Marine Fish Supplies and Food Security in India

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Abstract

We examine the role of marine fisheries in food and nutritional security in India, focusing on Karnataka. We pool data from various sources and analyze them using descriptive and econometric analysis. Results indicate stagnating/declining catches of important species, rising seafood exports, and inelastic response of marine fish supply to changes in price, all of which imply reduced availability of fish for local markets. We find positive correlation between fishers' income and landings of commercially important species, which has implications for fishers' own food security. Government policies that promote seafood exports need to be revised to exclude domestically important species.

Keywords

Food security, fisheries, small-scale fisheries, supply elasticity, sustainability

JEL Codes

Q11, Q18, Q22

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1. Introduction

India ranked 71st out of 113 countries in the Global Food Security Index (GFSI) in 2020, improving the position by one rank from 2019 (The Economist Intelligence Unit, 2021). The GFSI considers mainly four broader parameters to measure GFSI, namely, affordability (income, vulnerability to price shocks and presence of support programs and policies), availability (sufficiency of food supplies, risks of supply disruption), and quality and safety (nutritional quality of the average diet and safety of food) and natural resources and resilience (exposure to the impacts of climate change, resource risks and capacity to adopt to these risks. Achieving food security requires that all the conditions i.e., availability, access and utilization are sufficient and stable over time (World Food Summit, 1996).

Typical traditional Indian diet is predominantly cereal-based (Tak, Shankar and Kadiyala 2019). Government policies since the country's Independence prioritized boosting the production of food grains such as cereals (rice, wheat), and the lentils. As a result, India achieved self-sufficiency in the production of carbohydrate-rich plant-based food items, whereas production of animal-sourced foods has not seen similar success. However, with increasing per capita income, population growth, and urbanization, the Indian food basket is witnessing greater inclusion of animal-sourced foods[1]. Reardon and Minten (2011) note that the share of cereals in India's food economy in 1972 was 52 percent, which declined to 29 percent by 2006. Non-grain foods such as pulses, fruits, vegetables, dairy, meat and fish thus form over 70 percent of India's food consumption, and hence are important for food and nutritional security.

In the Indian context, fish can be described as one of the most affordable nutrient-dense foods (Mohanty et al., 2019). Though national per capita fish consumption in India is comparatively very low, there are population segments such as the coastal populations (Bhatta, Sagarad and Rao 2000; Bhatta and Rao 2003; Ravikanth and Kumar 2015), the Northeastern states (Barman, Mandal and Kumar 2012), and low-income urban households (Jyotishi et.al., 2021) for whom fish is an important dietary component. India exported seafood worth USD 6.68 billion in the year 2019-20, earning valuable foreign exchange. In the last five years, the fisheries sector (primarily through aquaculture, i.e., farming of aquatic products) has shown the highest growth within the agriculture and allied sectors, providing employment, food and nutritional security and income to millions of Indians. Realizing the potential of the fisheries sector in achieving food security and revenue generation, the Government of India has undertaken a slew of initiatives to develop the fisheries sector. The Blue Economy initiative recognizes *Marine Fisheries, Aquaculture and Fish Processing* as one of the seven priority areas (Government of India 2020). In 2019, the Government of India created a separate ministry for Animal Husbandry, Dairying and Fisheries, and a Department of Fisheries

[1] Bennett (1954) postulated that consumption of non-grain foods would increase disproportionately with increasing income, compared to carbohydrate-rich staples. However, as shown by Behrman and Deolalikar (1987), increasing income itself may not result in better nutrition for households.

(previously under the Ministry of Agriculture) to oversee the management of the fisheries sector.

Given this emphasis on the development of the fisheries sector, it would be useful to have a “baseline” estimation of the contributions of the sector in terms of food and nutritional security. This paper explores the prospects of marine fish supplies in contributing to achieve food security and its different dimensions, i.e., food availability, access, utilization and stability. In this study, we define food availability as the availability of sufficient quantities of marine food fish supplied through domestic production. Secondly, access refers to the ability of the people to buy fish at an affordable price. The utilization refers to the distribution of the marine fish supplies between edible and non-edible purposes. The stability of resources implies that the fluctuations in fish supplies for food is relatively less and would be available to individuals regularly. We explore these aspects in the context of Karnataka, one of the top fish-producing states of India, and discuss how our findings could be relevant for Indian fisheries.

2. Literature Review

2.1. The fisheries sector of India

India is the world’s second largest fish producer (11 million tons/year). The official estimated potential of fishery resources in India is 22.31 million metric tons (MMT), of which marine fisheries has 5.31 MMT (24%), and inland fisheries 17 MMT (76%) (National Fisheries Policy, 2020). The annual average value of fish production in India is US$ 11.46 billion out of which US$ 5.5 billion is exported and the share of marine capture is around 35 percent. According to the National Marine Fisheries Census of 2016 conducted by the Central Marine Fisheries Research Institute (CMFRI), there are around 3.8 million marine fishermen in India, of whom around 24.5% are active fishermen. About 67.3% of marine fisher families are below poverty line (BPL).

Figure 1 shows the percentage composition of India’s total production of aquatic products for the 1950-2019 period, broken down into the FAO-defined broad taxonomic categories and by the source of production (i.e., aquaculture and capture)[2]. The traditionally important categories- i.e., *Demersal Marine Fish* and *Pelagic Marine Fish*, together with *Crustaceans*- initially formed the bulk of India’s aquatic production. After contributing substantial shares during initial years of motorization and mechanization of the Indian fishing industry, these categories have seen a steady decline in their shares. Over the same period aquaculture production has expanded substantially. This is a global phenomenon in which aquaculture production outpaces and outgrows capture fisheries production. This probably implies that long-run marine capture fish

[2] Data source for Figure 1: FAO FISHSTATJ (2021). The abbreviation NEI in the figure stands for *Not Elsewhere Included*.

stock levels are overwhelmed by overfishing aided by the open-access nature of resources and excess capacity.

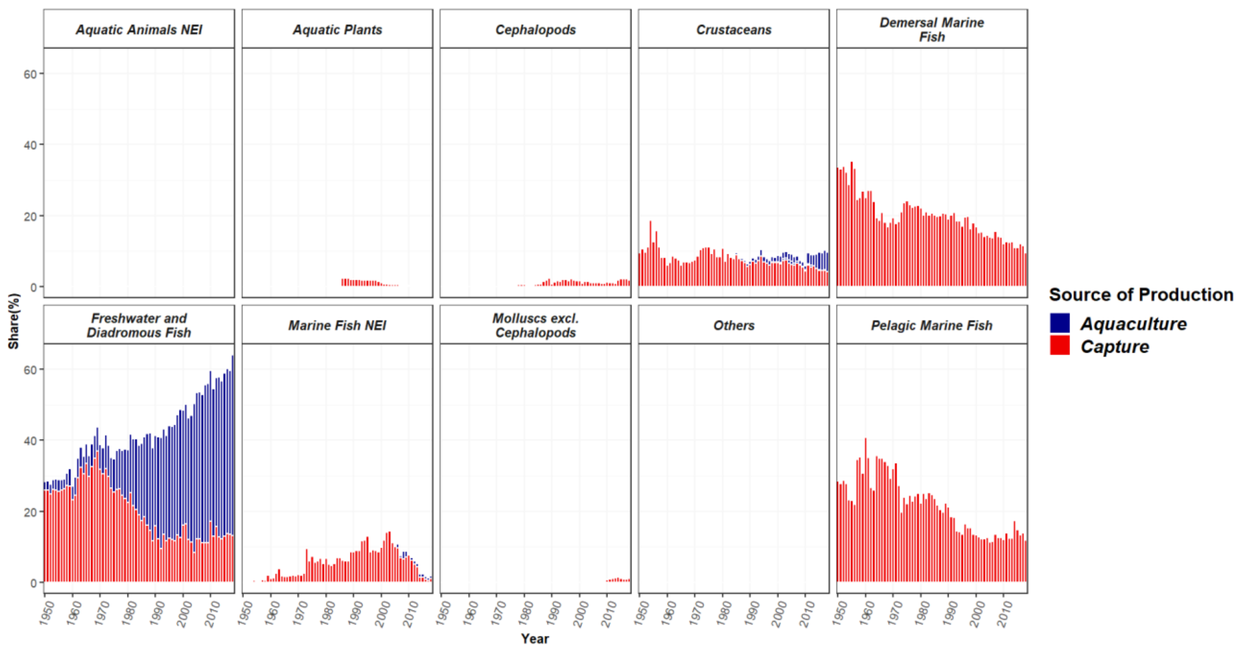

Figure 1. Percentage composition of aquatic production of India:1950-2019.

As shown in Table 1, mechanized fishing units are playing increasingly dominant role in marine fish production in India. Mechanized fishing units of India such as large trawlers are essentially in competition with small-scale fishers for the extraction of fishery resources of inshore waters, since the deep waters of India are unproductive and deficient in oxygen (Hornby et al. 2015). Mechanized trawling and light fishing are notorious for catching trash fish including juveniles and non-edible species of fish which were not targeted earlier. Estimated landing of low value bycatch (LVB) in trawl fisheries increased from 14 % in 2008 to 25 % in 2011 and increased to 35-40% in 2018. Non-edible catch consists of 237 species/groups of marine fauna including juveniles of commercially important fish, indicating loss of rich marine biodiversity. The landing center price for LVBs is on an increase due to increased demand for trash fish for the production of fishmeal/oil/surimi[3].

[3] With increasing mechanization, landings of trash fish have increased substantially over the years in Karnataka. Bhatta (2020) reports that trash fish landed in Mangaluru harbor by smaller boats (those fitted with 140 horsepower engine or lesser) is 81 kg/trip, medium sized boats (with 141 to 300 horsepower engines) is 974 kg/trip, and large boats (over 300 horsepower engine) is 2280 kg/trip. Trash fish are mainly purchased by fishmeal companies. Substantial increase in demand for fishmeal as an ingredient in livestock feeds has created lucrative market for trash fish.

Table 1. Fish landings in India over the years, by type of fishing unit.

Year	Total fishing units	Total marine fish landings (tons)	Mechanized		Motorized		Non-Motorized	
			Number of Units	Share in landings (%)	Number of Units	Share in landings (%)	Number of Units	Share in landings (%)
2005	2,38,722	17,69,175	58,911	69	75,591	26	1,04,220	5
2010	1,99,141	22,47,594	72,749	73	73,410	25	52,982	2
2018	2,69,047	34,87,614	2,03,118	81.3	66,198	17.4	65,876	1.3

Data source: Handbook on Fisheries Statistics, Government of India, various issues.

Fisheries, especially small-scale fisheries, provide a critical indirect pathway to enhanced food and nutritional security by generating regular revenue stream to fishing households. For small-scale fishers, fishing and allied activities such as dry-processing of fish may not be very high income-generating activities but often this income is critical in supporting their livelihood (Béné et al., 2015), apart from being source of nutritious fish for home consumption. Fishing households can sustainably increase their income by harvesting high value fish and receive remunerative prices. It is plausible that the revenue effect of reduced landings of high value fish on fishers' income is more than compensated by the higher prices. Further, declining share of high value fish in total landings could mean increased dependency of fishing units on trash/miscellaneous/ juvenile fish by resorting to destructive fishing practices to sustain their income and economic feasibility. This study assesses the relationship between the composition of fish landings, their prices, and fishers' income.

2.2. *Food security and the role of fish in India*

Role of fish in India's diet and nutritional contributions have not received the due research emphasis (Jyotishi et al., 2021), making it difficult to appreciate the challenges and opportunities facing the fishery sector vis-à-vis the food security question. Per capita annual fish consumption in India is 2.85 kg, which is one among the lowest by international comparison[4]. Projections up to 2030 by Kobayashi et al (2015) show the growth in fish consumption would be fastest in India owing to positive demand shifters such as population, rising per capita income and urbanization. However, contrary to expectations, per capita fish consumption in most Indian coastal states decreased between 1983 and 2009-10, with more marine fish harvests going to export markets than catering to domestic markets (Ravikanth and Kumar 2015). Karnataka recorded the steepest fall in Gini index for fish consumption inequality over the period.

[4] However, there is a large variation in per capita fish consumption among individual states of India. For example, while the annual per capita fish consumption in southern coastal state of Kerala is 22.7 kg, in the mountainous northern state of Himachal Pradesh it is only 0.03 kg (de Jong 2017).

There are severe deficiencies in logistics and infrastructure necessary for quality maintenance in seafood value chain in Karnataka/India[5] (Jyotishi et al., 2021). This prevents fish transportation across the length and breadth of the country, and only 5% of marine fish is transported beyond 200 kilometers distance from the landing centers (Sathiadas, Narayanakumar, and Behera, 1995). Inexpensive methods of fish preservation such as salting and drying have not received the due attention. Viswanatha et. al. (2015) describe the growth in Karnataka's capacity for producing frozen and refrigerated fish since 1970, even as the capacity to produce dried fish declined. Dried fish play an important role in the nutritional security of poorer sections of the society (Siddhanth et al., 2020). Dried fish are not only nutrient-dense and inexpensive to produce, but are also easier to transport and require less-sophisticated storage (Gopakumar 1995). Such low-carbon technologies need to be encouraged to facilitate better food and nutritional security through fisheries.

The role of governmental policies in allocation of fishery products among competing markets is highlighted in the case of Karnataka's mackerel fishery. The Indian mackerel (*Rastrelliger kanagurta*), a traditionally important fish consumed in Karnataka, is being exported in large quantities in recent years. A huge share of mackerel landings at major fishing harbors of Karnataka (Mangaluru, Malpe and Karawara) is either exported to global markets or goes to interstate trade (Aswathy et al., 2020), thus reducing availability of the fish for local consumption. A major factor in the uptick in mackerel exports appears to be the support extended by the Government of India through the export promotion program called the "Merchandise Exports from India Scheme" (MEIS) made effective from 1st April 2015 under the Foreign Trade Policy[6]. Thus, solutions to the fish food security challenge depends not only on production performance of the capture and aquaculture sectors, but also on other factors such as their ability to be sustainable, supply chain transformation, and policy interventions that promote investments in efficient market system.

Carp farming is the largest segment of Indian aquaculture in terms of quantity of production[7]. Almost all of the carps produced is consumed in the domestic market, thus contributing to food and nutritional security in the country. Everything else staying the same, fish availability in India would have been adversely affected if not for the growth of aquaculture (Figure 1). Aquaculture will continue to play an important role in India. Between 2010 and 2030, aquaculture production of India is likely to expand by over 100%, the largest in the world (Kobayashi et al 2015). The Blue Economy initiative of India can be expected to further accelerate the expansion of aquaculture. For

[5] As pointed out by Ravikanth and Kumar (2015), it is puzzling that India has the logistics and infrastructure to meet the stringent quality assurance required for export markets, whereas domestic fish markets mostly lack even basic facilities.

[6] MEIS is a duty scrip offered as a reward by the government to exporters of eligible goods, and the scrip may be used by the exporter for paying duties or taxes.

[7] Shrimp/prawn farming is important in terms of export earnings.

aquaculture to better contribute to food security this expansion must not become export-centric, and must diversify to meet the tastes and preferences of all domestic fish consumers including those who prefer marine fish.

Production from marine capture fisheries of India have increased over the years, aided by subsidization and technological advancements in fishing. However, there are concerns about decreasing catches of commercially important species and increasing catches of juveniles and undersized fish (Rao 2013; Hornby et al., 2015). There are serious deficiencies in monitoring (including collection and reporting of catch statistics) and regulation in the fisheries sector. Such deficiencies mask the true trends in the status of fisheries (Hornby et al., 2015), making it difficult to assess their contributions to human well-being. For example, contributions of subsistence fishing, i.e., small-scale non-commercial fishing, are not at all reported in the official statistics of India (Ganapathiraju, 2012). Hornby et al (2015) estimate that the subsistence fisheries segment contributed about 51 million tons to India's fish production during the 1950-2010 period, with substantial share from Kerala, Odisha, and West Bengal[8]. Similarly, in Karnataka there are several *beach landing centers* along the coast where small-scale fishers, especially non-motorized fishing units, bring in their harvests from near-shore waters. Such catches do not enter official fisheries statistics. By totally ignoring the contributions of this vulnerable sector, actual role of fisheries in food security, especially of poor and marginalized sections, goes unappreciated.

The marine fisheries sector's contribution, both actual and potential, to food security needs to be better investigated. In this paper, we evaluate the supply side of fish food security by analyzing the data on fish landings in India. Taking Karnataka as the focus, the paper presents the broad changes in the availability of marine food fish and its responses to price changes, affordability of marine fish for the local communities and its impact on the per capita income of the marine/coastal fishers determining their quality of life. Focusing on the recent years, the specific objectives of the study are as follows:

1. To analyze the trends in landings and utilization of the commercially important species, and their implications for fish availability in India;
2. To estimate the growth rate of marine fish price index and its impact on fish affordability; and,
3. To describe the relationship of fishers' income with the quantity landed and with the price of fish.

[8] This points to the importance of beaches, estuaries, backwaters, and creeks in providing valuable ecosystem services.

3. Conceptual Framework and Methodology

3.1. Hypotheses and Methods

Before moving to econometric modeling, we conduct graphical and numerical descriptive analyses to understand the patterns in fish availability, fish affordability, and the impact of fish prices and fish quantity landed on the income of fisher families. We analyze growth rates in landings of the commercially important species using a simple regression of the logarithms of landings of individual species on a time trend variable. Specifically,

$$ln\ Q\ = \delta_0 + \delta_1 Trend + v \qquad (1)$$

where ln is the natural logarithm function, Q is the species-wise annual total landings, δ_i are the parameters to be estimated, $Trend$ is the time trend variable, and μ is the error term. The coefficient of the trend variable, δ_1, can be used to calculate the instantaneous growth rate.

Given the objectives of this study, a conceptual relationship between the fish landings, marine price index and its economic implications on the fishing households is presented through statistical testing of the following three null hypotheses:

Hypothesis 1. There is no shift in the marine fish landings towards more trash fish and by-catches and lesser quantities of commercially important fish;

Contribution of fish in achieving food security depends on sustainable levels of fishing maintained over the long-run. However, declining share of edible species in total harvests is considered to be a major concern. We therefore are interested in a formal test for a shift (i.e., structural change) in the landings of commercially important species.

Hypothesis 2. The marine fish wholesale price index (MWPI) does not influence the landings of commercially important fish;

In this hypothesis, we are interested in the impacts of the own-price on marine fish supply, with the landings being used as proxy for supply of marine fish. Economic theory suggests a positive relation between price and quantity supplied. However, given the open-access nature of India's capture fisheries, fishing effort levels above the maximum sustainable yield (MSY) of fish stock in the long-run can lead to dwindling of the stock, thereby higher prices lead to lower production. This is the backward-bending supply curve of industrial fishing proposed by Copes (1970), where the own-price elasticity of supply is negative. Therefore, it may not be a surprising result to find a contradiction of the standard law of supply such that for capture fisheries there is a negative relation between price and quantity supplied.

Hypothesis 3. The impact of total landing of commercially important fish on MWPI is not significant.

This is essentially a test for the parameters of an inverse supply function, where the supply equation is normalized on the price variable, not the quantity.

To test the first and second hypotheses we estimate a regression model of the supply function assuming a logarithmic functional form as follows:

$$ln\ Q\ = \alpha_0 + \alpha_1\ ln\ ln\ MWPI\ + \alpha_2 D_1 + \alpha_3 D_1 * MWPI + u \qquad (2)$$

where ln and Q are as described above, $MWPI$ is the marine fish wholesale price index, D_1 is a dummy variable that takes a value of 1 for the years 2011 through to 2016 and are 0 otherwise[9], α_i are the parameters to be estimated, and u is the residual term independently and identically/Normally distributed with zero mean and a constant variance. The magnitude and statistical significance of α_1 can provide the own-price supply elasticity, a negative α_1 coefficient could be interpreted as indicative of backward-bending supply curve. We test the restriction that $\alpha_2 = \alpha_3 = 0$ to infer about the structural break in the equation from 2011 onwards.

For the third hypothesis, we estimate an inverse supply function as in equation (3):

$$ln\ MWPI\ = \beta_0 + \beta_1 ln\ Q\ + \beta_2 D_2 + \beta_3 D_2 * lnQ + \epsilon \qquad (3),$$

where the notations ln, $MWPI$, and Q are as previously described, β_i are parameters to be estimated, D_2 is a dummy variable which takes a value of 1 for years 2011 and later and a value of 0 otherwise, and ϵ are the residuals[10]. A joint test of $\beta_2 = \beta_3 = 0$ would show if there was a structural break in the relationship from 2011 onwards.

All analyses were conducted in the proprietary spreadsheet software Microsoft© Excel© and the open-source statistical software R (R Core Team 2021).

3.2. Data and construction of variables

We pooled the requisite secondary data from different sources. We collected the annual fish landings data of CMFRI for Karnataka that provide quantities landed for major fish categories. In the landings data, we combine the edible and commercially important fish species into an aggregate group. This category is composed of landings of Oil Sardine, Indian Mackerel, Pomfrets, Anchovies, Seer Fishes, Croakers, Ribbonfishes, Silverbellies, Bombay duck, Threadfin Breams, and Penaeid and Non-Penaeid Prawns. The landings data contain a fish category called "Miscellaneous" which goes for industrial utilization and not for direct human consumption. We create a third aggregate group of fish by summing up total landings of all other species (i.e., not included in the "Edible/Commercially important" and "Miscellaneous" groups), and call it "Others".

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[9] Visual inspection of the data showed a clear change in trend at 2011 (see Figure 2). Hence, we selected 2011 to test for break.

[10] The residuals u and ϵ are assumed to be independent. The models are estimated using the ordinary least squares (OLS) estimator.

The data on fish prices was obtained from the Central Statistical Office (CSO) of the Government of India. The nominal and constant NDDP for the three coastal districts of Karnataka (i.e., Dakshina Kannada, Udupi, and Uttara Kannada) was obtained from the Directorate of Economics and Statistics of the Government of Karnataka. The NDDP serves as a proxy to fishing households' net income[11].

To analyze the relationship between fish availability and affordability we first develop variables that can measure these constructs. Our measure of fish availability is the annual total landings of species that are mostly used for human consumption. We apply a broader definition to affordability as the cost of food, and measure fish affordability using the MWPI (excluding miscellaneous fish).

4. Results and Discussion

4.1. Marine Fish Production and Availability for Consumption

Figure 2 displays the total marine capture fisheries production of Karnataka over the 2005-2018 period (Panel A at the top), and the share of the three categories of fish in total marine landings for those years (Panel B at the bottom). Figure 1 shows that the total marine fish production grew from 2.29 million tons in 2005 to 3.48 million tons. Adoption of modern fishing methods has improved the ability to catch fish, leading to higher total production. During the same period the share of miscellaneous and other fishes have steadily increased from 37% in 2005 to almost 50% in 2018. Much of the increase in the production appears to be contributed by the miscellaneous and the other groups of fish, even as production of high value food fishes stagnated or declined. One interpretation of this pattern in fish landings is that Karnataka has reached maximum possible supplies of traditionally preferred species. Given the increasing population and per capita income, Karnataka can be expected to follow India in experiencing higher fish demand.

[11] The NDDP of a district is analogous to the Gross Domestic Product (GDP) that measures the size of economy of a country. NDDP is equal to the income generated by the production of goods and services within the geographical boundaries of a district. It is arrived at by netting the gross district domestic product by the consumption of fixed capital.

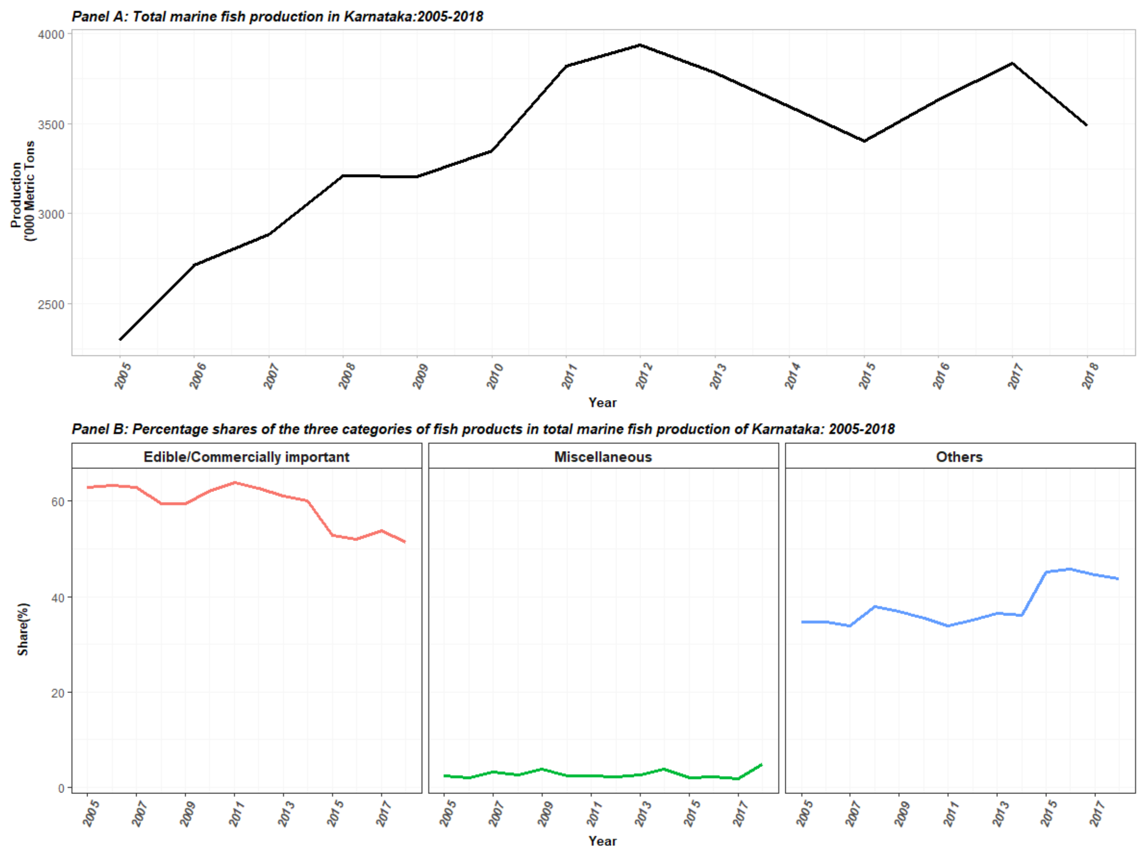

Figure 2. Marine fish production in Karnataka and its composition: 2005–2018.

Panel A of Figure 3 shows prices (unit values) of seafood exports of Karnataka, and Panel B shows the shares of exports in Karnataka's total marine fish production. The prices as well as shares of exports have increased sharply since around 2006-07, which implies less fish is available for domestic markets of the state. This supports the findings of Ravikanth and Kumar (2015) who argued that greater exports of marine fish is a cause of concern as it impacts domestic food security. Particularly in the absence of reasonable substitutes for marine fish, rising exports imply lesser fish for domestic consumers. As argued by Garcia and Grainger (2005), quantities of seafood exported from developing countries need to be compensated by augmented production of low-value aquaculture fish to ensure food security. However, consumers in coastal states of India have a stronger preference for marine fish (Ravikanth and Kumar 2015) which makes Karnataka's situation trickier to manage in terms of achieving food security as there are not many low-value marine fish species farmed in the state except may be some bivalves. An upshot of higher exports is that it could lead to better income to fishers and indirectly lead to better food security outcomes, but it is conditional on complete price transmission from the export market to fishers.

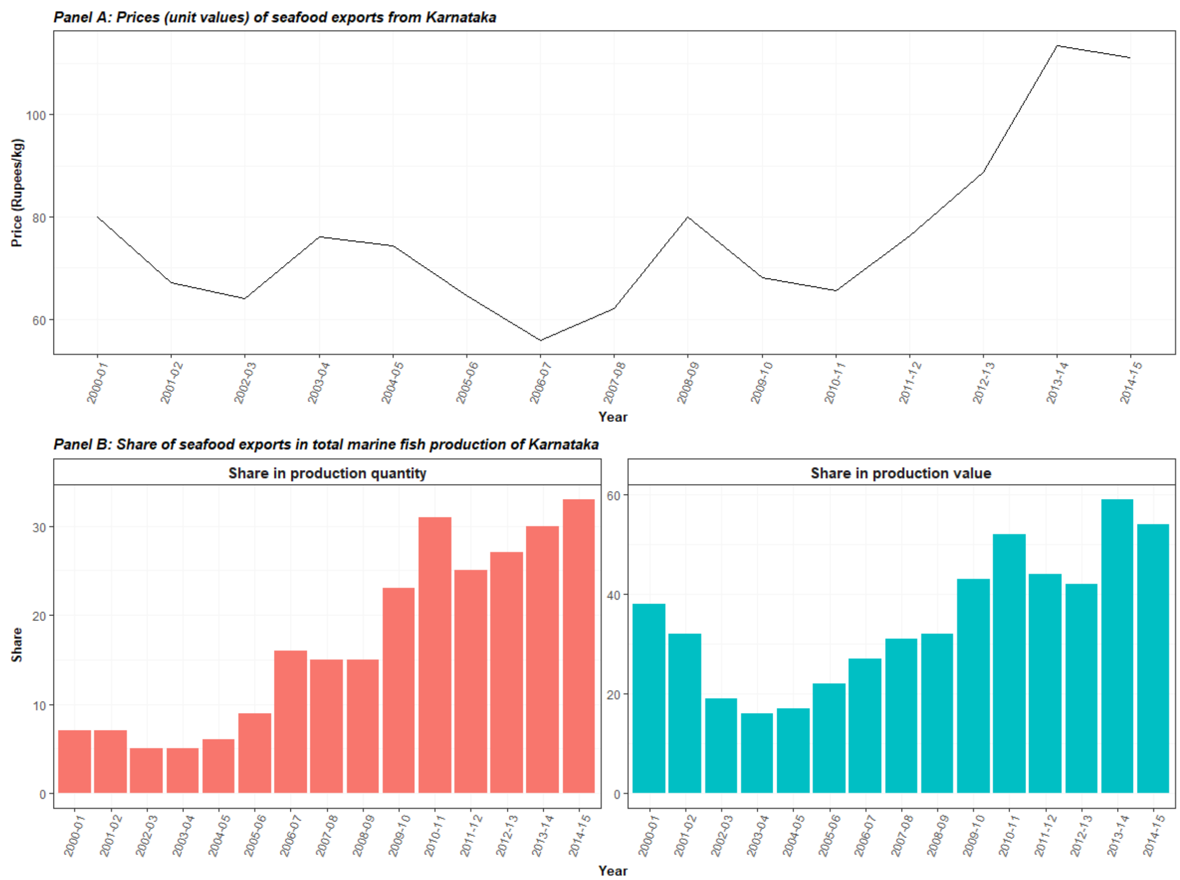

Figure 3. Exports of seafood from Karnataka: Prices and shares in total marine fish production.

In light of these findings, a promising development is the Blue Economy initiative of the Government of India (2020), which proposes regulatory mechanisms and improved monitoring to achieve sustainability in marine capture fisheries. Some such proposals are: bringing out a new national marine fisheries policy that provides legal and institutional frameworks for marine fisheries management; making it mandatory for fishers to enter fishing details through log sheets; tracking the location, method, and quantities of fish caught by boats through improved surveillance; improved fish stock assessment capacity; encouraging low-carbon fisheries; and, patrolling of high seas. The document also has provisions for promoting mariculture in the country. However, as described previously, formulated policies are only as good as their implementation in the field, and a *business-as-usual* approach would not bring positive changes.

4.2. Econometric Estimation of Marine Fish Supplies and Price Responsiveness

Table 2 shows the instantaneous growth rates of landings of the major species over the 2005-2016 period, estimated using equation (1). Landings of some species such as ribbonfish, and pelagic fish such as Indian mackerel, threadfin breams, and silverbellies- are showing higher growth rate. Lowest growth rates (less than 1% per year) can be observed for oil sardine, Bombay duck, pomfrets, and seer fish. The remaining species show moderate growth rates of 1%- 3% per year. Prawns, seer fish, and pomfrets are high value species and much of the landings are destined for the export market. Fall in landings of such high-value species can significantly impact fishers' income. Moreover, continued decline in catch of edible species would have implications for food security. Fall in catch of preferred species combined with higher exports would mean less fish for domestic consumers. As shown by Ravikanth and Kumar (2015) it is the lower income households that suffer the most if fish becomes less affordable. Aquaculture production would then become even more important in filling the gap between fish demand and supply, and in maintaining prices of fish at affordable levels.

Outputs from the estimation of equations (2) and (3) are presented in Table 4. Equation (2) is a supply function in logarithmic form that also tests for a structural break. The heteroskedasticity-adjusted joint test of parameters $\alpha_2 = \alpha_3 = 0$, with an F-ratio of 5.2503 and a p-value of 0.031. Therefore, we reject the hypothesis that $\alpha_2 = \alpha_3 = 0$ to infer that there was a structural break in the marine fish landings starting from 2011. This indicates a strong decline in the landings of commercially important species starting from 2011.

Table 2. Rate of growth of fish landings: 2005-2016

Species	Growth rate
Oil Sardine	-0.349
Ribbonfish	4.514
Penaeid prawns	1.541
Non-penaeid prawns	2.586
Croakers	2.733
Indian mackerel	5.293
Threadfin breams	5.149
Bombay duck	0.709
Silverbellies	6.534
Pomfrets	0.567
Anchovies	2.706
Seer fish	0.722

The estimated own-price supply elasticity is 0.2244, which is numerically close to the inelastic supply responses reported for other marine capture fisheries products (see for example, Pascoe and Mardle 1999 for temperate water fisheries; and Kumar, Dey and

Paraguas 2006 for Indian fisheries)[12]. In general, it is observed that supplies of capture fisheries products are less responsive to own-price changes than aquaculture products, since aquaculture offers better control over production and harvest- thus allowing quicker response to changes in price. It is not surprising that the supply elasticity is not negative. The positive relationship between capture fisheries supply and price can be explained by the expansion of fishing activities into deeper/offshore waters. This spatial expansion has no doubt led to increased catches in India, but the fisheries are being operated unsustainably (Hornby et al., 2015). Short time span of our data could also hide the long-run response of fish supply. Therefore, it would be informative to capture the long-run supply elasticity of capture fisheries in India. This would provide a better insight into the role that fisheries in the food and nutritional security.

While the p-value associated with the supply elasticity indicates statistical insignificance, it may only be a manifestation of the small sample size used in the regression. The fact that the coefficient $\alpha_1 = 0$ is large enough implies the effect size is strong, i.e., the relationship between the landings and the price is strong. However, lack of statistical significance could mean that there is not enough data with lesser noise. Hence, a larger and better data with sufficient sample size could lead to rejection of the hypothesis that $\alpha_1 = 0$.

In Table 3, coefficients of all the explanatory variables of equation (3) have p-value of greater than 0.1, implying statistical insignificance at usual confidence levels. However, as described above, this could be only a matter of sample size: with larger sample size the coefficient might turn statistically significant. The test for structural break ($\beta_2 = \beta_3 = 0$) resulted in an F-ratio of 10.272 and a p-value smaller than 0.01, strongly rejecting the hypothesis of no structural break. Thus, there is a significant change in MWPI from 2011 onwards.

Table 3. Summary of econometric models of marine fish supply.

Explanatory variables	Equation (2)	Equation (3)
Intercept	13.5047 (<0.01)	-11.5516 (0.255)
$\ln MWPI$	0.2244 (0.20)	
$Dummy$	5.7621 (0.042)	24.8615 (0.107)
$Dummy * \ln MWPI$	-1.1911 (0.045)	
$\ln Q$		1.0857 (0.133)
$Dummy * \ln Q$		-1.6676 (0.115)
F-statistic	5.412 (0.021)	13.03 (0.001)
Adjusted R^2	0.524	0.751

Values in the parenthesis are the p-values.

[12] Apart from Kumar, Dey and Paraguas (2006), ours is probably one of the limited number of studies that have analyzed supply response in Indian fisheries.

4.3. Fishers' Income and its Association with Supply Constraints

We divide the annual sum of NDDPs (at constant price) of the three coastal districts of Karnataka by the total numbers of fishing households to calculate a proxy variable for fishers' net income for the time period of 2004-2016. We calculate the pairwise correlation coefficients among the fishers' income (i.e., NDDP of fishing households in the coastal districts), quantities of edible/commercially important fish species landed, and the MWPI to determine the strength of association among the three variables.

Table 4 shows the correlation matrix and the associated p-values. All the estimated correlation coefficients are positive and statistically significant at the 10% level of significance or lower. The income variable shows a moderate positive correlation with landings of commercially important species. Hence, as landings of commercial species decrease so does fishers' income. This has important implications since a fisher who is earning sufficient income through legal fishing activities is less likely to enter into illegal or destructive fishing. Therefore, maintaining fishery stocks at optimum levels is in the interest of fishers to earn through legal fishing activities.

Table 4. Correlations among MWPI, Commercial Landings, and Fishers' Income.

	MWPI*	Commercial species' landings*	NDDP of fishing households*
MWPI	1.000		
Commercial species' landings	0.921 (<0.01)	1.000	
NDDP of fishing households	0.559 (0.047)	0.506 (0.078)	1.000

*Numbers in parenthesis are the p-values.

Discussion and Conclusions

In this paper we analyzed the patterns in fish production and their implications for food and nutritional security in the Indian context with a particular focus on the Karnataka state. The premise for the study is the more concerning issue of declining catches of some of the commercially important species that are traditionally preferred for consumption in Karnataka. We compiled secondary data on marine fish prices, landings, exports, and income variables from various sources and used them in descriptive and econometric analysis. Our descriptive analysis showed that the share of exports in Karnataka's fish production has been rising since 2006-07, eventually crossing 50% of production value. Moreover, growth rates of landings of many commercially important species are either low or moderate. If the catches remain low, aquaculture would need to play more substantial role for ensuring fish availability in India.

Our econometric results showed that there indeed was a structural break in the landings of commercially important species. The break was timed at 2011, and following the break the landings have decreased. Lower catches and higher exports would imply less fish in the domestic market, which would make fish less accessible to lower income groups. Thus, government policies such as the MEIS need to be revised to exclude species such as mackerel that are important for the domestic market. The own-price supply elasticity for commercially important species shows inelastic supply response, as is expectable for capture fisheries. We recommend estimating long-run supply elasticity for commercially important species.

We found a positive correlation between fishers' income and the quantities of commercially important species landed. Therefore, fishers' income would fall if these landings were to fall. It is not in fishers' interest to overfish these valuable stocks. Higher exports may indirectly lead to better food security of fishing households if changes in export prices are perfectly transmitted to ex-vessel prices. Better discovery of prices at the fish landing centers would help achieve governmental programs such as the doubling of farmers'/fishers' income.

Role of small-scale fisheries, especially that of subsistence fisheries, is not properly appreciated in India. For example, salting and drying is an ancient and inexpensive method of fish preservation commonly practiced by small-scale fishers across Indian coast and even hinterlands. Dried fish products are a valuable source of vital nutrients to poorer sections of the society. Government policies since Independence have not aimed at promoting such pro-poor practices, concentrating instead more on expensive preservation methods such as freezing and refrigeration to cater to the export markets. India's Blue Economy policy intends to promote *innovations in low-carbon technologies that yield economic dividend for large sections of the society*. Small-scale fisheries and associated practices offer opportunities to promote low-carbon fisheries. A better understanding of the contributions of small-scale fisheries in fish production and utilization needs to be developed through research on its socioeconomic characteristics. More research on the contributions of small-scale fisheries can provide a better appreciation for the role of fish in achieving food and nutritional security in India.

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