutllt study in the Hiwasa River, southern central Japan that substrate coarseness affects the decapod distribution [27]. Several species of shrimp in the Western Gulf of Carpentaria of Australia (*P. semisulcatus, M. ensis and S. australiana*) were more abundant in mud sediments, while othersspecies (*P. esculentus and M. endeavouri*) were more abundant in sand sediments. [28]. Shrimp preferes shallow muddy zones as a place to feeding and shelter, while deeper zones ware preferred for reproductive areas [29]. The main factors that influence the spatial and temporal abundance of shrimp on the southeastern Brazilian coastal were sediment texture (phi) and bottom temperature [30], while the high abundance of the shrimp (*Pleoticus muelleri*) was related to a sediments with a higher percentage of silt and clay [31].

Water temperature range from 29.62^0C-31.12^0C in the sampling locasion was possibility to be tolerated by shrimp. Penaeid shrimp had a temperature tolerance between $10\ ^o$C – $49\ ^o$C, but rarely found in waters with temperatures above $36\ ^o$C [9]. The salinity range from 24.83 ‰ - 31.00 ‰ was also possibility to describe the optimum conditions for shrimp. A good growth rate for Penaeid shrimp was in the salinity range of 5 ‰- 35 ‰ [32]. Penaeid shrimp tend to be euryhaline, so the water conditions with a salinity range of 14.40 - 30.10 ppt are still suitable for shrimp life [33] but there is an optimum salinity limit for Penaeid shrimp which supports the presence of Penaeid shrimp in the waters [11].

Nitrates content ranged from 0.020 mg/liter - 0.047 mg/liter. Based on KEPMEN-LH No. 51 Tahun 2004 for marine biotas, the nitrates content have exceeded the water quality standards for marine biota which was equal to 0.008 mg/L. Nitrate is one type of macro nutrients that play a role in the process of phytoplankton growth [34]. Phytoplankton abundance did not affect the shrimp catches due to Penaeid shrimp feeds on various types of food both detritus and other organic material residues. In addition, the nitrates content had a very low correlation to the presence of macrozoobenthos [35].

Phosphates content ranged from 2.349 mg/liter – 5.11 mg liter (> 0.015) also had exceeded the water quality standards for marine biota. The Phosphates content had a very low correlation to the

presence of macrozoobenthos [35]. While Phosphate plays a role in the development process of phytoplankton and was an essential element for plants, so this element becomes a limiting factor for water productivity [34].

In shallow rivers in South East Côte d'Ivoire, spatial variation of shrimp diversity and abundance were strongly influenced by several environmental variables such as water conductivity, dissolved oxygen, temperature, percentage of mud, and pH [7]. Determinant factors in the distribution of shrimp (*Pleoticus muelleri*) in southeastern Brazil were temperature and the type of sediment [35]. The shrimp abundance (*Macrobrachium felicinum)*in the lower Taylor Creek, Niger Delta, Nigeria was positively correlated with water level and total hardness, but negatively with pH and dissolved oxygen [36].

The white shrimp prefer in intermediate depths and temperatures [10]. The lower limit of depth for red shrimp at least to depth of 800 m [9]. The rate of freshwater discharge from river water into the marine ecosystem significantly influences the total catch of shrimp [37].

In this study, although water pH and substrate type offer a most influence to the shrimp relative abundance, it is important to realize that other factors can also affect the shrimp relative abundance. In addition, various biotic and abiotic parameters such as seabed characteristics, food availability, tidal and sea-level patterns, community composition, prey-predator relationships, interactions among species, and the reproductive strategies of their component species can also affect benthic communities [38]. The environmental and biotic factors simultaneously influence the species appearance through an adaptive process during evolution that describes the species capacity to tolerate environmental changes [30].

5. Conclusion
Based on the analysis results of the stepwise multiple regression, the model between the shrimp relative abundance (Y) with pH (X_3) and substrate type (X_7) were appropriate the classical assumption of multiple regression. Variations in the effect of pH and substrate parameters to the shrimp relative abundance had a strong correlation ($0.50 <$ adjusted $R^2 = 0.645 \leq 0.75$). Both simultaneously (F-Test) and partially (t-Test), the parameters had a significant effect to the shrimp relative abundance. The shrimp relative abundance was positively correlated with pH, but negatively with the subtrate type.

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