

# Production, export and competitiveness of fish and fishery products in India: An analysis across technology and policy phases

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## Abstract

India's marine product sector has seen significant growth, benefiting consumers, boosting foreign exchange earnings, and supporting livelihoods. This progress is attributed to the research and development (R&D) efforts, developmental efforts supportive institutional and policies. The Government of India has implemented targeted schemes to enhance fish production and exports, drawing from past experiences to inform future strategies. This study identifies five structural breaks in fish production and exports, coinciding with shifts in technology, policy, and institutions. From 1980–81 to 2023–81, national fish production increased annually by 6.3% for inland fish and 2.4% for marine fish. However, production performance varied widely across states. The study examines export performance in terms of growth, instability, and competitiveness, revealing variations across product groups and structural break periods since 1995. Although marine products exports show competitiveness according to revealed comparative advantage (RCA), this advantage has diminished over time. Granger causality analysis indicates a bidirectional causation between fish production and exports, emphasising the importance of comprehensive R&D and policy interventions along the value chain. The study underscores the critical role of enhancing production and value addition through favourable R&D and policies to sustainably boost fish production and its value.

## Introduction

The fisheries sector has been a cornerstone of the Indian economy, playing a pivotal role in its growth and development. In 2024-25, India produced 19.8 million t of fish, of which 1.3 million t were exported, consolidating its position as a major player in the global market (Gol, 2020). This accounted for approximately 8% of global fish production and 3.9% of global marine product exports. The significance of fisheries in ensuring food security and nutrition is widely recognised (Belton and Thilsted, 2014), with fish serving as a vital source of high-value protein, essential amino acids, fatty acids (including omega-3), minerals, and vitamins (Mohanty *et al.*, 2014, 2016). Notably, 45.8% of men and 35.1% of women in the age group of 15–49 years in India consume fish in 2019-21, as per the National Family Health Survey -5 (IIPS, 2021), underlining its importance in the dietary habits of the population. India is home

to approximately 28 million fishermen (Gol, 2020), highlighting the sector's substantial contribution to employment.

The fisheries sector's contributions extend beyond food security, encompassing economic prosperity and foreign exchange earnings. Marine products have been a significant source of foreign exchange, contributing around US \$7.45 billion (approximately ₹ 62 thousand crores) in the fiscal year 2024-25. Notably, the value of marine product exports surged five-fold between 1995 and 2022 (MPEDA, 2022). India holds a leading position in shrimp exports globally and ranks third in total marine product exports (FAO, 2021), attesting to its growing influence in international markets. These advancements in the fisheries sector owe them to several factors such as technological progress in fishing, aquaculture and value addition; policy shifts; institutional changes (in credit, marketing and insurance); and the establishment of input



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### Keywords:

Fish production, Granger causality, Marine exports, Research and development policy, Structural breaks

Received : 04.05.2024

Accepted : 27.03.2026

and output supply chains, to mention a few. These changes have facilitated the establishment of robust input and output supply chains, fostering the emergence of intricate value chains both domestically and internationally. Moreover, public sector initiatives, spearheaded by institutions like the Indian Council of Agricultural Research (ICAR) and various research institutes and fisheries universities, have provided crucial technical support and infrastructure development, particularly in coastal areas.

The private sectors' contributions lie mainly in the supply of inputs and several agro-services, including information. These developments have helped to promote the emergence of intricate value chains, both domestically and internationally. This enabled India to view the fishing and aquaculture sectors as critical to achieving the Sustainable Development Goals (SDGs) due to their connections with sustainable food systems, aquatic environments, and the livelihoods of the dependent population. Wider application of technologies, providing an enabling policy environment, and greater dynamism on the institutional front are key to attaining these targets. Looking ahead, the government of India has set ambitious targets to further bolster the fisheries sector. Achieving these targets necessitates broader adoption of technology, a conducive policy environment, and enhanced dynamism in institutional frameworks.

In this context, the current study aimed to identify structural breaks in Indian fish and shrimp production and exports, and trace their linkage to major shifts in technology, policy, and institutions; establish the causal relationship between production and export in the case of fish and shrimp; as well as sketch the performance of marine product exports in terms of growth, instability, and competitiveness.

## Materials and methods

### Identifying structural breaks in time series

The structural breaks in the production of fish and its export (both in quantity and value) were analysed following Bai and Perron (2003). For the analysis, a multiple linear regression model with  $m$  breaks ( $m+1$  regimes) with a minimum length of  $h$  is assigned to each segment.

$$y_t = x_t' \beta + z_t' \delta_j + u_t \quad (1), \quad j=1, \dots, m+1$$

where,  $y_t$  is the observed dependent variable at time  $t$ ;  $x_t$  ( $p \times 1$ ) and  $Z_t$  ( $q \times 1$ ) are vectors of covariates and  $\beta$  and  $\delta_j$  ( $j=1, \dots, m+1$ ) are the corresponding vectors of coefficients;  $u_t$  is the disturbance at time  $t$ . The breakpoints ( $T_1, \dots, T_m$ ), are explicitly treated as unknown (we used the convention that  $T_0 = 0$  and  $T_{m+1} = T$ ). The purpose was to estimate the unknown regression coefficients together with the breakpoints when  $T$  observations on ( $y_t, x_t, z_t$ ) are available. This is a partial structural change model since the parameter vector  $\beta$  is not subject to shifts and is estimated using the entire sample. When  $p = 0$ , we obtain a pure structural change model where all the coefficients are subject to change. The variance of  $u_t$  needs not to be constant. Indeed, breaks in variance are permitted provided they occur on the same dates as the breaks in the parameters of the regression. A detailed description of the model is provided in Suresh and Parappurathu (2018).

The breakpoints can be estimated by a grid search; however, it is computationally demanding when the number of breakpoints is

more than 2. Therefore, a dynamic programming algorithm which estimates the breakpoints as global minimizers of the sum of squared residuals was devised. In the study, the period of analysis was 1976-2020 and the minimum period of the segment was 6 years. Bayesian Information Criterion (BIC) was used to select the best combination of break points.

### Identifying structural breaks in time series

RCA is used to measure the competitiveness of exports. RCA, based on Ricardian trade theory, postulates the trade pattern between countries is based on their relative differences in productivity. Even though the productivity differences are difficult to observe, an RCA metric can be calculated with trade data to reveal such differences (Balassa, 1965). The lower costs of production are largely a function of comparative advantage in physical and capital endowments. Given a trade policy, the changes in the quality and composition of the human and capital endowments would bring forth shifts in the trade pattern (Balassa, 1986). The RCA can be measured by the formula:

$$RCA = \frac{(X_{ij}/X_{ik})}{(X_{nj}/X_{nk})}$$

where,

$X_{ij}$  = Exports of country 'i' of commodity 'j'

$X_{ik}$  = Exports of country 'i' of a set of commodities 'k'

$X_{nj}$  = Exports of a set of countries 'n' of commodities 'j', and

$X_{nk}$  = Exports of a set of countries 'n' of a set of commodities 'k'

RCA value greater than unity indicates the economy's international competitiveness in a particular commodity (UNCTAD, 2022). RCA for shrimp and fish exported from India were calculated using the formula:

$$RCA_{Shrimp} = \frac{\text{Shrimp export from India/ Total fish export of India}}{\text{Global shrimp export/ Global fish export}}$$

$$RCA_{Fish} = \frac{\text{Fish export from India/ Total agricultural export of India}}{\text{Global fish export/ Global agricultural export}}$$

### Growth and instability in the export of fish and fish products

Export growth was computed by using a semi-log growth model (Gujarati, 2004). The instability estimator of a time series data has to satisfy two properties viz. comparability across data sets having different means and should be devoid of the trend elements in the data set (Chand and Raju, 2009). Accordingly, the methodology proposed by Ray (1983) was used to estimate the instability. The instability index was calculated as:

$$\text{Instability index} = \text{Standard deviation of } \ln(Y_{t+1}/Y_t) * 100$$

where  $Y$  is the export of fish,  $t$  represents the current year,  $t+1$  corresponds succeeding year. When there were no deviations from the trend, the ratio of  $Y_{t+1}/Y_t$  is constant and thus the standard deviation is zero. As the series fluctuates more, the ratio of  $Y_{t+1}$  and  $Y_t$  also fluctuates more, and the standard deviation increases.

## Granger causality test

An important consideration was to identify the cause-effect relationship between fish production and exports. The presence of an external market has remained one of the major drivers for domestic fish production. Granger causality test (Granger, 1969) postulates that a variable (exports) is said to Granger cause another variable (catch) if the past and the present value of one variable (exports) helps to predict the other variable (catch). As opposed to the classical regression, where the dependent variables are predicted based on one or more independent variables, the Granger causality framework uses the values of the independent variables from both previous years and current years. For this study, the Granger causality test involving two variables, exports (E) and catch (C) can be expressed as:

$$E_t = \sum_{j=1}^p \alpha_j E_{t-j} + \sum_{j=1}^p \beta_j C_{t-j} + u_t$$

$$C_t = \sum_{j=1}^p \eta_j E_{t-j} + \sum_{j=1}^p \gamma_j C_{t-j} + v_t$$

The null hypothesis to be tested is:

$H_0: \eta_j = 0, j = 1, 2, \dots, p$ , which means exports do not Granger cause catch

$H_0$  (reverse):  $\beta_j = 0, j = 1, 2, \dots, p$  which means catch do not Granger cause exports

Traditional F test for testing Granger causality among variables have been used in several previous studies (Darat, 1996; Pompanio, 1996; McCarville and Nadozie, 1995). If the variables under study are integrated to the order one 1(1) and cointegrated these traditional F test do not hold good (Engle and Granger, 1987).

If the variables are 1(1) and cointegrated, Granger causality should be done based on Error Correction Model (ECM) which can be expressed as:

$$\Delta E_{t-1} = \sum_{j=1}^p \alpha_j \Delta E_{t-j} + \sum_{j=1}^p \beta_j \Delta C_{t-j} + \theta_1 \varepsilon_{1t-1} + u_t$$

$$\Delta C_{t-1} = \sum_{j=1}^p \eta_j \Delta E_{t-j} + \sum_{j=1}^p \gamma_j \Delta C_{t-j} + \theta_2 \varepsilon_{2t-1} + v_t$$

where  $\varepsilon_{1t-1}$  and  $\varepsilon_{2t-1}$  are the lagged values of the error term from the following cointegration equations:

$$E_t = \delta + \theta C_t + \varepsilon_{1t}$$

$$C_t = \alpha + \psi E_t + \varepsilon_{2t}$$

As the first step, the variables under study, i.e. the time series on exports and catch for both shrimp and total fish (including shrimp) were subjected to Augmented Dickey-Fuller (ADF) test, to test the stationarity of time-series data.

The Engle-Granger test which tests the null hypothesis that the two or more time series which is 1(1) are not cointegrated was performed. An econometric methodology which corrects for autocorrelation and endogeneity parametrically using a Vector Error Correction Model (VECM) specification was used. Defining a vector  $x_t$  of 'n' endogenous variables, it is possible to specify the data generating process and model  $x_t$  as an unrestricted autoregression (VAR) involving up to k- lags of  $x_t$  specified as:

$$x_t = \mu + A_1 x_{t-1} + \dots + A_k x_{t-k} + \varepsilon_t, \quad u_t \sim \text{IN}(0, \Sigma)$$

where  $x_t$  is (nx1) and each of the  $A_i$  is an (nxn) matrix of parameters.

This is a system reduced form and each variables in  $x_t$  is regressed on the logged values of itself and all the other variables in the system. The above equation can be re-written as a Vector Error Correction Model as:

$$\Delta x_t = \mu + \Gamma_1 \Delta x_{t-1} + \dots + \Gamma_{k-1} \Delta x_{t-k+1} + \Pi x_{t-k} + \varepsilon_t$$

Where  $\Gamma_i = -(I - A_1 - \dots - A_i)$ , ( $i = 1, 2, \dots, p$ )

$\Pi_i = -(I - A_1 - \dots - A_k)$  where I is a unit matrix and  $A_i$  ( $i = 1, 2, \dots, p$ ) are coefficient vectors, p is the number of lags included in the system,  $\varepsilon$  is the vector of residuals which represents the unexplained changes in variables or influence of exogenous shocks.

The  $\Delta$  represents variables in a different form which are I(0) and stationary and  $\mu$  is a constant term.  $\Pi$  is a vector which represents a matrix of long-run coefficients and it is of paramount interest. The long-run coefficients are defined as a multiple of two (nxr) vectors, and  $\alpha$  and  $\beta'$  and hence  $\Pi = \alpha\beta'$ , where  $\alpha$  is a vector of the loading matrices and denotes the speed of adjustment from disequilibrium, while  $\beta'$  is a matrix of long-run coefficients so that the term  $\beta x_{t-1}$  in the above equation represents up to (n-1) cointegration relationships in the cointegration model.

## Data

Data regarding the production and export of total shrimp, total fish and total agricultural products were collected from FAOSTAT and FishStatJ (FAO, 2021, 2022). For analysis of the trend in growth rate and instability, data on product-wise and market-wise exports of fish from India during the period 1995 to 2020 were sourced from MPEDA (2022). The FAO data on export from 1976 to 2019 were used for RCA analysis. Data on fish and shrimp production were sourced from Gol (2020), MPEDA (2022) and FAO (2021, 2022), respectively. The analysis was based on secondary data and literature on key milestones in fisheries development in India. Data were limited to 2019-20, to avoid distortions associated with COVID-19 pandemic related fluctuations, as inclusion of post-2020 data may lead to deviation of results from the general trend.

## Results and discussion

### Trends in fish production

With an increase in fish production, from 0.75 million t in 1951-52 to 17.5 million t in 2023-24, a compositional change occurred such that the share of marine fisheries in total fish production reduced from 71% to 25%. The shift in favour of inland fish production owes to the development and popularisation of aquaculture technologies (both shrimp and fin fish), the availability of inputs like feed and trade policies.

At the national level, from 1980-81 to 2023-24, the production of inland and marine fish increased at an annual rate of 6.3 and 2.3 %, respectively. Fig. 1. provides the trend in fish production, disaggregated between inland and marine systems, for 1979 to 2023. Aquaculture, mainly using Indian major carps (IMCs; catla,

rohu, and mrigal), is the main driver of inland fish production. This mainly caters to the domestic market and direct food and nutritional security of the population. Shrimp produced is mostly exported.

The trend in production is reflected in exports as well. The share of fish exported hovered around 10% of total production in the year 2023. The total fish available to the domestic market for consumption was about 75-80% of total production (FAO, 2021).

### Structural changes in production and export

While the total fish production in India was driven by aquaculture of fin fish and shrimp, the exports were mainly driven by the latter. Therefore, the structural break analysis was carried out separately for total fish production as well as for export of total marine products and shrimp, for quantity and revenues. Stationarity was tested using augmented Dickey-Fuller (ADF) and KPSS tests on the time series. Once the stationarity assumption of the time series was rejected, the time series on total fish export values was made stationary using level differencing. Structural breakpoints in the mean and variance were estimated using Binary Segmentation, Segmented Neighbour method, and the PELT algorithm with the BIC information criteria. The data set covered the period from 1976 to 2020. To identify the structural breaks, an AR(1) regression model was generated using the residuals. The Quandt Likelihood Ratio (QLR) statistic was generated using the Fstats() command of the *strucchange* package in R. The results of the Bai and Perron (2003) test for multiple structural break points are provided in Table 1, and a summary of which is provided in Table 2.

The analysis was carried out using the data for the period 1976 to 2020 (45 years). In general, five break years, with an average break length of 6 years were obtained. The results for the total exports (value) are presented in Fig. 2, as a case example. On a generalisation of results, the years 1981-1983, 1988, 1994-1995,

2000-2002, and 2006-2009 saw structural breaks of various intensities. There are significant technological, economic, and political reasons for the structural breaks.

### Growth rate and instability in the export of fish and fish products from India

A disaggregated analysis of the marine products exported from 1995 to 2020 is provided in Table 3. The exports have grown from 0.29 million t in 1995-96 to 12.89 million t in 2019-20. The value of exports increased from US \$3.5 billion to US \$6.68 billion. In the year 2019-20, shrimp accounted for more than half of the total exports in volume and about three-fourths of the total revenue from marine products (Fig. 1).

The export of marine products has seen significant shifts with the introduction of trawl fisheries that have helped the harvest of marine shrimp (Kurien, 1985). The emergence of processing technologies accentuated the exports (Pillai and Katiha, 2004). The export of marine products has registered positive growth since its start in early 1990s, but a disaggregated analysis for the period, from 1995-96 to 2019-20 is provided in Table 3. Marine products from India registered a positive growth rate, with an overall annual growth of 7% in volume and 9% in value. The annual growth rate was the highest in the case of dried fish (14% in terms of quantity and 15.8% for value). During the entire period, shrimp remained the major commodity exported. The marine products exports have seen significant instabilities as well. Policies for marine products export have been relatively liberal with few licensing restrictions since the beginning. The trade reforms initiated in the 1990s seem to have further facilitated the export of fish and fish products from India (Kumar, 2004). Exports of dried fish, frozen fish and squid showed high degrees of instability, while global economic and financial fluctuations pose significant risks to the demand and price dynamics of fishery products.

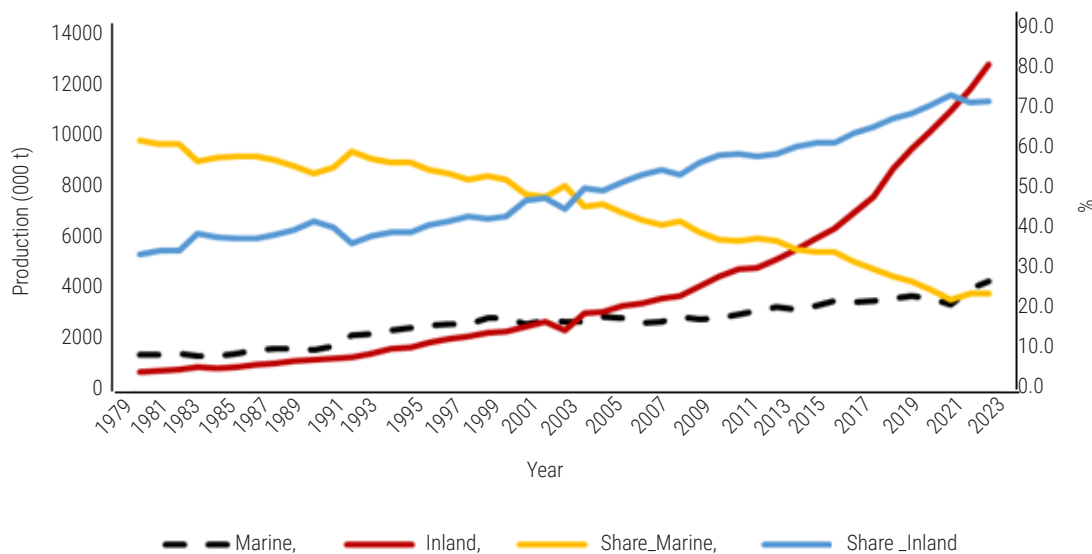


Fig.1. Trends in fish production in India (1979-2023)

Table 1. Results of the structural change analysis in the fish production and exports

Series	Number of breakpoints estimated (h=4)		Breakpoints				BIC
Total fish production	m=0						204.8
	m=1			2004			192.8
	m=2			2001	2008		191.3
	m=3			1994	2001	2008	198.1
	m=4		1985	1994	2001	2008	204.4
	m=5	1980	1985	1994	2001	2008	214.1
Total shrimp production	m=0						81.86
	m=1					2007	72.06
	m=2			1992		2007	78.68
	m=3			1992	2000	2007	85.03
	m=4		1986	1992	2000	2007	90.54
	m=5	1981	1988	1995	2001	2007	101.23
Quantity of total fish exports	m=0						106.07
	m=1					2006	112.97
	m=2		1987			2006	123.52
	m=3		1988	1994		2006	133.45
	m=4		1988	1994	2000	2006	144.40
	m=5	1982	1988	1994	2000	2006	155.59
Quantity of shrimp exports	m=0						28.55
	m=1					2006	23.94
	m=2			1996		2006	31.67
	m=3		1989	1995		2006	42.4
	m=4	1983	1989	1995		2006	53.13
	m=5	1983	1988	1994	2000	2006	64.89
Value of total exports	m=0						635.2
	m=1					2006	633.1
	m=2				2002	2009	643.9
	m=3			1992	2002	2009	654.6
	m=4		1988	1995	2002	2009	665.5
	m=5	1981	1988	1995	2002	2009	676.7
Value of shrimp exports	m=0						614.3
	m=1					2007	607.0
	m=2			1992		2007	617.8
	m=3			1992	2000	2007	628.7
	m=4		1986	1992	2000	2007	639.7
	m=5	1981	1988	1995	2001	2007	651.1

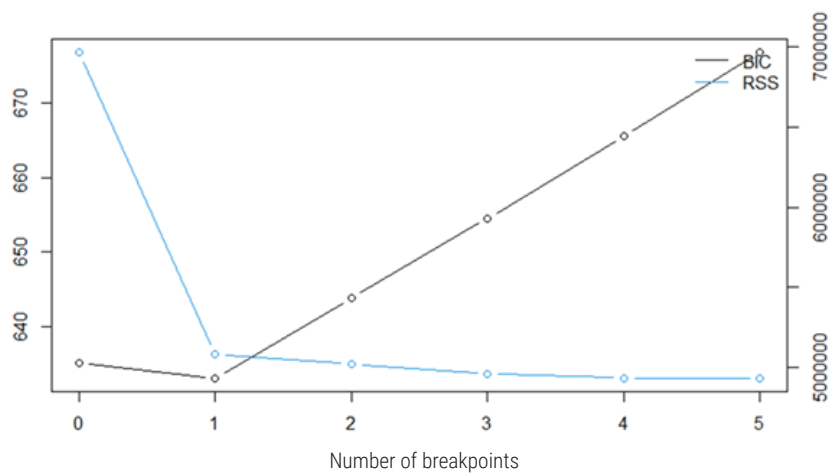


Fig. 2. Structural breaks in the export of total fish: Breakpoints in total fish export value time series (m+5)

Table 2. The break years, summarised from the structural break analysis in marine products exports (1976-2020)

Item	Year 1	Year 2	Year 3	Year 4	Year 5
Fish export (Quantity)	1982	1988	1994	2000	2006
Shrimp export (Quantity)	1983	1988	1994	2000	2006
Fish export (Value)	1981	1988	1995	2002	2009
Shrimp export (Value)	1981	1988	1995	2001	2007
Total fish production	1980	1985	1994	2001	2008
Total shrimp production	1985	1990	1995	2001	2005

## Shifts in technology and policy in fish production and exports

Traditionally, Indian fisheries depended largely on marine capture, which used traditional technologies with a large quantity of untapped potential for harvest (Kurien, 1985). Institutions undertaking research on fisheries were developed in the country even before independence, for example, Central Marine Fisheries Institute (CMFRI) and Central Inland Fisheries Institute (CIFRI). The R&D targeting fisheries got a fillip with the establishment of research institutions across the nation, immediately after independence, boosting the hitherto fisheries research being done by the Zoological Survey of India (Pillai and Katiha, 2002; Silas, 2003). Along with this, the development on the technological front by the Indo-Norwegian Project (INP) has resulted in the introduction and adaptation of trawls for Indian settings. Several trawl designs were developed, by the ICAR-Central Institute of Fisheries Technology (ICAR-CIFT), Kochi, an organisation under

the ambit of the Indian Council of Agricultural Research (ICAR), and were popularised (Gopal and Edwin, 2013). The export of the first consignment of shrimp from India occurred in 1953, with just 13 t (Vinay *et al.*, 2016). Since then, the export of shrimp from India has skyrocketed, aided by an increase in the unit price of shrimp for quite a long period (Immanuel and Narayanan, 2022). The export was facilitated by research on post-harvest aspects, processing and quality assurance by ICAR-CIFT and promotional activities by the Marine Products Export Development Authority (MPEDA), which was established in 1972. The early 1970s were also characterised by a gradual shift in India's fisheries research and development towards inland fisheries and aquaculture (Bavinck, 2001; Pillai and Katiha, 2004; Jeffrey *et al.*, 2022). The 1980s saw establishment of research institutions of aquaculture in brackish water, and fresh water environments. Further, fisheries colleges and universities were established for educational purpose in many parts of the country post-independence, including Central Institute of Fisheries Education in 1961.

Scientific composite carp culture technology was introduced during the 1970s. The developmental effort was strengthened by the launching of five All India Coordinated Research Projects by ICAR in the early 1970s. Associated with the strategies to accelerate the credit flow, the aquaculture sector came into prominence. This continued till the end of the fifth five-year plan. This period also saw the issues of reduction of the stock of marine shrimp, as reflected in reduced productivity.

The first structural break in the data is seen in the year 1981-82, which coincided with the midway of the sixth five year plan (FYP). The budgetary outlay of the fisheries sector increased

Table 3. Trends in export growth and instability of marine products by category and structural break periods (1995-96 to 2019-20)

Particulars (1)	Export (t)				Growth (% year <sup>-1</sup> )				Instability (%)			
	1995-96 (2)	2000-01 (3)	2006-07 (4)	2019-20 (5)	1995-2000 (6)	2000-2006 (7)	2006-2020 (8)	1995-2020 (9)	1995-2000 (10)	2000-2006 (11)	2006-2020 (12)	1995-2020 (13)
Frozen shrimp	95724 (2356)	111874 (985)	137397 (997)	652253 (4889)	2.5 (3)	4.3 (0.1)	15.4 (16.8)	7.9 (8.6)	6.1 (9.1)	5.9 (10.5)	11.3 (20.9)	9.7 (17.4)
Frozen fish	100093 (372)	212903 (192)	270751 (321)	223318 (513)	0.7 (-3)	-3.9 (2.6)	1 (5.1)	4.1 (8.6)	45.6 (39.3)	29.3 (28.6)	18.7 (18.9)	27.1 (24.2)
Frozen cuttle fish	33845 (260)	33677 (63)	55701 (175)	70906 (286)	0.2 (-5.8)	8.9 (15.9)	2.3 (4.7)	3.8 (7.9)	11.1 (19.7)	14.1 (16.4)	14.6 (18.8)	13.7 (18.3)
Frozen squid	45025 (319)	37628 (71)	47252 (126)	87631 (314)	-7.1 (-9.5)	6.5 (13.1)	6.3 (9.7)	4.9 (8.1)	9.9 (12)	9.8 (11.8)	22.6 (24.4)	18.5 (20.8)
Dried items	7506 (44)	7532 (15)	24293 (40)	84417 (140)	-6.1 (-8.3)	12.2 (18.1)	9.4 (6.9)	14 (15.8)	34.8 (13.6)	25.6 (28.6)	32.6 (39.1)	30.5 (33.8)
Live items	1756 (21)	1844 (8)	2478 (14)	7287 (46)	-0.3 (7.1)	8.1 (9.5)	8.8 (10)	7.4 (10.1)	23.6 (30.9)	13.4 (12.6)	21.7 (17.3)	19.7 (18.1)
Chilled items	2773 (26)	3820 (15)	7200 (26)	21202 (90)	7.5 (7.7)	6.2 (3.7)	6.2 (10.3)	13.3 (14.3)	53.8 (67.9)	14.2 (20.5)	41.5 (19.6)	37.5 (30.2)
Others	9555 (99)	31195 (64)	67571 (149)	142638 (397)	18.6 (9)	18.6 (14.8)	6.9 (7.3)	11.8 (12.5)	23.1 (28.6)	9.3 (12.4)	11.3 (17.2)	14.2 (17.8)
Total	296277 (3501)	440473 (1416)	612641 (1852)	1289651 (6678)	0.7 (0.9)	2.5 (3.4)	7.4 (12.4)	6.7 (9)	20.7 (12.1)	13.1 (11.9)	10.7 (14.2)	12.6 (13.2)

Source: MPEDA (2022)

Figures in parentheses under column 2-5 indicate values in million US\$.

Values under parenthesis under column 6-9 indicates growth in % per year of export growth; and those under 10-13 indicates instability in %.

from 3.52% to 5.62% of the total agricultural outlay in this plan. The phase continued till 1988. The flow of subsidies to the sector for infrastructure creation was accelerated, and emphasis was accorded to developing hatcheries and feed technology domestically. Commercial shrimp farms were started, and extension and other institutional support were provided to private parties on liberal terms and conditions (Immanuel and Narayanan, 2022). The whole effort has led to increased shrimp production in India and enhanced its export performance.

The phase since 1988 has seen heavy investment in the aquaculture sector, with a strong emphasis on export-oriented and intensive aquaculture practices. Efforts were also directed towards attracting private investment, particularly in brackishwater aquaculture. To support this development, ICAR established the Central Institute of Brackish Water Aquaculture (ICAR-CIBA) in the year 1987 to boost shrimp production. The period from 1988 to 1995 was characterised by several macro-economic challenges, mainly with respect to on the balance of payments front, making the acquisition of foreign exchange an important national priority. This phase also coincided with the liberalisation of the Indian economy and associated structural reforms, including the relaxation of several licencing requirements. During this period substantial investments were made in aquaculture and several large aquaculture projects were implemented (Immanuel and Narayanan, 2022), which helped to boost farmed shrimp production. However, the latter part of the year 1995, witnessed the emergence of viral diseases, particularly the disease caused by whitespot disease virus (WSV), which caused widespread mortality in shrimp stocks. This led to a subsequent decline in productivity. In addition, concerns related to environmental degradation, particularly land and groundwater pollution, were increasingly reported. Subsequently, the period 1995–2000, saw a faster spread of viral diseases that affected the entire shrimp farming industry in India. Several farmers and companies withdrew from shrimp aquaculture, leading to a fall in productivity and total production.

The period from 2000 to 2006 witnessed a lull in shrimp aquaculture. The establishment of the Coastal Aquaculture Authority (CAA) for monitoring aquaculture activities, and the introduction of exotic white leg shrimp, *Penaeus (Litopenaeus) vannamei*, a native of the Pacific Coast (Thitamadee et al., 2016), was an important step. Pilot studies with *P. (L.) vannamei* were a success and following this, broodstock of *P. (L.) vannamei* was introduced to produce specific pathogen-free (SPF) shrimps. The cultivation of *P. (L.) vannamei* started spreading throughout the coastal area. Other than being white spot resistant, the new species is suitable for high-intensity farming, environmentally less polluting, and highly productive. The subsequent period saw the spread of the new species in most of the states of India.

The period from 2006 to the present is characterised by the rapid expansion of shrimp aquaculture across India's coastal areas and its intensification. The Government of India undertook several promotional activities to augment aquaculture production of both finfish and shrimp. A major development during this phase was the promotion and widespread adoption of *P. (L.) vannamei*, which significantly transformed the sector. Another important shift was in the emergence and strengthening of input supply systems, with specialised firms providing SPF seed through hatcheries, along with formulated feed, medicine, chemicals, and technical advisory services (Immanuel and Narayanan, 2022). In addition, a large number of feed mills established, ensuring a steady supply of feed to the whole aquaculture industry.

Since 1971, induced breeding technology of various finfish species particularly Indian major carps (IMCs) received significant impetus, accompanied by advancements in hatchery seed production technologies. Beyond meeting export demands, these R&D efforts have improved the domestic supply of fish, benefiting consumers. Development of inland fisheries, particularly the contribution of aquaculture, has been noteworthy.

### Revealed comparative advantage (RCA) of marine products export from India

The analysis of RCA showed that India maintains a competitive edge in the export of marine products as well as total fish. The RCA remained above unity throughout the study period for both overall marine products and shrimp, emphasising its competitiveness (Table 4). A comparative advantage in shrimp exports has been reported in earlier studies as well (Pavitra et al., 2014). However, recent trends suggest a gradual decline in RCA values. This tapering could be possibly due to the increase in share of shrimp and fish exports from countries such as Ecuador, Vietnam, China, Thailand and Indonesia, where production has increased at a faster pace than that in India (FAO, 2022), perhaps with a reduced cost of production.

Another key aspect is the adherence to sanitary and phytosanitary (SPS) conditions. Though compliance with the SPS measures is costly, it is found to increase the returns in the long run. The number of Indian export consignments rejected by the importing countries has reduced over recent years (Geetha et al., 2020). Using aggregate rejection rate, unit rejection rate and relative rejection rate analysis, Suresh et al. (2025) noted that the export rejection from India came down during 2010–2020. The major causes of rejection were poor hygienic conditions (33% of the total consignments rejected), bacterial contamination (30%) and veterinary drug residues (25%). The role of public sector institutions, including ICAR, in creating a pool of trained manpower in major quality assurance systems like HACCP as well as in providing essential support to ensure compliance with SPS standards, is quite noteworthy.

Table 4. Revealed comparative advantage (RCA) of India in fisheries sector (1976–2019)

RCA (year <sup>1</sup> )		1976	1980	1990	2000	2010	2019
Fish	Value	1.85	1.65	1.41	2.24	1.36	2.07
	Quantity	20.94	17.87	7.99	4.54	3.22	6.16
Shrimp	Value	6.39	5.90	3.88		3.06	4.74

Source: Calculated by the authors

Table 5. Results of cointegration analysis

Engle-Granger test Alternative : Cointegrated	Engle Granger statistic Lag 3	p value
Shrimp catch and quantity of shrimp exports		
Type 1 – No trend	-3.5687*	0.011
Type 2 – Linear trend	-1.52	0.10
Type 3 – Quadratic trend	0.787	0.100
Shrimp catch and quantity of shrimp exports		
Type 1 – No trend	-4.31*	0.01
Type 2 – Linear trend	0.426	0.10
Type 3 – Quadratic trend	-0.571	0.100
Total fish catch and quantity of total fish exports		
Type 1 – No trend	-6.35*	0.01
Type 2 – Linear trend	1.81	0.10
Type 3 – Quadratic trend	-0.512	0.100
Total fish catch and quantity of total fish exports		
Type 1 – No trend	-6.34*	0.01
Type 2 – Linear trend	1.47	0.10
Type 3 – Quadratic trend	0.453	0.100

## Granger causality between production and export of fish and shrimp

The Engle-Granger test was performed to analyse the existence of cointegration between the production and exports of marine products. Analysis was undertaken for total marine products and shrimp separately. The Granger causality analysis results in Table 5 show that at a 1% level of significance, both the quantity and value of exports are cointegrated with the time series of catch on shrimp and fish.

Since the cointegration between the variables was established using the Error Correction Model, the direction of causality was explored. Table 6 gives the results of the Granger Causality test, which was performed between the exports (of shrimp and total marine products) and the production (of shrimp and marine products). The hypothesis of a production-led export boom has been established for shrimp as the Wald statistic computed based on both the past

three years and past five-year values, is significant at 5% level of significance in value terms and at 1% level of significance in quantity terms.

In the case of total marine product exports, when the time series on quantity and value of exports were subjected to the Granger causality test with total fish production/catch, an export-led increase in fish production and catch was established at a 1% significance level, based on past 3 year values of total fish exports. The reverse causality, *i.e.*, an increase in total fish catch has also led to an increase in the value of total fish exports when past 3 year data values were considered. Based on the past five year data values on the volume of total fish exports when Wald statistics were computed, it was observed that total fish exports Granger caused an increase in the total fish catch at 1% level of significance. Therefore, it can be observed that there is bidirectional causality between the total fish catch and exports in general.

The results provide some important insights for the research and development of marine fisheries. Production and exports have a bidirectional causality, wherein increased production leads to exports, and expanding export demand in turn stimulates further production. Therefore, R&D that promotes both production and export is of critical importance. It could be safely anticipated that the investment in R&D in fisheries in public and private sectors could have led to the production and export of marine products. The research policy has to focus both on production/harvest and post-harvest management, including processing and quality assurance. Historical experiences with respect to the risks associated with zoonotic diseases in fish and shrimp in inland waters along with related sustainability issues, provides valuable insights for fisheries management. In this context, the adoption of responsible fisheries practices emerges as the major strategy to reduce the unsustainability in marine ecosystems.

The production, domestic supply and exports of fish and fish products in the country have improved over recent years, coinciding with shifts in technologies, policies and consequent developmental activities. The investment in R&D, collaboration with technology partners; and, creation of an input supply chain has yielded rich dividends. The Granger causality analysis has established a bidirectional

Table 6. Results of Granger causality test

H <sub>0</sub>	Order =3		Order=5	
	Wald statistic	Probability	Wald statistic	Probability
Value of exports and catch				
Shrimp exports (Value) does not Granger-cause Shrimp catch (Value)	1.0496	0.384	1.6827	0.176
Shrimp catch (V) does not Granger-cause Shrimp exports (V)	5.3292**	0.004	4.601**	0.004
Total fish exports (V) does not Granger-cause Total fish catch (V)	4.1063*	0.014	6.1104*	0.001
Total fish catch (V) does not Granger-cause Total fish exports (V)	4.1848*	0.013	2.2247	0.083
Quantity of exports and catch				
Shrimp exports (Q) does not Granger-cause Shrimp catch (Q)	0.3327	0.802	0.3525	0.876
Shrimp catch (Q) does not Granger-cause Shrimp exports (Q)	4.5647*	0.009	2.7113**	0.032
Total fish exports (Q) does not Granger-cause total fish catch (Q)	2.0209	0.131	5.4883*	0.002
Total fish catch does (Q) does not Granger cause Total fish exports (Q)	1.6877	0.190	1.1879	0.343

\* Indicates 1% level of significance

\*\*Indicates 5% level of significance

causality between the production and export of marine products. The competitiveness, which takes into consideration several underlying factors into it, including productivity and value addition, has shown that India is competitive, but the competitiveness has not improved over years. Since the comparative advantage occurs in a relative sense, it could be because of the improved performance of the competing countries. This warrants India to augment fish production to meet both the domestic and export demand. Expansion of area under aquaculture, sustainable marine fisheries, improving productivity, and augmenting value addition is key to addressing the demand of both domestic and export markets.

## Acknowledgements

The authors wish to thank the Director, ICAR-CIFT, Kochi, for the institutional support.

## References

- Bai, J. and Perron P. 2003. Computation and analysis of multiple structural change models. *J. Appl. Econom.* 18 (1): 1-22. <https://doi.org/10.1002/jae.659>.
- Balassa, B. 1965. Trade liberalization and revealed comparative advantage. *Manch. Sch. Econ. Soc. Stud.*, 33 (2): 99-124. <https://doi.org/10.1111/j.1467-9957.1965.tb00050.x>.
- Bavinck, M. 2001. *Marine resource management: Conflict and regulation in the fisheries of the Coromandel Coast*, Sage Publications India Pvt. Ltd., New Delhi, India, 394 p.
- Belton, B. and Thilsted, S. H. 2014. Fisheries in transition: Food and nutrition security implications for the global South. *Glob. Food Secur.*, 3(1): 59-66. <https://doi.org/10.1016/j.gfs.2013.10.001>.
- Darat, A. E. 1996. Trade and development: The Asian experience. *Cato J.*, 6, (2): 695-699.
- Engle, R. and Granger, C. 1991. *Cointegration and error correction: Representation, estimation, and testing*, In: Engle and Granger (Eds.), *Long run economic readings in cointegration*. Oxford University Press, New York, USA.
- FAO 2021. *Fisheries statistics*. Food and Agriculture Organization of the United Nations, Rome, Italy. Available at: <https://www.fao.org/fishery/en/statistics/software/fishstatj/en> (Accessed 22 December 2022).
- FAO 2022. *FAOSTAT*. Food and Agriculture Organization of the United Nations, Rome, Italy. Available at: <https://www.fao.org/faostat/en/#data> (Accessed 22 December 2022).
- Fayaz, M. and Ahmed, M. 2020. Fisheries exports of India: A constant market share analysis. *Indian Econ J.*, 68 (1): 29 - 39. <https://doi.org/10.1177/0019466220959572>
- Geetha, R., Ravisankar, T., Patil, P.K., Avunje, S., Vinoth, S., Sairam, C. V. and Vijayan, K. K. 2020. Trends, causes, and indices of import rejections in international shrimp trade with special reference to India: a 15-year longitudinal analysis. *Aquac. Int.* 28 (3) 1341-1369. <https://doi.org/10.1007/s10499-020-00529-w>.
- Gol 2020. *Handbook on fisheries statistics 2020*, Department of Fisheries, Ministry of Fisheries, Animal Husbandry and Dairying, Government of India, New Delhi, India.
- Gol 2022. *Export import database*, Director General of Commerce Intelligence and Statistics, Government of India, New Delhi, India.
- Gopal, S. T. K. and Edwin, L. 2013. Development of fishing industry in India. *J. Aquat. Biol. Fish.*, 1 (1): 38 - 53.
- Granger, C. W. J. 1969. Investigating causal relations by econometric models and cross-spectral methods, *Econom.* 37 (3): 424-438. <https://doi.org/10.2307/1912791>.
- IIPS 2021. *National Family Health Survey (NFHS-5), 2015-16*, IIPS, Mumbai, India India: Volume I. Mumbai: IIPS.
- Immanuel, J. J. and Narayanan, N. C. 2022. A brief history of blue revolution 2.0: Key drivers, actors and policies in the Indian context. *Econ. Political Wkly.*, 57 (24): 1-2.
- Kumar, A. 2004. Export performance of Indian fisheries: Strengths and challenges ahead. *Econ. Political Wkly.*, 39 (38): 4264-4270. <https://doi.org/10.2307/4415561>.
- Kurien, J. 1985. Technical assistance projects and socio-economic change: Norwegian intervention in Kerala Fisheries Development. *Econ. Political Wkly.*, 20 (25-26): A70-A88.
- McCarville, M. and Nadozie, E. 1995. Causality test of export-led growth: The case of Mexico. *Atl. Econ. J.*, 23 (2): 140-145. <https://doi.org/10.1007/BF02300439>.
- Mohanty, B. P., Ganguly, S., Mahanty, A., Sankar, T. V., Anandan, R., Chakraborty, K., Paul, B. N., Sarma, D., Syama, J. D., Venkateshwarlu, G. and Mathew, S. 2016. DHA and EPA content and fatty acid profile of 39 food fishes from India. *BioMed Res. Int.*, 2016 (14): 1-14. <https://doi.org/10.1155/2016/4027437>.
- Mohanty, B. P., Mahanty, A., Ganguly, S., Sankar, T. V., Chakraborty, K., Rangasamy, A., Paul, B., Sarma, D., Mathew, S., Asha, K. K. and Behera, B. 2014. Amino acid compositions of 27 food fishes and their importance in clinical nutrition. *J. Amino Acids.*, 2014 (7): 1-8. <https://doi.org/10.1155/2014/269797>.
- MPEDA 2022. *Export-import statistics*. Marine Products Export Development Authority, Kochi, India. Available at: [https://mpeda.gov.in/?page\\_id=438](https://mpeda.gov.in/?page_id=438) (Accessed 17 June 2022).
- Navghan, M. and Kumar, N. R. 2017. An empirical assessment of indian seafood export performance and competitiveness. *Int. J. Pure Appl. Biosci.*, 5 (6): 329-336. <https://doi.org/10.9734/AJAES/2017/37967>
- Pavithra, S., Ananthan, P. S. and Krishnan, M. 2014. Market shares, instability and revealed comparative advantage of seafood exports from India. *Indian J. Fish.*, 61(4): 90-97
- Pillai, N. and Katiha, P. K. 2004. *Evolution of fisheries and aquaculture in India*, ICAR-Central Marine Fisheries Research Institute, Kochi, India, 12 p.
- Pomponio, X. Z. 1996. A causality analysis of growth and export performance. *Atl. Econ. J.*, 24 (2): 168-176. <https://doi.org/10.1007/BF02299007>.
- Rajani, M. and Balasubramanian, A. 2020. Analysis of structural changes in the production of shrimp and scampi from certain states of India. *Int. J. Recent Sci Res.*, 11(08): 39504-39508. <https://doi.org/10.24327/ijrsr.2020.1108.5516>.
- Serin, V. and Civan A. 2008. Revealed comparative advantage and competitiveness: A case study and Turkey towards the EU. *J. Econ. Soc. Res.*, 10 (2): 25-41. <http://jesr.journal.fatih.edu.tr/jesr.serin.civan.pdf>.
- Silas, E. 2003. History and development of fisheries research in India. *J. Bombay Nat. Hist. Soc.*, 100 (2-3): 502-20.
- Suresh, A. and Parappurathu, S. 2018. Capital formation in fisheries sector in India: Trends, compositional changes and potential implications for sustainable development. *Agric. Econ. Res. Rev.* 31 (2018): 111-122. <https://doi.org/10.5958/0974-0279.2018.00027.7>.
- Suresh, A., Sabu, S. S., Kishore, P., and Panda, S. K. 2025. Non-tariff measures and export of marine products from India: Trends and future prospects. *Curr. Sci.*, 128(4): 373-380. <https://doi.org/10.18520/cs/v128/i4/373-380>.

Thitamadee, S., Prachumwat, A., Srisala, J., Jaroenlak, P., Salachan, P. V., Sritunyalucksana, K., Flegel, T. W. and Itsathitphaisarn, O. 2016. Review of current disease threats for cultivated penaeid shrimp in Asia. *Aquaculture*, 452 (2016): 69-87. <https://doi.org/10.1016/j.aquaculture.2015.10.028>.

UNCTAD 2022. *Revealed comparative advantage (RCA)*. United Nations Conference on Trade and Development, Switzerland. Available at:

[https://unctadstat.unctad.org/en/RcaRadar.html#:~:text=Revealed%20comparative%20advantage%20\(RCA\)%20is,their%20relative%20differences%20in%20productivity](https://unctadstat.unctad.org/en/RcaRadar.html#:~:text=Revealed%20comparative%20advantage%20(RCA)%20is,their%20relative%20differences%20in%20productivity) (Accessed 24 June 2022).

Vinay, A., Kumar, R., Rahangadale, S., Kumar, B.T.N., Azeez, P.A., and Kumar, D.K. (2016) Indian Seafood Export: Trends, Forecast and Market Stability Analysis. *Indian Journal of Ecology*, 43 (Special Issue 2), 793-796.