Indian Journal of Agricultural Economics
Volume 77, Number 4, October-December 2022

Estimation of Growth, Trend and Decomposition Analysis of Shrimp Production in West Bengal

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ABSTRACT

Growth trends and decomposition analysis of area, production and productivity of shrimp in the state of West Bengal were carried out for a period of 16 years from 2005-2006 to 2020-21 by splitting the production data into two sub-periods i.e. period I 2005-06 to 2012-13 and period II 2013-14 to 2020-21. The growth rates were calculated using exponential function while the instability in the production was worked out using coefficient of variation (CV) and Cuddy Della Valle's Instability Index (CDVI). The change in output in terms of relative contribution of area and yield was estimated by using Minhas decomposition model. During the first sub period, the compound growth rate for the area (-6.38) of shrimp culture was found to be significantly negative (p<0.05) while production (14.55 per cent) and productivity (23.12 per cent) were positively significant. Whereas during second sub period, the growth rate of shrimp production (-57.54 per cent) was negative while area (5.54 per cent) and productivity (60.05 per cent) were insignificantly positive. However, the study revealed that the overall compound growth rate of area (1.52 per cent) and production (5.94 per cent) of shrimp in West Bengal for the entire study period from 2005-06 to 2020-21 were found positively insignificant. The maximum growth in productivity was observed during the sub period II (60.05%) followed by sub period I (23.12 per cent). The instability indices i.e. CV and CDVI were found low during all the periods in the case of area. Goodness of fit under cubic model proved as best fit among the parametric models fitted to the area, production and productivity of shrimp culture in the state of West Bengal. The area effect was found to be 100.31 per cent, whereas yield and interaction effect were 1.72 per cent and (-) 0.94 per cent respectively in the study period. Finally, the analysis emphasized that the decomposition analysis and area effect played key role in making differentiation in the shrimp production of West Bengal.

Key words: Shrimp, Growth rate, Instability, Trend, Decomposition.

JEL: C87, O47, Q16, Q22

1

INTRODUCTION

Shrimp farming is nowadays considered as one of the important practices to meet the protein need of the world population. Shrimp contributes 20 per cent of the world's seafood production and 30 per cent of the world seafood trade (Bhattacharya, 2008). India is the fifth largest shrimp producing country in the world while it ranks third position in total aquaculture production (Danya and Mude, 2014). Shrimp accounts for 58 per cent of the total value of marine product exports from India and it could be attained due to considerable progress achieved in shrimp production (Bhattacharya, 2008). At present, a remarkable increase in farming of *Penaeus vannamei* replacing *Penaeus monodon* culture is noticed since the candidate species has good traits like high growth rate, short culture duration and high resistance to

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diseases (Seidman and Lawrence, 1985). Marine Products Export Development Authority (MPEDA) reported that the shrimp production in West Bengal rose to 76,534 tonnes in 2017-18 from 26,800 tonnes in 2001-02 due to increase in area under cultivation from 47,650 to 55,211 hectares. In 2020-21, the shrimp production and culture area in West Bengal mounted up to 19,190 metric tonnes and 50,000 hectares respectively (Anon, 2021). In order to improve the productivity of shrimp in India various steps have been taken which includes upgradation of technology. In India, semi-intensive scientific shrimp farming technology was introduced to enhance the productivity of shrimp farming. But traditional (improved) and extensive shrimp farming continue to dominate in the country and occupy more than 70 per cent of the area for shrimp farming. The productivity of shrimp farming in India can be enhanced either by adopting advanced scientific techniques or by increasing production efficiency. However, improvement in efficiency is more cost-effective than introduction of new technologies if the producers are not efficient (Belbase and Grabowski, 1985; Dey et al., 2000). Brackish water aquaculture especially *vannamei* shrimp farming has been increasing rapidly due to higher profit gain than traditional agriculture or fishery in the coastal areas and has played an important role in the development of socio-economic status at Contai under Purba Medinipur district of West Bengal, India (Pritiranjan et al., 2021). The Stochastic Frontier Production Function approach is adopted in this study for examining the efficiency of shrimp farming in the state of West Bengal. A review of technical efficiency analysis in shrimp culture by Sharma and Leung (2003) provides some useful insights towards the use of appropriate methodologies for efficiency analysis in aquaculture. Evidence of antibiotic resistant bacteria has also been detected in several regions in India, affecting both intensive and traditional farming systems in West Bengal (Srinivasan and Ramasamy, 2009; Priyadarsani and Abraham, 2013; Abraham and Sasmal, 2014).

In this context, the study was carried out to assess the growth, instability, trend and decomposition analysis that occurred in area, production and productivity of shrimp culture in West Bengal for the period of last 16 years from 2005-06 to 2020-21.

II

MATERIALS AND METHODS

Shrimp production data for the state of West Bengal was collected from Marine Products Export Development Authority (MPEDA), Government of India for a period of 16 years from 2005-06 to 2020-21. The collected data was divided into two sub-periods consisting of eight years per period, viz., period I (2005-06 to 2012-13) and period II (2013-14 to 2020-21). The analysis was carried out utilising the data pertaining to the area of shrimp culture in hectare (ha), production in million tonnes and productivity in million tonnes/ha/year to calculate the growth performance, instability index and degree of instability relationship between area, production and productivity in shrimp farming practice. Various statistical tools and techniques were employed in this study to analyse the above attributes.

2.1 Analytical Tools and Techniques

The data on shrimp production collected for the last 16 years from the state of West Bengal were subjected to estimate the growth rates, instability, production trend and decomposition of output growth.

Compound Growth Rate Analysis

The growth of exports for the seven major export market regions and eight major export items was analysed using the following exponential growth function

$$Y = ab^t e \quad \text{…. (1)}$$

Where 'y' is dependent variable for which growth rate is to be estimated (quantity exported and value realized), 'a' is intercept, 'b' is regression coefficient, 't' is time variable and 'e' is error term. The compound growth rate was estimated transforming the above function into logarithmic form as mentioned below:

$$\text{Log } y = \text{Log } a + t \text{ Log } b \quad \text{…. (2)}$$

Further, the per cent compound growth rate was computed using the following relationship;

$$\text{CGR} = (\text{Antilog of } b - 1) \times 100 \quad \text{…. (3)}$$

Instability Analysis

The instability variability in area, production and productivity were measured using various instability indexes like Coefficient of Variation and Cuddy Della Valle's Instability Index. The coefficient of variation or index of instability was computed by using the following method;

Coefficient of Variation (CV) = $\frac{\sigma}{\overline{X}} \times 100$, where, σ =Standard Deviation, $\overline{X}$ =Mean

The simple Coefficient of variation often contains the trend component and thus it over estimates the level of instability in time series data characterized by long term trends. For overcoming this, the instability index (II) given by Cuddy Della Valle's instability index of variation was used in this study. Cuddy Della Valle's instability (CDVI) is a close approximation of the average year to year per cent variation adjusted for trend. Its algebraic form is,

$$\text{CDVI} = C.V \times \sqrt{1-\overline{R}^2} \quad \text{….(4)}$$

Where, C.V is the simple Coefficient of Variation in percent, $\overline{R}^2$ is the coefficient of determination from time trend regression adjusted by the number of degree of freedom.

The level of instability was categorized into low (between 0 - 15), medium (15 - 30) and high (>30).

Trend Analysis

The trend in area, production and productivity of shrimp were computed for the shrimp production data series of last 16 years, i.e. 2005-06 to 2020-21. Different parametric trend models applied to trace the path of process are given in Table 1. Among the competitive trend models, the best function was selected based on their goodness of fit and significance of the coefficients. The Goodness of fit of models for the analysed data was measured in terms of R^2. If R^2 is high, the fit is considered as appropriate fit.

TABLE 1. DIFFERENT PARAMETRIC MODELS EMPLOYED

Sl.No (1)	Name of Model (2)	Mathematical Model Expression (3)
1.	Linear	$Y_t = a + bt$
2.	Quadratic	$Y_t = a + b_1 t + b_2 t^2$
3.	Cubic	$Y_t = a + b_1 t + b_2 t^2 + b_3 t^3$
4.	Exponential	$Y_t = a + Exp(bt)$
5.	Logarithmic	$\log(Y_t) = a + b\log(t)$

Where ‘a’, ‘b’ and ‘t’ represent constant, coefficient and time respectively in the above model.

Decomposition of Output Analysis

Decomposition analysis model (Minhas and Vaidyanathan, 1965; Hemant et al., 2017) was used to measure the relative contribution of area and yield to the total output of the shrimp production. In this method variables used as A_o, P_o and Y_o indicate the respective area, production and productivity or yield in base year while another set of variables A_n, P_n and Y_n indicate the respective variables in n^{th} year.

$$P_o = A_o \times Y_o \text{ and } P_n = A_n \times Y_n \qquad \text{…. (5)}$$

The variation in production, area and yield are calculated using following functions;

$P_n – P_o = \Delta P$

$A_n – A_o = \Delta A$ and

$Y_n – Y_o = \Delta Y$ …. (6)

For equation (5) and (6) we can write

$P_0 + \Delta P = (A_0 + \Delta A)(Y_0 + \Delta Y)$

Hence

$$P = \frac{A_o \Delta Y}{\Delta P} \times 100 + \frac{Y_o \Delta A}{\Delta P} \times 100 + \frac{\Delta Y \Delta A}{\Delta P} \times 100$$

Production = yield effect + area effect + interaction effect

Thus, the total change in production is decomposed into three components, viz., yield effect, area effect and the interaction effect due to change in yield and area.

III

RESULTS AND DISCUSSION

The data on area, production and productivity in shrimp farming from the state West Bengal for the period from 2005-06 to 2020-21 is presented in Figure 1. The illustration revealed that the area of shrimp culture was in decreasing trend with a flux during the period of 16 years. In the recent years, shrimp aquaculture has played a vital role by providing alternative source of income for shrimp farmers along the costal state of west Bengal and is considered as a sunrise sector for supporting economic development. The maximum decline in the area of culture was observed in the year 2008-09 and 2009-10 over the last 16 years. The maximum increasing trend was observed in the year 2018-19 followed by 2019-20 and 2017-18. In case of production, maximum increasing trend was observed in the year 2015-16 followed by 2014-15 and 2013-14. However, a huge decline in production was observed in the year 2008-09 which might be due to uncertainty in the profitability of shrimp farming due to disease outbreak (Animesh and Biswarup, 2020), shift of farming practices from Tiger shrimp to newly introduced Pacific white shrimp during the year 2009 and lack of technique know-how of the farmers about the new candidate species. Conversely, later years the production and productivity were picked up gradually in West Bengal as well as India (Maity *et al*., 2020) due to standardisation of culture technology and knowledge acquired by the farmers on improved culture techniques of grow out system.

In case of shrimp productivity, maximum increasing trend was observed in the year 2015-16 followed by 2014-15 and 2013-14 as the culture of tiger prawn was replaced with vannamei shrimp during these periods as it could be grown in low saline water through semi intensive culture methods (Anon, 2015; Maiti et al., 2019) and less prevalence of diseases during this period. Generally, the productivity is direct function of the level of technology adopted and the species farmed. However, maximum decline in the productivity as well as production were observed in the year 2020-21 though the area of culture was stable. The decline in this period might be due to non- availability of seed, feed, transport and labour in view of lock down during the pandemic Covid-19 and many farmers cultivated winter crops in 2020 (Pradhan and Dash, 2022) and as reported by Sahadevan and Sureshkumar (2020) in the state of Kerala during the same period. However, a declining trend in productivity and production cropped up from the year 2017-18 due to disease, instability in quality seed supply, price rate, increment in production cost, poor credit facilities and other socio-economic problems.

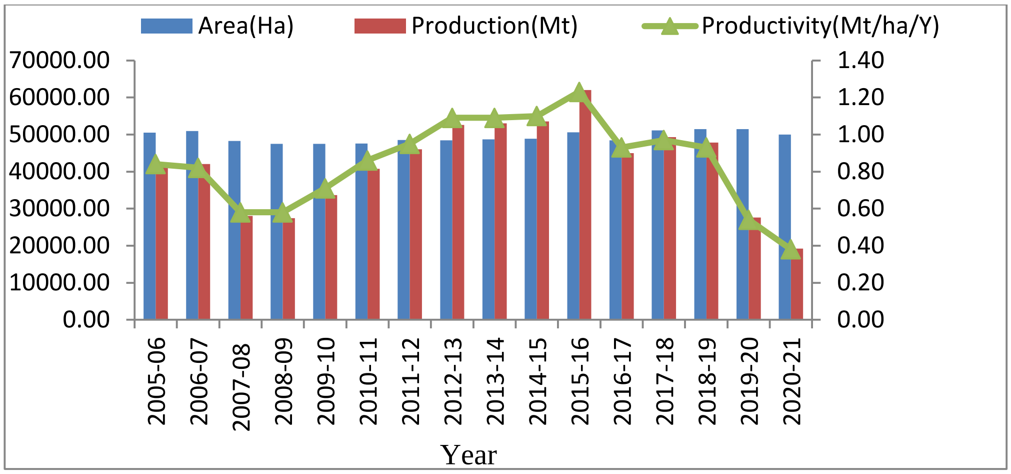

Figure 1. Area, Production and Productivity of Shrimp Production of West Bengal.

3.1 Growth Rates of Area, Production and Productivity of Shrimp in West Bengal

Period wise estimated compound growth rates of area, production and productivity are presented in Table 2. During period I, growth rate of area (-6.38 per cent) was negatively significant ($p<0.05$) while production (14.55 per cent) and productivity (23.12 per cent) showed positive growth rate. The positive growth in production and productivity might have occurred due to increase of awareness among the farmers about profitability in shrimp culture than crop farming and hence lot of agriculture lands were converted into shrimp farms during this period (Animesh and Biswarup, 2020). In Period II, growth rate of production was negatively declined (-57.54 per cent) whereas the area (5.54 per cent) and productivity (60.05 per cent) showed positive growth rate. The decrease in production during the period II might be attributed lack of personal supervision, high capital cost demand for getting seeds due to lack of SPF brood stock and feed (Pradhan and Dash, 2022; Dubey et al, 2016). In addition, lack of knowledge and experience persisted among farmers in handling and managing disease problems in shrimp farming and their predominant existence in grow-out systems (Bhaumik *et al*., 1991; Mohan and Bhatta, 2002). Even if it is known that agriculture and aquaculture are the major cause for aquatic pollution, the farmers were not ready to perceive the long-term impact of the pollution which turned later for collapse of production and source of many diseases (Ghosh *et al*., 2017).

However, positive growth in area and productivity could be observed during the period II which might be due to development of technology, awareness among the farmers of profitability of the venture and introduction of new species Pacific white shrimp *Penaeus vannamei* (Bhattacharya, 2008; 2010; Animesh *et al.*, 2019; Pallavi et al., 2021). However, in overall period, area (1.52 per cent), production (5.94 per cent) and productivity (4.55 per cent) showed positive growth rate due to improvement in technical efficiency, expansion of culture area and diversified culture of shrimp species.

TABLE 2. GROWTH RATES OF AREA, PRODUCTION AND PRODUCTIVITY FOR THE VARIOUS GROUPED AND OVERALL PERIOD FROM 2005-06 TO 2020-21

Attributes (1)	Period –I (2)	Period-II (3)	Overall Period (4)
Area	-6.38*	5.54	1.52
Production	14.55	-57.54	5.94
Productivity	23.12	60.05	4.55

* Significant at p<0.05.

3.2 Instability in area, production and productivity of shrimp in West Bengal

Estimated period wise coefficient of variation (CV) and Cuddy Della Valle Instability Index (CDVI) of area, production and productivity of shrimp in West Bengal are presented in Table 3. The CVs as well as CDVIs obtained for area were lower than production and productivity. The lower CDVIs revealed that area had lower instability while production and productivity had medium instability during period I, period II and overall period. Low instability observed in area might be due to limited and constant development of culture area in entire period of study while production and productivity encountered instability due to various environmental factors like heavy rain, temperature fluctuation and lower salinity which led to various diseases like white feces and early mortality (Srinivasan and Ramasamy, 2009; Anon, 2020). Further, medium instability might have existed in sub periods and over all period could be due to stumble in the culture practices owing to poor existence of ecological and economical sustainability in farming which made uncertainty in the minds of shrimp farmers of profitability of the culture in continuing the practice (Animesh *et al*., 2021).

TABLE 3: PERIOD WISE INSTABILITY INDICES OF AREA, PRODUCTION AND PRODUCTIVITY

	Period -I		Period-II		Overall Period	
Particulars (1)	CV (2)	CDVI (3)	CV (4)	CDVI (5)	CV (6)	CDVI (7)
Area	2.75	2.34	2.49	2.09	2.94	2.74
Production	22.46	21.64	31.89	19.3	28.16	29.10
Productivity	21.91	19.63	32.44	17.54	27.89	28.86

3.3 *Trends in Area, Production and Productivity of Shrimp in West Bengal*

The trend in area, production and productivity was appropriated for the time series data of shrimp farming of West Bengal for the period from 2005-06 to 2020-21 and are presented in Table 4. The slope of the curve was given by the value associated with year. In general, the Trend analysis provides the rate of change of particular variables during the period of reference and the direction of change but it fails to provide the rate of change per annum. Among the various parametric models fitted to the area, production and productivity under shrimp culture from West Bengal, the cubic model yielded high R^2 on all three components (Table 4). Hence, the cubic function was regarded as best fit to area, production as well as productivity in shrimp culture from West Bengal for the appraisal period. Similarly, the same parametric model could be observed in Bidyut Kumar (2010) they found the cubic model as best model in production of crops in West Bengal. The actual and predicted value of various components in shrimp production from West Bengal during 2005-06 to 2020-21 through cubic models are graphically represented in Figure 2.

TABLE 4: TRENDS IN GROWTH OF AREA, PRODUCTION AND PRODUCTIVITY OF SHRIMP CULTURE

Particulars (1)	Function (2)	Constant a (3)	Coefficients b1 (4)	b2 (5)	b3 (6)	R2 (7)
Area	Cubic	52998.38	-2201.83	273.93	-9.11	0.74
Production		51441.41	-11795.20	2235.35	-102.33	0.84
Productivity		0.98	-0.20	0.04	0.00	0.87
Area	Quadratic	50349.18	-573.31	41.54	-	0.50
Production		21692.85	6491.88	-374.17	-	0.39
Productivity		0.42	0.14	-0.01	-	0.47
Area	Linear	48230.55	132.90	-	-	0.19
Production		40775.46	131.01	-	-	0.003
Productivity		0.84	0.00	-	-	0.0004
Area	Exponential	-0.16	0.00	-	-	0.0001
Production		41890.00	-2.60	-	-	0.0001
Productivity		48970.00	0.49	-	-	0.236
Area	Logarithmic	37790.00	4925.00	-	-	0.020
Production		48740.00	744.20	-	-	0.031
Productivity		0.77	0.10	-	-	0.019

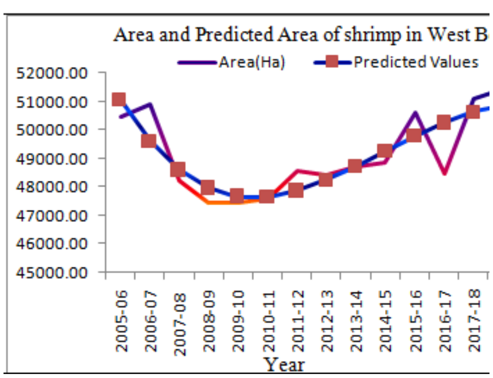

Fig.2.a. Area

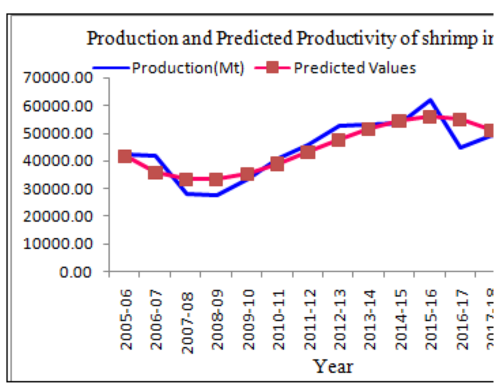

Fig.2.b.Production

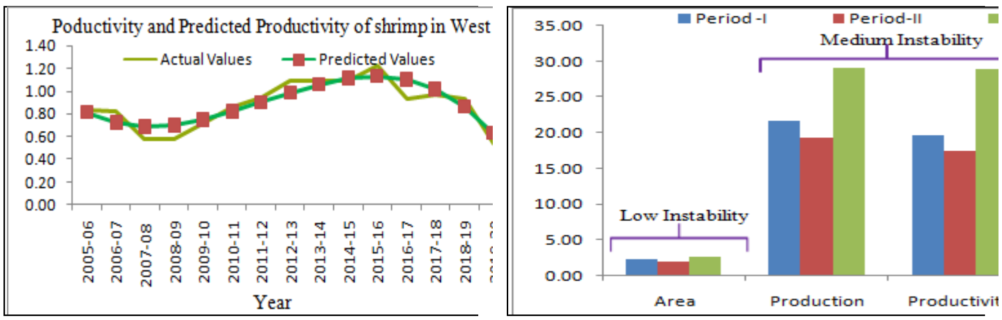

Fig.2.c. Productivity Fig.2.d. Instability for various period

Figure 2. Actual and Predicted Value of Various Components in Shrimp Production under Cubic Model from West Bengal During 2005-06 to 2020-21.

3.4 Decomposition Analysis in Shrimp production of West Bengal

Decomposition analysis included the effect of area, yield and interaction between them were estimated in percentage and are presented in Table 5.

TABLE 5: PERCENTAGE CONTRIBUTION IN THE EFFECT OF AREA, YIELD AND THEIR INTERACTION IN SHRIMP PRODUCTION OF WEST BENGAL

Attributes (1)	Period-I (2)	Period-II (3)	Overall (4)
Area Effect	123.17	102.18	100.31
Yield Effect	-16.92	-4.09	1.72
Interaction Effect	-5.04	2.66	-0.94

Area Effect

The area effect played a major role in the growth of shrimp production (100.31 per cent) under shrimp culture in West Bengal during 2005-06 to 2020-21. The area effect was positive in both sub-periods and it was high in sub-period I (123.17 per cent) followed by sub-period II (102.18 per cent). The positive area effect could be due to the expansion and conversion of agricultural lands into shrimp ponds in anticipation of huge profit than agricultural practices (Suman *et al*., 2016). As per the remote sensing data, it has been reported that aquaculture area in West Bengal has increased 2 to 3 per cent annually in the last two decades through conversion of 98 per cent of agricultural land at 821.9 hectare per year data (Das Gupta *et al*., 2019; Giri *et al*., 2021).

Productivity Effect

In growth decomposition, the productivity effect in sub-period I (-16.92 per cent) and sub-period II (- 4.09 per cent) was found to be negative (Table 5). Though the yield effect was positive in overall period i.e. 2005-06 to 2020-21, only negligible amount of 1.72 per cent was quantified for the entire period of appraisal. Ghoshal *et al*. 2019 reported that farmers were attracted to semi intensive vannamei shrimp farming due to high yield, profitability and less pathogenic infection compared to tiger shrimp which ultimately led to high productivity in overall period of study. Nevertheless, the negative productivity effect in sub-periods might be due to adverse change in weather conditions, technological changes, poor technical knowledge due to lack of training programmes, poor and sudden viral, culture practices, seed availability and fungal disease outbreak, etc., especially while culturing the tiger shrimp as described by Animesh and Biswarup (2020).

Interaction Effect

The interaction effect between area and yield together played a vital role in augmenting the production in shrimp culture in the state. The overall interaction effect influenced the shrimp production in the West Bengal heavily in negative trend by -0.94% during 2005-06 to 2020-21. Similarly, negative interaction effect was observed during the sub-period I (-5.04 per cent) despite, the positive interaction effect was observed in sub-period II (2.66 per cent). It indicated obviously that area effect alone might have influenced the interaction effect as the productive effect was negative in both the periods. Further, the increased area of culture for the last two decades, demand of shrimp products, availability of commercial feeds and Government's policies favoured the intensive shrimp culture practices in this region which in-turn augmented the yield in shrimp farming (Philcox et al., 2010; Giri et al., 2022).

IV

CONCLUSION

In West Bengal, shrimp production growth was declined in the first sub-period despite improvement was noticed in the second sub-period due to adoption of farming practices of newly introduced species *P.vannamei*. However, productivity was positively progressed from 2005-06 to 2020-21 due to technological development as well as improvement in input availability. Nonetheless, the medium instability could be observed in production and productivity despite low instability existed in area of shrimp culture. It is inferred from decomposition analysis that effect of area played major role in overall growth of shrimp production in West Bengal compared to interaction effect between area and yield. Further, the study clearly indicated that composition analysis is one of the important statistical means in assessing the overall development of shrimp production followed by interaction effect.

Received May 2022. *Revision accepted November 2022.*

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