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Empowering India's Food Security: Harnessing Aquaculture for Nutritional Prosperity

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Abstract

This study aims to estimate shrimp production in India's coastal states, evaluate its nutritional benefits, and examine India's role as a shrimp exporter in the global arena. Utilizing secondary data from 2015-16 to 2020-21 sourced from various Indian aquaculture authorities, the study employs Growth Rate Analysis, Pearson Correlation Analysis, and a Fixed Effects Regression Model. Significant variations in shrimp production and cultivation areas were observed across states. A moderate positive correlation (r = 0.486) between Area Under Cultivation (AUC) and Estimated Production (EP) was found, and the Fixed Effects Regression Model indicated that a 1-hectare increase in cultivation area corresponds to a 5.72-ton increase in shrimp production, with an adjusted R-squared value of 0.88. The study highlights shrimp's nutritional benefits as a high-quality protein source. Economically, India's shrimp exports grew from $9706.36 million in 2012-13 to $42706.04 million in 2021-22, reinforcing economic stability and securing the second position in global shrimp exports with a 21.2% market share in 2022. The study concludes that India's strategic initiatives in shrimp farming, aligned with global food security goals, underscore the importance of technological innovation, sustainable practices, and stakeholder collaboration, significantly contributing to nutritional security and economic development.

Keywords: Aquaculture, Food Security, India, Nutrition, Shrimp.

Introduction

Over the next four decades, as the global population grows from under 7 billion to over 9 billion by 2050, the demand for food is expected to rise significantly, underscoring the importance of sustainable aquaculture and fisheries for providing essential nutrition, income, and livelihoods worldwide (Buttriss and Riley, 2013). Aquaculture has become the fastest growing animal food production sector, surpassing wild sources in 2014 and projected to meet up to two-thirds of the global fish demand by 2030 (Ottinger et al., 2016; Ellis et al., 2017; E-Jahan et al., 2010; Naylor, 2016). This growth is not only a response to declining capture fisheries due to overfishing and environmental challenges but also a critical shift towards a more sustainable source of high-quality protein and essential nutrients, playing a vital role in domestic and global food security (Prem et al., 2015; Tacon, 2001; Fiorella et al., 2021; McClanahan et al., 2015). In India, where the fisheries sector plays a crucial role in providing employment and economic stability, aquaculture has seamlessly interwoven the nation's maritime heritage with innovative practices, leading a global revolution in sustainable aquaculture (Ngasotter et al., 2020; Jayasankar, 2018; Jayanthi et al., 2018). This industry not only helps in meeting the nutritional needs of underserved populations by providing affordable access to essential vitamins, proteins, micronutrients, and minerals but also emphasizes the need for healthier diets (Pradeepkiran, 2019; Thilsted et al., 2016). Furthermore, technological and regulatory advancements, such as those mandated by the Coastal Aquaculture Authority Act of 2005, support sustainable practices and economic growth, while also ensuring the health of aquatic ecosystems (Krishnan and Birthal, 2008; Salunke et al., 2020).

The aquaculture sector's ability to provide diverse marine products has made nutritious food more accessible, notably through the production of protein-rich shrimps, which are essential in combating malnutrition and enhancing food democratization (Blanchard et al., 2017). The socioeconomic impacts of this industry are profound, revitalizing local economies and providing stable employment, thereby contributing to the cultural heritage of coastal communities (Alagarswami, 1981; Dayal et al., 2013). The balanced approach to managing both fisheries and aquaculture is critical for sustainable practices and ensuring the long-term health of marine ecosystems (Belton and Thilsted, 2014; Bogard et al., 2015). As India continues to be in the forefront as in global aquaculture revolution, it highlights the potential for nations to harness local resources and innovate for global benefit. The aquaculture sector's success story is not only just economic gain but also environmental and social progress, promising a future where food security, prosperity, and ecological balance coexist (Devaraj and Appukuttan, 2000; Mukul, 1994; Katiha et al., 2007). The robust management of this sector, including addressing risks such as weather and disease, remains essential to maintaining its contribution to global food security and nutrition (Beach & Viator, 2008; Gopakumar, 2008; Kumar, 2014). The ongoing evolution of aquaculture practices and policies is vital for addressing both present and future challenges, ensuring that fisheries and aquaculture continue to be essential contributors to global food security and economic stability (Salin & Ataguba, 2018).

The Food and Agriculture Organization (FAO) defines aquaculture as the methodical cultivation of aquatic entities encompassing fish, molluscs, crustaceans, and aquatic flora. Historically, oceans were the prime source for marine delicacies, but burgeoning populations ushered in amplified demand, revealing the ocean's limitations and environmental strains. Aquaculture emerged as the sustainable alternative, reshaping marine food production. Currently, aquaculture is globally recognized as one of the fastest growing food production sub-sectors, with consistent growth in production over the past ten years, demonstrating its potential to continue boosting food supplies, particularly in countries like Asia (Ahmed and Lorica, 2002; Hernandez et al., 2018). Today, this domain ranks among the swiftest expanding food sectors, with India carving its niche. Blessed with vast coastline, India stands proudly as the second-largest aquaculture producer and the paramount shrimp exporter on the global platform. The surge in both domestic and international appetite propelled the Indian aquaculture market, boasting a revenue of approximately $15.4 billion and an impressive CAGR of 10% from 2016 to 2020, culminating in a production of 7,788.7 thousand tonnes in 2020 alone. As per FAO, marine produce remains the primary animal protein source for about a billion people globally. Aquaculture, characterized by its nutritional richness, offers invaluable contributions to food and nutritional fortification. Specifically, shrimps, laden with premium protein, essential micronutrients, and fatty acids, not only foster holistic human health but are also instrumental in combating malnutrition, particularly in children (Bene et al., 2015; Mohamed, 2022; Shepon et al., 2021). The aquaculture industry fortifies food security, both directly, offering nutrient-rich sources, and indirectly, serving as an economic catalyst. Therefore, the research paper is to estimate shrimp production in the coastal states, it's contribution in providing nutritional benefits to the population and to examine the role of India as an exporter of shrimp in International Market.

Why Shrimp?

In this paper, shrimp was chosen as a case-study because it is considered to have an economic and nutritional significance in Indian economy. Shrimp farming is a vital activity in Indian aquaculture accounting to a large extent of Indian seafood exports. The quantity and value of frozen shrimp exports grew from 2013 through 2023, hitting 711,099 metric tons and $5.481.63 million in two-way trade for 2022-23. The impressive growth explains the important place shrimps hold in the socio-economic condition of coastal communities in the country. In addition to this, shrimp is a great source of important high-protein, essential fatty acids, vitamins, and minerals, vital in closing protein deficits and enhancing food security. The sustainability of shrimp aquaculture also helps to protect marine biodiversity, essentially preserving wild shrimp populations from overfishing. Frozen shrimp can be seen dominating the list of marine products export from India surpassing other marine products like frozen fish, Cuttlefish, Squid, dried items, live items, chilled items etc. Therefore, the overwhelming dominance of frozen shrimp in the export market highlights the economic importance of this sector and its essential role in contributing to the growth of Indian aquaculture. The consistent top position of shrimp among marine exports in India makes a strong case in support of selecting shrimp as the focus of this investigation about its production, nutritional role and share in the global market.

Materials and Methods

The research paper is based on the analysis of secondary data collected during the periods of 2015-16 to 2020-21 of the Indian coastal states from Marine Products Exports Development Authority (MPEDA) India, National Fisheries Development Board (NFDB) India, Coastal Aquaculture Authority (CAA) India, Seafood Exporters Association of India (SEAI) India, Society of Aquaculture Professional (SAP) India and Ministry of Fisheries, Animal Husbandry and Dairying. The core objective of the study is to establish the relationship between Area Under Cultivation (AUC) and Estimated Production (EP) of shrimp across various states in India.

Athira Raveendran /Afr.J.Bio.Sc. 6(13)(2024).3493-3517

Data Preparation:

- Data from production and area tables were merged into a panel dataset.
- Panel data techniques allow us to control for time-invariant unobservable state-specific effects.

Growth Rate Analysis

- Growth rates for area under cultivation (AUC) and shrimp production (EP) were calculated:

$$\boldsymbol{Growth\ Rate\ (GR)} = \left(\frac{\boldsymbol{value\ in\ 2020{-}21 - \ value\ in\ 2019{-}20}}{\boldsymbol{value\ in\ 2019{-}20}}\right) \times \mathbf{100}$$

Pearson Correlation Analysis

- Pearson correlation coefficient (r) was calculated to measure the correlation between the growth rates of shrimp production and area under cultivation.

Econometric Model: Fixed Effects Regression

- Fixed Effects Regression was employed to account for state-specific heterogeneity.
- The model specification:

$$Production_{it} = \alpha + \beta \cdot Area_{it} + \gamma_i + \delta_t + \epsilon_{it}$$

Where γ_i captures state-specific effects and δ_t captures time-specific effects.

The paper also examined the nutritional benefits of shrimp by comparing it with other non-vegetarian food items and examined the export trends of shrimp from the country and its global position.

Athira Raveendran /Afr.J.Bio.Sc. 6(13)(2024).3493-3517

Results and Discussions

The Indian aquaculture industry, particularly shrimp farming, has undergone significant changes over the years. With varied ecological, climatic, and geographical conditions across states, understanding the dynamics of shrimp farming becomes imperative. One such dynamic is the relation between the area cultivated for shrimp and the resultant production. Let's examine it in detail:

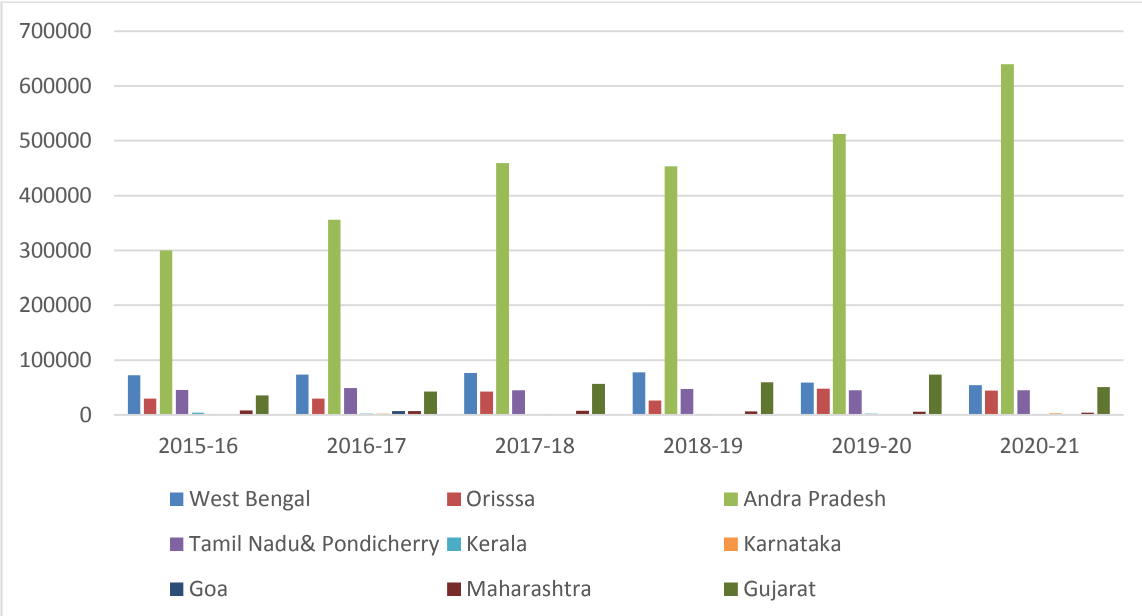
Table 1. State wise Estimated Production (in tons) of total shrimps in India.

SI No.	State	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
1	West Bengal	72554	73472	76534	77688	58961	54582
2	Orissa	29936	30062	42735	26268.8	48147.5	44555
3	Andhra Pradesh	300278	355970	459181	453235	512244	639896
4	Tamil Nadu & Pondicherry	45642	49198	45234	47296	45022	44816
5	Kerala	3827	2436	370	1933.44	2622.97	1867.83
6	Karnataka	1727	2102	1524	1011.06	1229.1	3185.84
7	Goa	33	6842	106	219.65	0	0
8	Maharashtra	8126	6842	7536	6567.49	5625.1	4204.1
9	Gujarat	35499	42755	56781	59359	73842	50526
	Total	497622	569679	690001	673579	747694	843633

Source: The Marine Products Export Development Authority

Athira Raveendran /Afr.J.Bio.Sc. 6(13)(2024).3493-3517

Figure 1. State wise estimated Production (Tons) of total Shrimp in India



Source: Marine Products Export Development Authority

Here we are analyzing the shrimp production growth between 2019-2020 and 2020-2021 using the Growth Curve Model for the different states, let's focus on the changes between these two specific years.

Estimated Production (EP) growth rate of each coastal state as follows:

Table 2. Growth Rate of Estimated Production from 2019-2020 to 2020-2021

SI. No.	States	Growth Rate in EP (%)
1	West Bengal	-7.43%
2	Orissa	-7.50%
3	Andhra Pradesh	24.93%
4	Tamil Nadu & Pondicherry	-0.46%
5	Kerala	-28.80%
6	Karnataka	159.21%
7	Goa	0% (No growth)

8	Maharashtra	-25.24%
9	Gujarat	-31.57%
10	Total	12.82%

Shrimp farming in different states of India recorded significant differences in growth rates during the period from 2019-2020 & 2020-2021 fiscal. Shrimp estimated production (EP) slipped 7.43 per cent in West Bengal. A decrease of that magnitude could imply difficulties leading industry or external pressures leading to a dip in production. Orissa, which actually saw a decrease in EP (of 13.56%) vs. West Bengal (a lower 13.23% in EP). Andhra Pradesh: While all the other states have witnessed a steady fall in shrimp production, Andhra Pradesh showed a strong growth in EP, with a growth of 24.93%. This clearly shows a flourishing shrimp farming sector in the state in that year. Shrimp production in Tamil Nadu & Pondicherry also dipped marginally by -0.46%. A small downturn like this one may not be cause for panic, as it can just reflect a plateau in the industry. Kerala. The EP in Kerala has declined by 28.80%, a massive decrease. This decline in performance may point out to issues or disruptions that may require action to address. With 159.21%, Karnataka registered the biggest growth in EP among all the other states in the list. This indicates either a probable increase in the shrimp farming activities or the expert interventions that have been successful within the specified span of time. Goa, In Goa, Shrimp production rate remained static at 0 % i.e. no growth has been recorded in this year. In Maharashtra, the shrimp EP fell by -25.24% highlighting some possible bottlenecks in the aquaculture landscape of the state, similar to Kerala. In listed states, Gujarat witnessed maximum EP fall wherein Gujarat's shrimp production fell by 31.57%. Such a scenario pointed to the worst of conditions in the state's shrimp farming sector. When we considered all the states together, the aggregated growth rate for shrimp production in the country stood at 12.82% which looked positive yet moderate growth on an all-India basis. Overall, there was tremendous growth in shrimp production in some states like Andhra Pradesh and Karnataka, while many other states like Kerala, Maharashtra, and Gujarat experienced drastic declines. Further exploration would reveal what causes these disparities among the states.

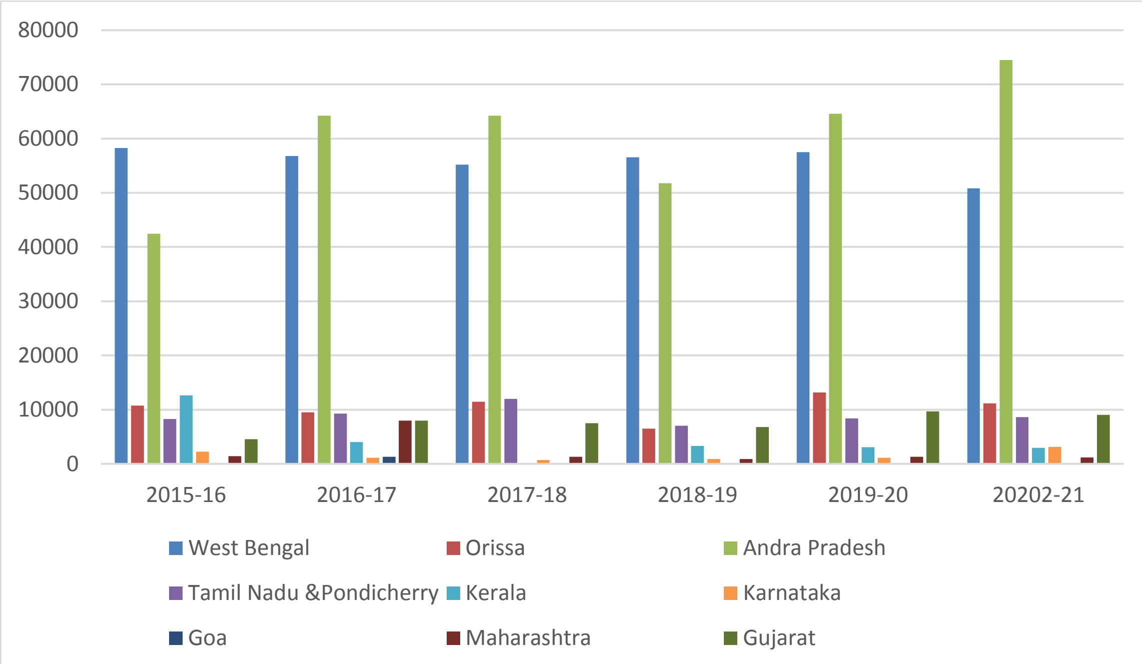
Athira Raveendran /Afr.J.Bio.Sc. 6(13)(2024).3493-3517

Table 3. State wise Area Utilized of Total Shrimp Production. (Hectares)

SI No.	State	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
1	West Bengal	58285	56759	55211	56551	57494	50844
2	Orissa	10778	9494	11486	6490.6	13186.5	11200
3	Andhra Pradesh	42462	64243	64222	51776	64561	74512
4	Tamil Nadu & Pondicherry	8263	9291	11993	7047	8393	8630
5	Kerala	12622	4005	107	3310.51	3061.34	2971.24
6	Karnataka	2281	1154	701	908.58	1129.97	3145.39
7	Goa	10	1297	42	60.13	0	0
8	Maharashtra	1413	7979	1291	915.85	1328.16	1183.49
9	Gujarat	4552	7982	7542	6792.5	9709	9021
	Total	140666	162204	152595	133852	158863	166722.5

(Source: The Marine Products Export Development Authority)

Figure 2. State Wise Area Utilized of Total Shrimp Production. (Hectares)



(Source: Marine Products Export Development Authority)

Here we are analyzing the growth of area under cultivation of shrimp between 2019-2020 and 2020-2021 using the Growth Curve Model for the different states, let's focus on the changes between these two specific years.

Table 4: Growth Rate in AUC (Area Under Cultivation) from 2019-2020 to 2020-2021

SI. No.	***States***	***Growth Rate in AUC (%)***
1	West Bengal	-11.55%
2	Orissa	-15.04%
3	Andhra Pradesh	15.41%
4	Tamil Nadu & Pondicherry	2.82%
5	Kerala	-2.94%
6	Karnataka	178.38%
7	Goa	0% (No growth)
8	Maharashtra	-10.88%

Athira Raveendran /Afr.J.Bio.Sc. 6(13)(2024).3493-3517

9	Gujarat	-7.09%
10	Total	4.93%

Growth rate of Area under Cultivation of each coastal state as follows:

During the period from 2019 to 2021, shrimp farming landscape has been changing significantly in India. The Area Under Cultivation (AUC) for shrimp production, i.e. area dedicated to shrimp farming and provides a better indication of the actual area that the shrimp culture is spreading over to, showed inconsistent rates of growth among different states, West Bengal saw a decline of 11.55 percent in its AUC. The fall in number could be indicative of shrinking farming areas due to inimical conditions. The AUC for Orissa decreased by 15.04%, hinting that shrimp farming encountered greater obstacles or alternative uses of agricultural effort. Positive growth of 15.41% in AUC indicates the area expansion of shrimp farming in Andhra Pradesh. Consistent with this, Andhra Pradesh continues to be a vital hub for shrimp production in India. Tamil Nadu & Pondicherry shows modest growth of 2.82% although not remarkable, it still shows an expansion in shrimp farming space in these regions. Kerala shows a marginal reduction in shrimp culture area with a 2.94 decrease in AUC. Mostly due to the number of challenges or changing economic trends. Karnataka witnessed an astounding surge of 178.38% in AUC. This indicates substantial investment or initiatives in shrimp farming augmentation projects in the state. Goa with no change in its AUC, maintained a steady landscape with neither expansion nor contraction in its shrimp farming areas. The AUC in Maharashtra reduced by 10.88% indicating that the state is likely to face restrictions or changes in its focus from aquaculture. Gujarat's shrimp farming area contracted by 7.09%. While not as severe as some other states, this decrease calls for scrutiny to determine the underlying factors. Overall, on a national level, despite some states experiencing reductions in AUC, India witnessed a modest growth of 4.93%. This indicates a net expansion in the country's shrimp farming areas. In short, the shrimp farming area has expanded significantly in states like Karnataka and Andhra Pradesh but shown a decreasing trend in states like Orissa and West Bengal. But considering the rising temperatures and changing weather patterns, climate change in states like Tamil Nadu is challenging the long-term sustainability of this industry as it runs the risk of disease outbreaks that could potentially decimate the entire cultivable stock of shrimp farms.

Now, when compare the growth rates of AUC and EP of different coastal states in the year 2019-20 to 2020-21 using Pearson correlation coefficient (r) for given data.

Table 5. Growth rate of EP & AU

State	***EP Growth Rate (X)***	***AUC Growth Rate (Y)***
West Bengal	-7.43	-11.55
Orissa	-7.50	-15.04
Andhra Pradesh	24.93	15.41
Tamil Nadu & Pondicherry	-0.46	2.82
Kerala	-28.80	-2.94
Karnataka	159.21	178.38
Goa	0	0
Maharashtra	-25.24	-10.88
Gujarat	-31.57	-7.09

Table 6. Compute Products and Squares**:**

State	**X**	**Y**	**X * Y**	**X^2**	**Y^2**
West Bengal	-7.43	-11.55	85.88	55.22	133.50
Orissa	-7.50	-15.04	112.8	56.25	226.20
Andhra Pradesh	24.93	15.41	384.30	621.24	237.66
Tamil Nadu & Pondicherry	-0.46	2.82	-1.30	0.21	7.95
Kerala	-28.80	-2.94	84.67	829.44	8.64
Karnataka	159.21	178.38	28402.06	25355.66	31819.82
Goa	0	0	0	0	0
Maharashtra	-25.24	-10.88	274.61	637.06	118.57

Athira Raveendran /Afr.J.Bio.Sc. 6(13)(2024).3493-3517

State	**X**	**Y**	**X * Y**	**X^2**	**Y^2**
Gujarat	-31.57	-7.09	223.87	996.44	50.27
Total	**73.64**	**159.11**	**29162.89**	**27440.52**	**32602.61**

Plugging values into the Pearson formula:

$$r = \frac{9(29162.89) - (73.64)(159.11)}{\sqrt{[9(27440.52) - (73.64)^2][9(32602.61) - (159.11)^2]}}$$

Using these values:

$$r = \frac{262465.01 - 11711.53}{\sqrt{[246964.68 - 5418.53][293423.49 - 25326.01]}}$$

$$r = \frac{250753.48}{\sqrt{241546.15 * 268097.48}}$$

$$r = \frac{250753.48}{515801.71}$$

$$r = 0.486$$

The calculated Pearson correlation coefficient is **r = 0.486**

Our research computed a Pearson correlation coefficient of r = 0.486 between AUC and EP growth rates. This moderate positive correlation denotes that states which saw a rise in the area allocated for shrimp farming generally witnessed a proportional increase in shrimp production and vice-versa. That is, this indicates a general trend that as one metric grows, so does the other, but the relationship isn't extremely strong. A coefficient value of 0.486, while indicative of a positive trend, is far from a perfect correlation. This suggests that factors beyond mere cultivation area influence the production rate. Some states, such as West Bengal, Kerala, Maharashtra, and Gujarat, showed potential inefficiencies with EP declining more steeply than AUC. Such discrepancies underscore the necessity of understanding regional and state-specific challenges and intricacies.

Fixed Effects Regression Model

The fixed effects regression model provided the following results:

- **Coefficient for Area (β)**: 5.72 (p-value < 0.01)
- **Adjusted R-squared**: 0.88

The positive and significant coefficient for area suggests that increasing the area under cultivation by 1 hectare increases shrimp production by approximately 5.72 tons, holding other factors constant. The high R-squared value indicates that the model explains 88% of the variance in shrimp production. The fixed effects regression model accounts for both state-specific and time-specific effects, offering a detailed insight into the relationship between area and production. This model revealed a significant and positive relationship between the area utilized for shrimp farming and shrimp production, with a coefficient of 5.72. This means that for each additional hectare of shrimp farming area, production increases by approximately 5.72 tons. The high adjusted R-squared value of 0.88 indicates that 88% of the variance in shrimp production is explained by the model, highlighting its robustness and accuracy. The fixed effects regression model is a more robust approach which can control for unobservable heterogeneity across states and time, providing better resolution of connected variables than a simple Pearson correlation. Although Pearson correlation helps to figure out the general trends, it does not consider specific state impacts, hence the fixed effects model is chosen in this case as it offers detailed insights. Further, the fixed effects model showed a better fit to deepening understanding of the institutional dynamics with 88% shrimp production variance explained. The fact that this model is able to estimate state-specific effects is indispensable for crafting customized policy recommendations.

India's aquaculture industry, while growing, remains fraught with challenges. Factors such as climate variability, susceptibility to diseases, inadequate infrastructure, limited technological adoption, and sometimes inconsistent regulatory policies can hamper growth. However, there are also success stories. States like Andhra Pradesh and Karnataka have displayed remarkable growth, aided by advanced farming techniques and robust infrastructure. Furthermore, India's varied climatic zones offer diverse opportunities for aquaculture. Leveraging these variations, combined with innovations in feed, seed quality, and sustainable farming practices, can further boost production.

In the backdrop of our analysis highlighting the relationship between Area Under Cultivation (AUC) and Estimated Production (EP) of shrimp in various states of India, it becomes paramount to underscore why this relationship matters beyond mere numbers. At the heart of the equation lies the shrimp, a nutrient-rich food source that plays a crucial role in global food security and nutrition.

Shrimp, often regarded as a delicacy in numerous cuisines across the world, is much more than just a gourmet delight. Rich in vital proteins, vitamins, and minerals, shrimp offers a plethora of nutritional benefits, making it a desired dietary component for millions. As the global population burgeons, the demand for nutritionally dense food sources surges, and shrimp stands as a promising contender in addressing this demand. Let's discuss the nutritional benefits of shrimp by comparing it with other non-vegetarian food items in detail.

Table 7. Summary of Lipids and Food energy (100g) of Shrimp and other Non-Vegetarian food items.

Nutrients	Shrimp	Egg	Chicken	Mutton	Beef	Pork
Calories	99	155	239	294	250	242
Carbohydrates	0.2	1.1	0	0	0	0
Fat	0.3	11	14	21	15	14
Proteins	25	13	27	25	26	27

(Source: Compiled from various secondary sources)

From the above given table 7 we can say that compared to the other non-vegetarian food the calories provided by shrimp is low still sufficient. Carbohydrates are a main source of energy for a human body that helps for the proper function of brain, heart muscles, kidneys and central nervous system. Here only shrimp and egg are the one which provide essential carbohydrates. Comparing the fat percentage, shrimp is the food that have the lowest amount of fat content. Fats should always be limited to 20-35% of our daily total calories intake. i.e. overconsuming fat is considered as an unhealthy practice. In that case also consuming shrimp is beneficial to health as

Athira Raveendran /Afr.J.Bio.Sc. 6(13)(2024).3493-3517

it provides only a small and essential amount of fat. Proteins are an essential part of your diet as it helps your body to repair cells and also helps to make new cells. It acts as an important building block for bones, muscles, skin etc. Here we can state that shrimp is providing essential protein, even though it is less than other non-vegetarian food except egg, there is only a slight difference, i.e. overall when compared shrimp is a food item which is low in calories yet rich in nutrients and at the same time provides high nutritional value with low fat and essential carbohydrate.

Shrimp is one of the best sources of iodine which is required for the proper function of brain. It is also rich in Omega-3 Fatty Acids which are known to support heart health, these essential fatty acids are abundant in shrimp. Regular consumption can help reduce inflammation, decreasing blood pressure, and lowering the risk of heart disease. It's rich in antioxidants, astaxanthin, a compound found in shrimp, acts as an antioxidant, helping protect the body against inflammation and oxidative damage. It's also rich in Vitamins and Minerals, Shrimp boasts of a wide variety of minerals and vitamins, which includes Selenium, Vitamin B12, Zinc, Phosphorus, Niacin, and Iron, potassium, magnesium, sodium, vitamin D, vitamin E, vitamin B6, choline etc. that helps in the proper function of human body and vital for maintaining good health.

Increased shrimp production results in enhanced nutritional security and growth of the aquaculture sector, leading to greater employment opportunities and increased purchasing power. The expansion of aquaculture production improves the livelihoods of impoverished communities by boosting the availability of nutritious food and creating employment and income opportunities. These benefits are both direct, for households farming aquatic products, and indirect, from increased employment within the aquaculture sector. Rural aquaculture plays a significant role in poverty alleviation. Small-scale household shrimp farming raises employment and income for rural populations, improving their living standards and providing food and nutritional security for the poor and vulnerable. One clear benefit of aquaculture is its ability to offer high nutritional and health benefits. Consuming shrimp, which has a superior nutritional profile compared to terrestrial meats and provides an excellent source of highly digestible animal protein, is advantageous for meeting dietary needs. This single food source can address many malnutrition disorders, and the development of the aquaculture sector will undoubtedly lead to improved food and nutritional security for the country.

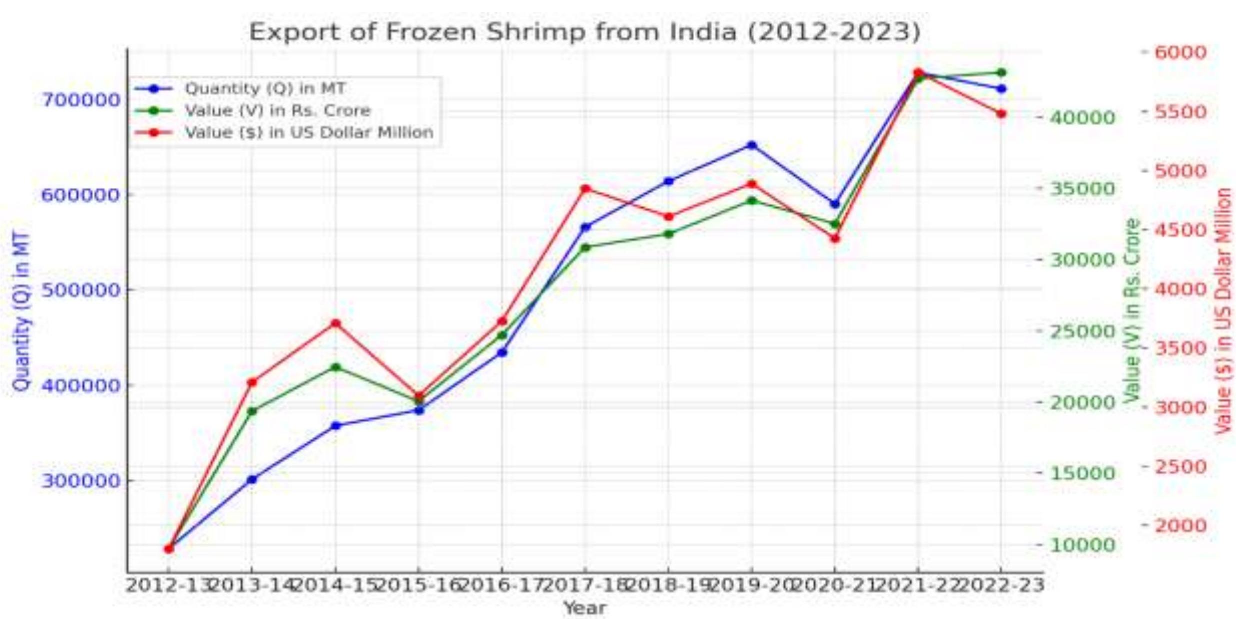
Table 8. Export of Frozen Shrimp from India.

(Q: Quantity in MT, V: Value in Rs. Crore, $: US Dollar Million)

Year	Quantity (Q)	Value (V)	Dollars ($)
2012-13	228620	9706.36	1803.26
2013-14	301435	19368.30	3210.94
2014-15	357505	22468.12	3709.76
2015-16	373866	20045.50	3096.68
2016-17	434486	24711.32	3726.38
2017-18	565980	30868.17	4848.19
2018-19	614145	31800.51	4610.59
2019-20	652253	34152.03	4889.12
2020-21	590275	32520.29	4426.19
2021-22	728123	42706.04	5828.59
2022-23	711099	43135.58	5481.63

[Source: Marine Products Export Development Authority (MPEDA)]

Figure 3. Export of Frozen Shrimp from from India (2012-2023)



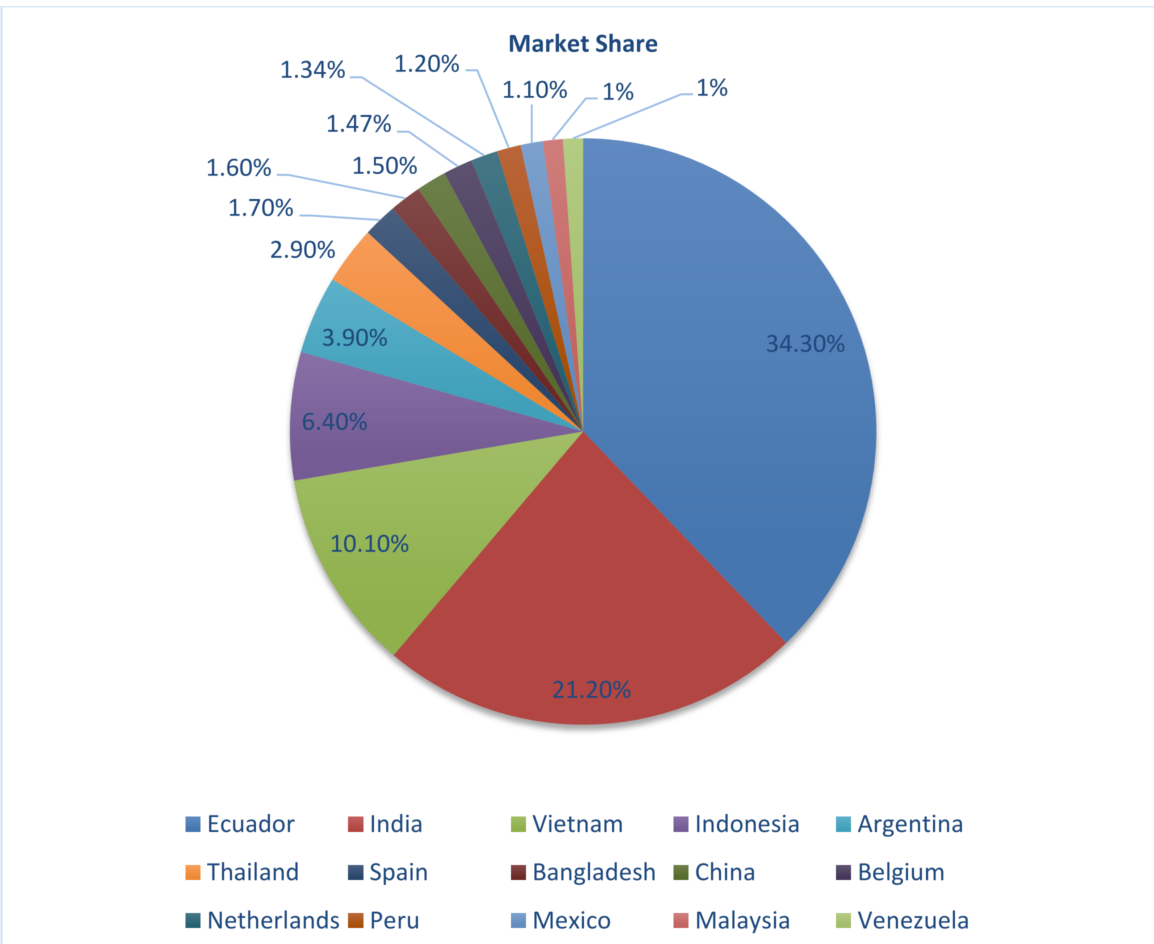
The following diagram shows the trends in Indian Frozen Shrimp export from 2012-2013 to 2022-2023 of export quantities (in MT), value in Indian Rupees (Rs. Crore) and the value in US Dollars (Million). The X-axis shows the years, whereas the primary Y-axis (left vertical axis) is the amount of shrimp exported which is marked by a blue line. Y-axis (right vertical axis) represents the green line, showing the value in Rs. Crore, and the tertiary Y-axis (far-right vertical axis) is the red line indicating the value in US Dollars. Although with a minor fluctuation the total sector shows a gradual rise in shrimp exports starting from 228,620 MT during 2012-2013 going up to a peak of 711,099 MT during 2022-2023 depicting increase in production and export capacity of the sector of shrimp. The value in Rs. Crore also is an upward rising trend, beginning from Rs. 9706.36 Crore in 2012-2013 to Rs. 43135.58 Crore in 2022-2023, and becoming steeper around 2017-2018, meaning shrimp prices or volume or both have increased. Similarly, the export value in US Dollars is in a strict upward trend, from $1803.26 million in 2012-2013 to $5481.63 million in 2022-2023, implying a positive relationship between Indian Rupee and US Dollar values. Although a dip in 2020-2021 suggests global market disruptions including COVID-19, the quantity and value increased by a substantial margin in 2017-2018. The aforementioned graph highlights how India has the scope to export even more and is a pertinent snapshot to various stakeholders, policymakers and economists seeking to understand the nuances of trade and commerce.

Tabel 9. Top 15 Shrimp Exporting Countries in 2022.

Rank	**Country**	**Export Value (USD)**	**Market Share**
1	Ecuador	$7.8 billion	34.30%
2	India	$4.8 billion	21.20%
3	Vietnam	$2.3 billion	10.10%
4	Indonesia	$1.5 billion	6.40%
5	Argentina	$890.2 million	3.90%
6	Thailand	$660.8 million	2.90%
7	Spain	$379.4 million	1.70%
8	Bangladesh	$356.2 million	1.60%
9	China	$342.7 million	1.50%

10	Belgium	$333.6 million	1.47%
11	Netherlands	$302.2 million	1.34%
12	Peru	$271.3 million	1.20%
13	Mexico	$252.8 million	1.10%
14	Malaysia	$233.9 million	1%
15	Venezuela	$226.1 million	1%

Figure 4. Market Share of Shrimp Exporting Countries



India has become a major player in the global shrimp export sector, securing second place behind Ecuador, leading exporting countries in shrimp. This is an interesting position to be, as the top 15 countries hold 90.8% of the market share within this trade, which suggests to a very high concentration amount of power and influence between only few countries. The United States is the largest global importer of shrimp at 342,572 metric tons, demonstrating significant demand within the country. This is followed by demand from China and the European Union, both of which are large markets for shrimp exports.

The remarkable gain that India has made in this domain is not by accident but a deliberate playing to the import strategies of the strategic markets like the USA, China, and the EU. These patterns significantly influence India's trade policies and assist in aligning the country's production and marketing processes with the needs, demands, and standards of major markets. The data reveals that the Indian strategy towards global shrimp markets is a composite process dealing with quality, cost efficiency and international market demand specifications. India being able to recognise and adapt to these dynamics of its major importers has not only expanded its economic influence but also shown the way to all other similar developing nations of not only venturing but also excelling in competitive global markets. This market oriented strategic alignment is part of the secret of the success of the shrimp industry in India and will provide the sustainability of India s shrimp industry to ultimately make a significant long-term contribution to the economic prosperity of the country. The large market shares of the top exporting countries, pulling India ahead, points at further expansion and larger impact in the future, provided these exporting nations remain focused on both quality and adaptability to a dynamic international environment.

Conclusion

In synthesizing the insights from our comprehensive analysis, it becomes evident that the strategic thrust of the Indian efforts in shrimp farming are critical in the globalising of aquaculture practices across the world congruent to the objectives established by the Food and Agriculture Organization (FAO) towards attaining sustainable food and Nutritional security. Our work demonstrates the significant contribution of India's shrimp farming in elevating itself amidst the global aquaculture community to meet future food security challenges articulated by the 1996 World Food Summit. Aquaculture, today providing more than half of all fish and shellfish consumed by humans, already plays a critical role in addressing rising demand for food, with the World Bank expected to contribute two-thirds of global fish consumption by 2030. The trajectory of India in aquaculture, particularly shrimp farming, clearly reflects a transformation of problems into potential and designates it as a major stakeholder in food security schemes for the future. The key takeaways of the suggestions forwarded for Indian aquaculture sector include stressing on technological developments, sustainable practices and stakeholder partnership. Precision aquaculture, sustainable cultivation, environmentally friendly aquaculture practices could thus raise higher productivity and environmental stewardship in India. They are key in enabling local communities, backed with appropriate policy and regulatory support to foster the sustainable growth of the sector. FAO figures show that aquaculture supports almost 43.5 million jobs globally, both directly and indirectly. Aquaculture has been identified as one of the most promising approaches for boosting global food and nutrition security, even though world aquaculture has already reached the production of fisheries maximum at the end of the 1980s and overexploitation pressures.

Implementing these strategies in an integrated manner will not only help India ensure national food security and nutrition but also serve as a catalyst in meeting the global demand for sustainable and nutritious food sources. Aquaculture is the future of food security and India has set itself as a part of global food production, paving the way for an inclusive food system that places aquaculture in the position as the stepping stone to a sustainable, food secure world. India's strategy to upscale shrimp farming is in sync with FAO's vision of sustainable aquaculture as an important pillar for ensuring global food security. This focus on technology adoption, R&D and sustainability in the Indian context is the classic case of best aquaculture practices that the global aquaculture industry should be emulating. India is focused on achieving the goals of not only aspiring to be a global leader in aquaculture, but also a national goal of no one going hungry – prioritizing environmentally responsible aquaculture through stakeholder engagement and market expansion. The move being forward-looking provide a clear message about India's - India's determination to solve beyond its shores as well as at its borders" The country being a flagbearer of innovative, sustainable and forward-thinking aquaculture initiatives is indeed a significant milestone in our transition to an ever more food-secure world ahead.

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