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A Time Series Analysis on Shrimp Production from India and Andhra Pradesh Using ARIMA Model

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ABSTRACT

The objective of present study was to analyse the forecasting of shrimp production for the future. Based on secondary data from 2001-02 to 2017-18, the future trend were predicted for up to 2023-24 by employing the Auto Regressive Integrated Moving Average (ARIMA) technique. Stationary of shrimp production data from 1995-96 to 2017-18 was tested by Augmented Dickey Fuller (ADF) test. Maximum R-Square, minimum Mean Absolute Percentage Error (MAPE) and Root Mean Square Error (RMSE) was used as a criteria to select the best model for price forecasting. Based on the above criteria the models (0,1,1) and (1,1,0) was found to fit the time series to predict future trend in India and Andhra Pradesh respectively. The linear relationship between sea food exports from India and shrimp production in A.P., Correlation coefficient (r) was found to be 0.87 and coefficient of determination was 0 .76 (i.e. about 76 per cent) indicating the variation in quantity exported due to changes in shrimp production.

Keywords: *ARIMA, Correlation Co-efficient and Shrimp.*

India is the third largest fish producing country in the world and ranks second in inland fish production. The 8,118 km coastline from both inland and marine resources provides it a greater scope for being associated with marine activities and exporting various marine products. Shrimp farming has grown from traditional, small-scale business in India into a global industry (Selvin *et.al.* 2009). In India extensive production systems of shrimp culture is more profitable (Leung & Engle 2006) than the other culture systems. Technological advances have led to growing shrimp at even higher densities. Tiger shrimp *Penaeus monodon* and Pacific white shrimp *Litopennaneus vannamei* occupied more than 90 per cent of the farmed shrimp production. Krishnan and Birthal (2002) have also explained that due to the demand and growth of coastal aqua culture in India, it also has been quite a promising sector for accelerating the exports and improving the foreign exchange.

Brackish water aquaculture in Andhra Pradesh is almost synonymous with shrimp culture. The establishment of Coastal Aquaculture Authority, 2005 in India helped to regulate and frame the guidelines for the shrimp farming in coastal areas based on the previous experiences faced by farmers in tiger shrimp and they successfully introduced the *Penaeus vannamei* in 2009 by permitting to import the SPF brood stock by the hatcheries. The Central Institute of Brackish Water Aquaculture (CIBA), Chennai and National Bureau of Fish Genetic Resources (NBFGR), Lucknow conducted the risk analysis studies for introduction of *P. vannamei* in India, following which the Government of India decided on a large scale introduction of commercial production of *P. vannamei* in 2009.

Fisheries sector has been identified as a growth engine for socio-economic development of the new state of Andhra Pradesh. Andhra Pradesh stands first in total fish and prawn/shrimp production in India since 2013-14 both in terms of production and value. The contribution of Andhra Pradesh fisheries sector was 6.01 per cent in Andhra Pradesh GSDP, and was about 0.83 per cent of GDP of the nation. During 2016-17, the fish and prawn production achieved 27.49 lakh tonnes with GVA of Rs.34,041 crore, with growth rates of 22.35 per cent and 35.65 per cent respectively. Andhra Pradesh has major share in the seafood exports from our country with 45 per cent share in the year 2016-17. Seafood worth Rs.17000 crore was exported from the state in the year 2016-17 against the total exports of worth Rs.37871 crore from India. Development of shrimp farming is an important activity in coastal waters of Andhra Pradesh and India. The objective of present study was Forecasting of shrimp production in India and Andhra Pradesh during the period 1995-96 to 2023-24.

MATERIAL AND METHODS

Correlation co–efficient

The shrimp production from Andhra Pradesh (quantity in tones) and total sea food export from India (quantity in tones) were used to analyse the dependency of Indian sea food export industry on the shrimp production of A.P.

Correlation coefficient 'r' is given by

$$r = \frac{N (\Sigma xy) - (\Sigma x) (\Sigma y}{\{[n (\Sigma x^2)-(\Sigma x)^2] [n(\Sigma y^2)-(\Sigma y)^2]\}^{1/2}}$$

Where,

r is correlation coefficient

x is Shrimp production in Andhra Pradesh

y is Sea food exports from India

N is period 17 years i.e. 2001-02 to 2017-18.

Auto Regressive Integrated Moving Average (ARIMA) Model

Auto Regressive Integrated Moving Average (ARIMA) Model Introduced by Box and Jenkins (1976), the ARIMA model has been one of the most popular approaches for forecasting. The ARIMA model is basically a data oriented approach that is adopted from the structure of the data itself. In an ARIMA model, the estimated value of a variable is supposed to be a linear combination of the past values and the past errors. Generally a time series can be modelled as a combination of past values and errors, which can be denoted as ARIMA (p,d,q) which is expressed in the following form

$$Yt = \theta 0 + \Phi 1\ Yt\text{-}1 + \Phi 2\ Yt\text{-}2 + ... + \Phi p\ Y\ t\text{-}p + et - \theta 1\ et\text{-}1 - \theta 2\ et\text{-}2 - ... - \theta\ et\text{-}q$$

where,

Yt and et are the actual values and random error at time t, respectively,

Φi (i = 1,2,……., p) and

θj (j = 1,2,……, q) are model parameters,

p and q are integers and often referred to as orders of autoregressive and moving average polynomials respectively.

Random errors are assumed to be independently and identically distributed with mean zero and constant variance. Basically this method has four steps identification of the model, estimating the parameters, diagnostic checking and forecasting.

RESULTS AND DISCUSSION

Forecasting of shrimp production from India (quantity in tonnes)

In order to estimate the future trend in shrimp production from India in quantity terms ARIMA technique was employed. At first, stationarity of shrimp production data from 1995-96 to 2017-18 was tested by Augmented Dickey Fuller (ADF) test. ADF test for unit root also confirmed that the data was non-stationary and it became stationary at first difference as the calculated values were lesser than critical values at 1%, 5% and 10% levels (Table 1). After fixing the value of d as 1, values of p and q were determined. From correlogram of ACF and PACF as shown in Fig.1 there was three significant spikes up to lag 3 for ACF only .

R^2 Co-efficient of multiple determination, MAPE mean absolute percentage error, RMSE Root mean square error

A Possible different ARIMA (p,d,q) models were compared to each other. Among all possible models, ARIMA (0,1,1) was selected as optimal and most appropriate model due to model selection criteria such as minimum values of MAPE, RMSE and high R-squared value as per Table 2. The parameters were estimated for the best selected model i.e. ARIMA (0,1,1) as mentioned in Table 3.

From the residual ACF and PACF plots of ARIMA (0,1,1), it was clear that all autocorrelations and partial autocorrelations lie between 95% control limits as shown in Fig. 2. This also confirmed the good fit of this selected model.

For checking normality and randomness, Shapiro- Wilk were applied respectively to residuals of ARIMA (0,1,1) and results were presented in Table 4. The probability values of the tests is greater than 0.05 indicating residuals were distributed normally and independently.

Finally, forecasting was done for Indian shrimp production from 2015-16 till 2023-24 by using ARIMA (0,1,1) with keeping first three years data for validation. Predicted values with 95% Upper control limits (UCL) and Lower control limits (LCL) were presented in Table 5. It is shown that shrimp production from India during 2017-18 was 994744 tonnes. By looking into the predicted trend in growth till the year 2022-23 it was 1159504 tonnes indicating the increase in shrimp production to about 164760 tonnes.

By using ARIMA (0,1,1), it was observed that the actual and predicted values were closely related and predicted values were within control limits as captured in Fig. 3.

Forecasting of Andhra Pradesh shrimp production (quantity in tonnes)

In order to estimate the future trend in shrimp production from Andhra Pradesh in quantity terms ARIMA technique was employed. At first, stationarity of shrimp production data from 1995-96 to 2017-18 was tested by Augmented Dickey Fuller (ADF) test. ADF test for unit root also confirmed that the data was non-stationary and it became stationary at first difference as the calculated values were lesser than critical values at 1%, 5% and 10% levels (Table 6). After fixing the value of d as 1, values of p and q were

Table 1. Results of ADF test for Indian shrimp production

Test	ADF Statics	Critical values at			Probability	Decision
		1%	5%	10%		
ADF at level	-1.24	-4.8	-3.79	-3.34	0.85	Data non stationary
ADF at first difference	-1.58	-4.99	-3.87	-3.38	0.03	Data stationary

Table 2. Selection of appropriate ARIMA model through different criterion in Indian shrimp production in quantity terms

Criteria	ARIMA model (p,d,q)		
	0,1,3	0,1,2	0,1,1
R^2	0.91	0.89	0.91
MAPE	8.01	8.37	8.2
RMSE	6.6	6.7	5.9

Table 3. ARIMA (0,1,1) model parameters estimation

Model parameter	Estimates	S.E	T_{cal} value	Significance
Intercept	2.79	1.259	2.22	0.038
Difference	1			
Moving average Lag 1	0.111	0.224	0.497	0.025

Table 4. Tests of Normality and Randomness of residuals ARIMA (0,1,1)

	Sharpio-wilk test		
	Statics	d.f	Significance
Residuals	0.899	22	0.07

Table 5. Forecasting of Indian shrimp production with control limits (Quantity in tons)

Year	Actual	Predicted	LCL	UCL
2015-16	896104	826680	688952	964408
2016-17	941993	916362	778634	1054090
2017-18	994744	967117	829389	1104845
2018-19		1019646	881918	1157374
2019-20		1047618	863343	1231892
2020-21		1075589	854354	1296825
2021-22		1103561	850711	1356411
2022-23		1131533	850604	1412462
2023-24		1159504	853058	1465950

Table 6. Results of ADF test for Andhra Pradesh shrimp production

Test	ADF Statics	Critical values at			Probability	Decision
		1%	5%	10%		
ADF at level	-1.19	-4.88	-3.82	-3.36	0.86	Data non stationary
ADF at first difference	0.4	-4.99	-3.37	-3.8	0.03	Data stationary

Table 7. Selection of appropriate ARIMA model through different criterion in Andhra Pradesh shrimp production

Criteria	ARIMA model (p,d,q)				
	1,1,2	1,1,1	1,1,0	0,1,2	0,1,1
R^2	0.91	0.96	0.96	0.96	0.94
MAPE	16.51	16.41	16.41	16.41	17.78
RMSE	3.67	3.36	3.28	3.28	3.97

Table 8. ARIMA (1,1,0) model parameters estimation Andhra Pradesh shrimp production

Model parameter	Estimates	S.E	T_{cal} value	Significance
Intercept	4.420	4.180	1.057	0.303
Difference	1.000			
Autoregressive Lag 1	0.841	0.176	4.780	0.000

Table 9. Tests of Normality and Randomness of residuals- ARIMA (1,1,0)

	Sharpio-wilk test		
	Statics	Df	Significance
Residuals	0.923	22	0.8

Table 10. Forecasting of Andhra Pradesh shrimp production with control limits

(Quantity in tons)

Year	Actual	Predicted	LCL	UCL
2015-16	390649	335994	269347	402641
2016-17	542193	477705	411058	544352
2017-18	693063	676702	610055	743350
2018-19		727005	760358	893653
2019-20		846707	807062	986353
2020-21		954429	834517	994341
2021-22		992072	848298	1055846
2022-23		1023236	852262	1130211
2023-24		1051288	849181	1297355

Table 11. Correlation between Indian sea food exports and Andhra Pradesh shrimp production

		Sea food exports	Shrimp production
Seafood exports	Correlation co-efficient	1.000	0.876**
	Sig. (2-tailed)		0.000
	N	17.000	17.000
Shrimp production	Correlation co-efficient	0.876**	1.000
	Sig. (2-tailed)	0.000	
	Nu	17.000	17.000

** Correlation is significant at the 1% level of significance

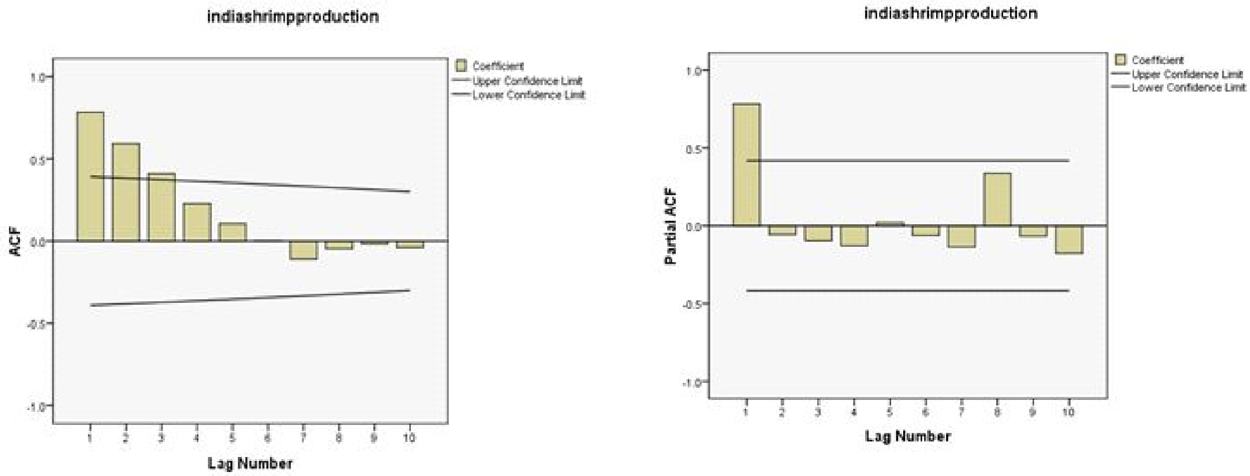

Fig. 1. Correlogram of ACF and PACF for first differenced Indian shrimp production

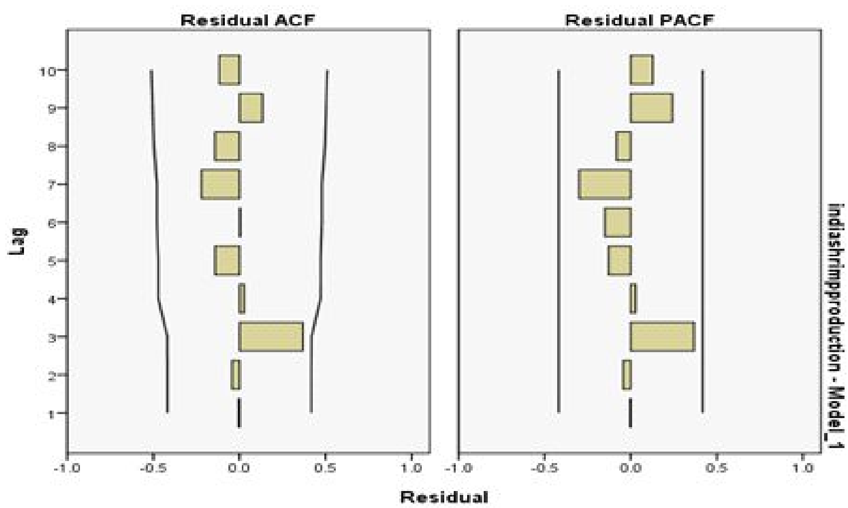

Fig. 2. Residual ACF and PACF of ARIMA (0,1,1) of Indian shrimp production

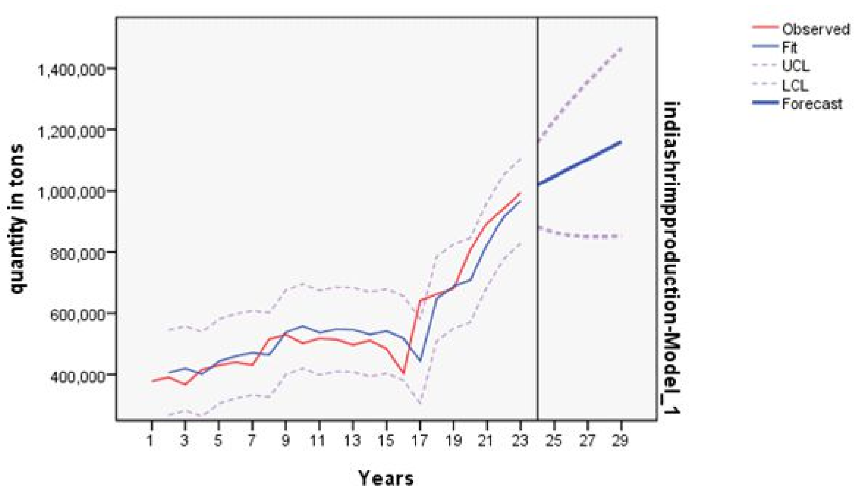

Fig. 3. Forecasting Indian shrimp production by ARIMA (0,1,1)

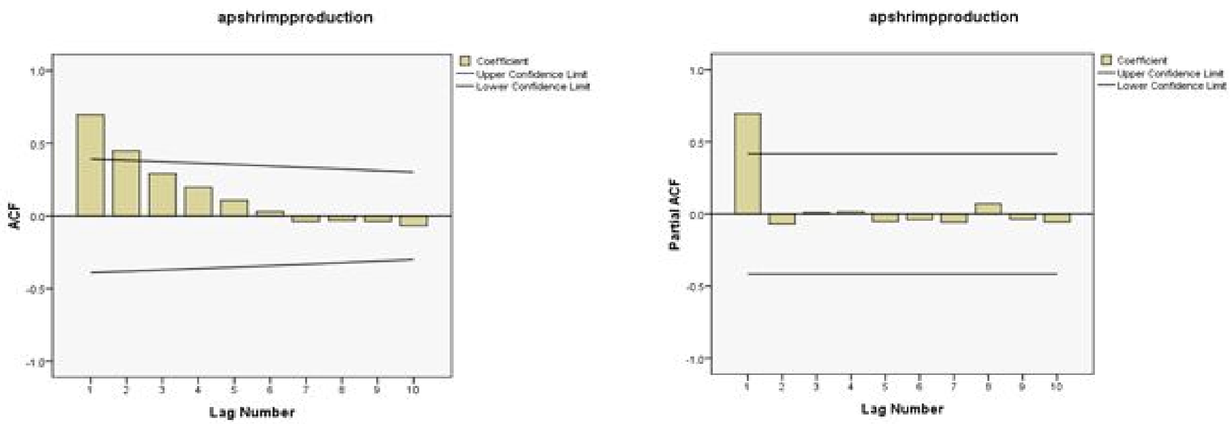

Fig. 4. Correlogram of ACF and PACF for first differenced Andhra Pradesh shrimp production

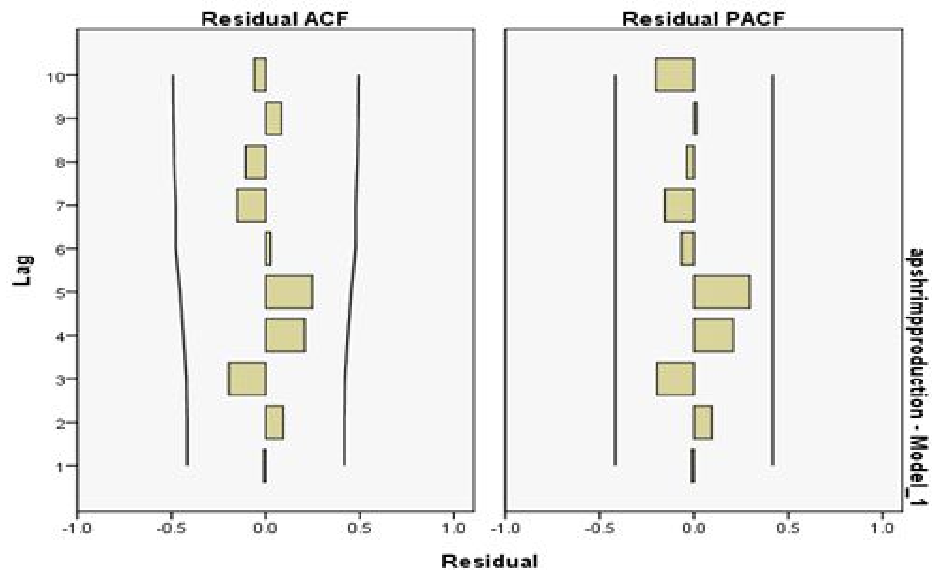

Fig. 5. Residual ACF and PACF of ARIMA (1,1,0) Andhra Pradesh shrimp production

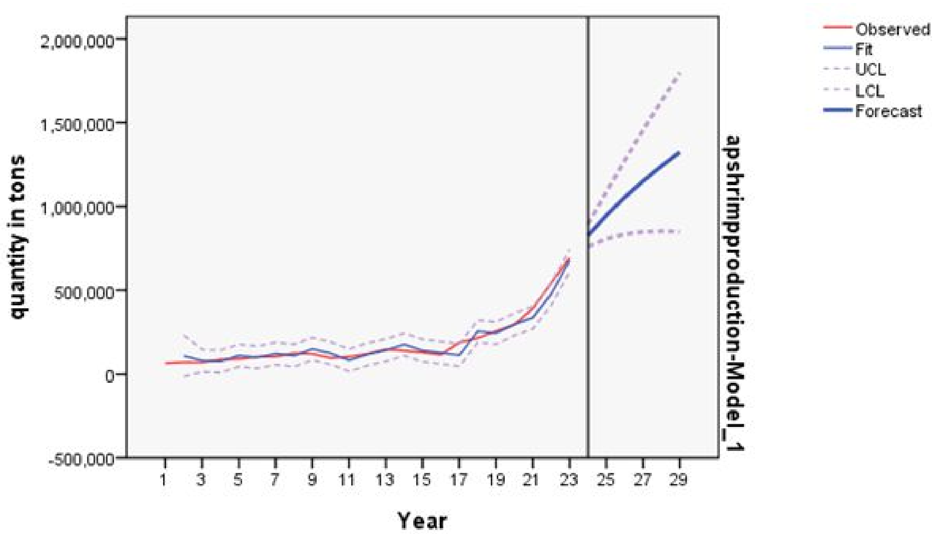

Fig. 6. Forecasting of shrimp production of Andhra Pradesh from by ARIMA (0,1,1)

determined. From correlogram of ACF and PACF as shown in Fig. 4, there was two significant spikes up to lag 2 for ACF while one significant spike on lag 1 for PACF.

R^2 Co-efficient of multiple determination, MAPE mean absolute percentage error, RMSE Root mean square error

A Possible different ARIMA (p,d,q) models were compared to each other. Among all possible models, ARIMA (1,1,0) was selected as optimal and most appropriate model due to model selection criteria such as minimum values of MAPE, RMSE and high R-squared value as per Table 7. The parameters were estimated for the best selected model i.e. ARIMA (1,1,0) as mentioned in Table 8.

From the residual ACF and PACF plots of ARIMA (1,1,0), it was clear that all autocorrelations and partial autocorrelations lie between 95% control limits as shown in Fig. 5. This also confirmed the good fit of this selected model.

For checking normality and randomness, Shapiro- Wilk were applied respectively to residuals of ARIMA (1,1,0) and results were presented in Table 9. The probability values of the tests is greater than 0.05 indicating residuals were distributed normally and independently.

Finally, forecasting was done for Andhra Pradesh shrimp production from 2015-16 till 2023-24 by using ARIMA (1,1,0) with keeping first three years data for validation. Predicted values with 95% Upper control limits (UCL) and Lower control limits (LCL) were presented in Table 10. It is shown that shrimp production from Andhra Pradesh during 2017-18 was 6,93,063 tonnes. By looking into the predicted trend in growth till the year 2023-24 it was 10,51,228 tonnes indicating the increase in shrimp production to about 3,58,156 tonnes.

By using ARIMA (0,1,1), it was observed that the actual and predicted values were closely related and predicted values were within control limits as captured in Fig. 6.

To understand the dependency of Indian sea food export industry on the shrimp production in Andhra Pradesh a correlation analysis was done by taking the variables as shrimp production from Andhra Pradesh (quantity in tonnes) and total sea food products export from India (quantity in tonnes) for the period 2001-02 to 2017-18 and presented in Table 10.

The linear relationship between sea food exports from India and shrimp production in AP are presented in Table 3.4. Correlation coefficient (r) was found to be 0.876 and coefficient of determination was 0 .76 (i.e. about 76 per cent) indicating the variation in quantity exported due to changes in shrimp production. Other factors responsible for the variation are fluctuations in exchange rate, contributions by other components in exports. The correlation coefficient (r) value shows that there is a significant positive relationship between shrimp production in Andhra Pradesh and sea food exports from India.

CONCLUSION

ARIMA model was used to forecast the 23 years export performance and production of shrimps from India and Andhra Pradesh. This forecast was in terms of the total quantity exported in tonnes and the total value of exports in rupees. The ARIMA model forecasted a significant and consistent increase in the total exported quantity from India during this period. In terms of the export value in Indian rupees, the forecast remained flat and constant. Shrimps form a major portion of the overall exports of the country. With the advancement of scientific farming methods and technology, the shrimp aquaculture industry holds high potential for growth in India in future. However the aquaculture industry is exposed to several risks of both operational and economic, which created pressure on the production of such species. Moreover due to tighter custom policies and quality check procedures from the importing countries, Indian seafood exports would have to find a solution for a sustainable growth of exports in future.

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