REVIEW ARTICLE

Resources and Productivity of Indian Aquaculture–Status and Prospects

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Abstract

India tops the world in aquaculture production next to China. The present blue revolution envisages tripling fish production of India by 2020, which necessitates effective resource utilization. The aquaculture resources of a country cannot only be limited to land and water availability but also to its species diversity, workforce and infrastructure facilities. Though Indian aquaculture has registered increased production in the past few years, the productivity in terms of water and manpower resources remain very low. There is also, a need for diversification of species for mariculture activities. Hence, this paper examines the status of Indian aquaculture from a global perspective to sort out ways for enhancing productivity.

Keywords: Biodiversity, Indian aquaculture, Marketing, Productivity, Resources.

Agricultural Reviews (2019)

Introduction

The rapidly growing world population is expected to reach 9.8 billion in 2050, which needs to be fed a protein rich diet (United Nations, 2019). Nonetheless, it would also be competing with food production sectors for land and water and hence, there is an urgent need to increase the productivity of these sectors with the available resources. Usually, aquaculture sector is debated on its resource usage and efficiency (Chamberlain and Rosenthal, 1995). The global aquaculture land area including those utilized for plant based aqua feed cultivation and other associated aquaculture activities is 0.22 Million Km^2 while that of agriculture and animal husbandry sectors is 49.2 Million Km^2 and 38.67 Million Km^2 respectively (Verdegem and Bosma, 2009). Though, the latter two utilize nearly 200 times more area than aquaculture, their productivity is comparatively lower (2.3 t/ha of paddy and 0.23 t/ha of livestock products respectively) than that of land-based aquaculture (2.04 t/ha of fish) (Boyd and McNevin, 2014). Hence, aquaculture turns out to be the most prominent food production sector and so the objective of this paper is to analyze the scope of increasing Indian aquaculture productivity with the available resources.

Aquaculture Production

Aquaculture contributes about 43% of the 171 million tonnes (MT) of fish produced globally in 2016 which includes 54.1 MT of finfish, 17.1 MT of molluscs, 7.9 MT of crustaceans and 0.93 MT of other aquatic animals such as turtles, sea cucumbers, sea urchins, frogs and edible jelly fish (FAO, 2018). The continuous raise in the contribution of aquaculture to global fish production from 25.7% in 2000 to 46.85% in 2016 stresses the importance of aquaculture worldwide. Among the total fish production, 64.2 % of the global farmed food fish production is from an inland sector which is dominated by finfishes (90% of inland production). In contrast, shelled mollusks dominate coastal aquaculture and mariculture by about 58.8% of the production from these sectors (FAO, 2018).

Presently, India is the second largest aquaculture country in the world next to China (FAO, 2018). The total fish production has grown from mere 7.5 lakh tonnes in 1950-51 to 11.41 MT in 2016-17 with a contribution of 7.77 MT from the inland sector and 3.64 MT from the marine sector. The contribution of freshwater aquaculture to the inland fisheries has grown from 34% in the mid-1980s to about 80% in recent years (DAHDF, 2017). Though finfishes continue to be a significant contributor in inland fish production, the growth rate of crustaceans is also not negligible (Table 1). The proportion of finfishes in the total inland fish production has reduced from 95.93% in 2001-02 to 93.40% in 2014-15 as against the crustaceans proportion of 4.06% in 2001-02 to 6.59% in 2014-15 and it shows a continuously growing trend with its peak at 2011-12, due to the introduction of *Littopenaeus vannamei* in 2009 (DAHDF, 2017). However, following the WSSV breakout in *Penaeus monodon* during the late 1990s

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Table 1: Year-wise production and growth rate of inland species groups in India

Year	Finfishes (lakh tonnes)	Growth Rate of finfish Production (%)	Shrimps (lakh tonnes)	Scampi (lakh tonnes)	Crustaceans (lakh tonnes)	Growth Rate of crustacean Production (%)	Total (lakh tonnes)
2001-02	29.99	-	1.02	0.25	1.27	-	31.26
2002-03	30.64	2.12	1.15	0.31	1.46	13.01	32.10
2003-04	33.1	7.43	1.13	0.35	1.48	1.35	34.58
2004-05	33.61	1.52	1.25	0.39	1.64	9.76	35.25
2005-06	35.7	5.85	1.43	0.43	1.86	11.83	37.56
2006-07	36.71	2.75	1.44	0.30	1.74	-6.90	38.45
2007-08	40.74	9.89	1.06	0.27	1.33	-30.83	42.07
2008-09	45.49	10.44	0.76	0.13	0.89	-49.44	46.38
2009-10	47.9	5.03	0.98	0.06	1.04	14.42	48.94
2010-11	48.41	1.05	1.37	0.03	1.4	25.71	49.81
2011-12	50.75	4.61	2.16	0.04	2.2	36.36	52.95
2012-13	54.45	6.80	2.7	0.04	2.74	19.71	57.19
2013-14	58.02	6.15	3.27	0.03	3.3	16.97	61.32
2014-15	61.43	5.55	4.26	0.08	4.34	23.96	65.77

(Source: DAHDF, 2017; MPEDA , 2018)

and problems with scampi farming, the contribution of the latter two to total crustaceans has considerably decreased (Rajalashmi, 2014).

The trend of aquaculture growth rate in India is depicted in Figure 1. With a humble beginning at 1950s, the inland sector has gone through leaps and bounds from a mere growth rate of 2.29% in 1955-56 to 7.2% in 2016-17. The induced breeding and seed production of carps in 1957 by Hirlal Chaudry and K.H.Alikunhi ensured seed availability and favored production in mid 20th century (Chaudhari and Alikunhi, 1957). The success stories of carp polyculture in the Kolleru lake basin and other areas in the Krishna-Godavari delta region in the mid-1980s spread to Punjab, Haryana, Uttar Pradesh, and so the inundated paddy fields were converted to dugout ponds (Gopakumar, 1999; Sarangi., 2004). The setting up of experimental brackishwater farm in 1973 followed by the 1975 AICRP on shrimp farming (CIFRI, 1978) and the establishment of commercial shrimp hatcheries by the marina products export development authority (MPEDA) in 1988-89 led to a drastic increase in shrimp production from 10,000 MT in 1984 to 92,000 MT in 1994. However, the production decreased to 70,686 MT in 1996 due to disease outbreaks, crop holidays and natural disasters (Kutty, 1999). Though shrimp production showed stagnation from 1996-2000, the sector recovered with a gradual increase in production, which reached a maximum of 1,40,000 MT in 2006-07. However, the introduction of *L. vannamei* in China, Thailand, Indonesia, and Vietnam led to decrease of global shrimp price which in turn led to a drastic decline in production in the following years (Ayyappan *et al*., 2011).

The decline in shrimp production following white spot syndrome virus (WSSV) break out in the mid-1990s, and the Supreme Court's order on closure of farms in Coastal Regulation Zone (Aquaculture Authority, 2002) led to the

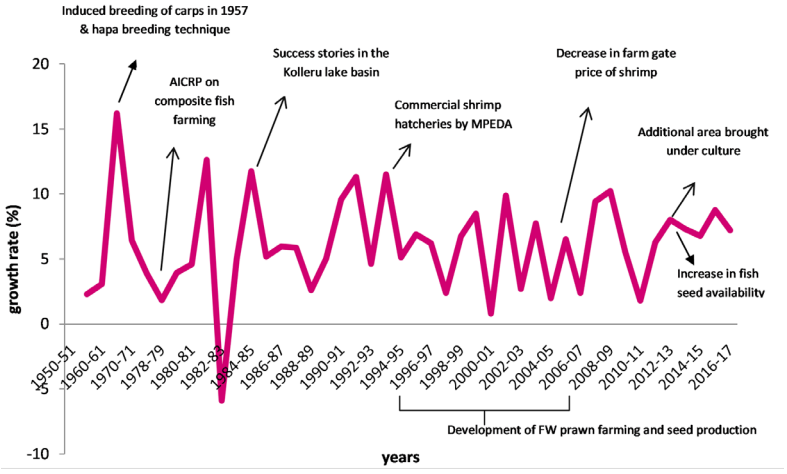


Figure 1: Trend of Aquaculture growth rate in India

development of freshwater prawn farming in India. The scampi production increased from 178 T in 1996 to 42,870 T in 2005. However, the production declined from 2006 due to disease outbreaks (White tail, Branchiostegite blister and Appendage deformity syndrome), increase in input cost, fluctuations in farm gate price, lower export demand and Salmonella issue in exported scampi (Nair and Salin, 2006). All these issues favored the introduction of *L. vannamei* into India in 2009 (Srinivas *et al*., 2016).

During 2011-12, the farming area was expanded horizontally and farmers were trained on improved practices due to which the national average productivity of ponds and tanks increased to 3 tonnes/ha/yr (DAHDF, 2017). As evident from the Table 1, the year 2012-13 registered a remarkable growth rate in both finfish and shellfish groups. The fish seed availability grew from 15,758 million fry in 2001 to 50,252 million fry in 2017 which favored an increase in growth rate during these years (DAHDF, 2018). Similarly, the adoption of good management practices in shrimp culture helped the sector to reach a record production of 2,70,819 T during 2012–2013 from approximately 1,15,826 ha area under production (MPEDA, 2018). The higher growth in the crustacean group is also guided by high export demand, availability of quality seed and other inputs like formulated feed, easy accessibility of institutional finance, entrepreneurship and higher profit margins (Yaligar, 2019).

Aquaculture resources of India

The resources for aquaculture can not only be confined with land and water but also the biodiversity, manpower, market and infrastructure resources.

Land and Water availability

By virtue of geographical location, India has extensive area for aquaculture in the form of ponds and tanks distributed in almost all the states of India. The inland water bodies cover an area of over 7.312 million hectares, with the largest areas being in the state of Odisha (9.89 lakh ha) followed by Andhra Pradesh (8.11 lakh ha), Karnataka (7.4 lakh ha) and Tamil Nadu (6.9 lakh ha) accounting for about 50% of India's aquacultural waters (DAHDF, 2014; ICAR-DCFR, 2019). The water resources suitable for aquaculture in India are depicted in Figure 2.

The DAHDF (2017) reported that about 0.895 million hectares of water area have been brought under culture with an average annual yield of 3.0 tonnes/ha. The production from upland waters contributes about 35% of the inland fish production of the country. India has 1.24 million hectares of brackish water area, but only 155 hectares area is utilized for fish farming (DAHDF, 2017).

There are about 24.32 lakh hectares of tanks and ponds like Panchayath, temple, irrigation, private and quarry ponds with high potential for aquaculture. The exact area available with each type of ponds is not estimated, and the available data is highly fragmented (Ghosh and Indu, 2005). Another issue is with the ownership of these ponds ranging from individuals to cooperative management.

In addition to this, Ministry of Agriculture and Farmers' Welfare (Anonymous, 2017) had identified 2.3 million hectares of paddy fields in India which serve to be a potential resource for integrated fish farming. Another untapped resource is the inland saline areas which are unfit for agriculture. About 8.62 million hectares of salt and alkalinity affected soils exist across the states of Haryana, Rajasthan, Uttar Pradesh and Gujarat (Singh *et al*., 2017). Countries like China, Egypt and Israel, are known to efficiently utilize this resource for increasing aquaculture productivity (FAO, 2018). Besides these resources, India holds about 40,000 hectares of abandoned shrimp ponds which can be used for culture of *E. suratensis,* seabass and mullet with the minor technological intervention (Ravisankar *et al*., 2014 and Saraswathy *et al*., 2016).

Most of the major producer countries effectively utilize their exclusive economic zone (EEZ) area for mariculture

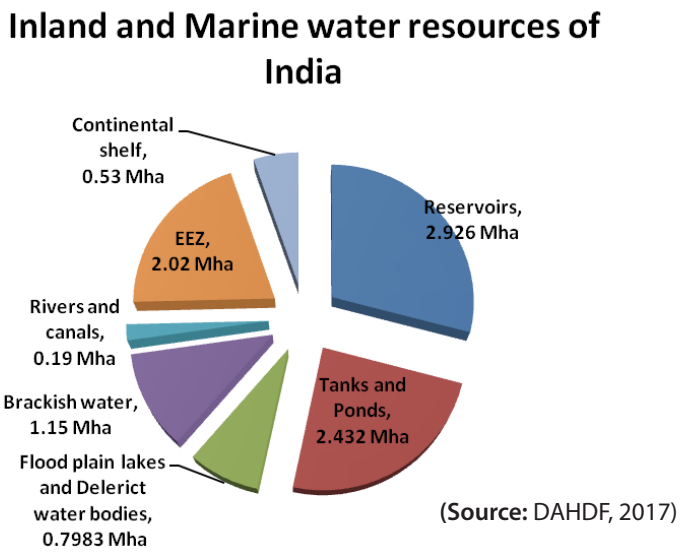


Figure 2: Inland and Marine water resources of India

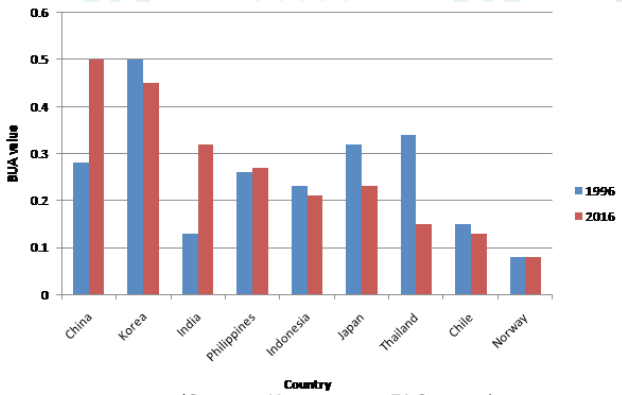
and seaweed farming operations (Table 2). Though some countries like Norway, Chile, and Japan do not have a considerable amount of inland water area, they rank top in mariculture activities. On a gross scale, China is found to be the effective utilizer of its offshore area followed by Norway which solely depends on mariculture for its total culture fish production (FAO, 2018). Similarly, the seaweed productivity of China mounts to 14 tonnes/ Km^2 if it is assumed to utilize its entire continental shelf area. It is followed by Philipines producing 7.63 tonnes of seaweed/ Km^2 of its shelf area. Though Indonesia out turns to be the second largest producer of seaweeds, the lack of information on its continental shelf area due to the maritime boundary disputes with adjacent countries makes the comparative estimation impossible (Khafid, 2019). However, in the freshwater finfish production sector, Vietnam holds the first place with a productivity of 0.5 tonnes/ Km^2 over-riding China's productivity (0.16 tonnes/ Km^2) (Table 2). It is clearly evident that the productivity of India is very low compared to other countries indicating the non-utilization of available resources.

Biodiversity

As of 2016, global production has been recorded for a total of 598 "species items" including 369 finfishes, 109 molluscs, 64 crustaceans, 7 amphibians and reptiles, 9 aquatic invertebrates and 40 aquatic algae. But only 27 species contribute 90% of the total production in 2016 of which 84.2% is by the 20 most produced species (FAO, 2018). Of the 31.2 MT of wild-collected and cultivated aquatic plants obtained in 2016, 96.5% was from aquaculture. According to the FAO (2018), farming of microalgae like *Spirulina* spp., *Chlorella* spp., *Haematococcus pluvialis* and *Nannochloropsis* spp., recorded 89,000 T in 2016 with China being the major producer with 88,600 T. However, the real scale of world microalgae production is underestimated because of data unavailability from important producers like Australia, France, India, Israel, Japan, Malaysia and Myanmar (FAO, 2018).

More precise information on biodiversity utilization in aquaculture can be obtained from a country-wise comparison of the number of species cultured. The index used is Crude Biodiversity Utilization in Aquaculture (BUA) given by Kutty (2000). It is calculated by dividing the number of species utilized by a specific country, by twice the maximum recorded number for any country.

The BUA index reflects the farmed species diversity of a country and/or the level of its aquaculture development (Kutty, 2000). The decadal change in BUA values for major producers is depicted in Figure 3. Among the different



(**Source:** Kutty, 2000; FAO, 2018)

Figure 3: Decadal change in crude BUA values of major aquaculture producers

Table 2: Comparison of productivity of major producer countries

S.No	Country	*Mariculture productivity/ EEZ (tonnes/km²)*	*Marine mollusks productivity/EEZ (tonnes/km²)*	*Seaweed productivity/ Shelf area (tonnes/km²)*	*Productivity/ Freshwater area (tonnes/km²)*
	China	1.34715	14.71503	13.98833	0.160867
	Norway	0.945455	-	-	-
	Indonesia	0.143402	-	NA	0.034
	Chile	0.1452	0.003	NA	-
	Philipines	0.192386	-	7.63587	-
	Vietnam	0.303	0.225	0.014286	0.5657
	Japan	0.0611	0.092	1.678112	-
	India	-	-	0.00566	0.0821
	Thailand	-	-	-	0.104
	Republic of Korea	-	1.02	5.919662	-

(Source: FAO, 2018; FAO, 2019)

producers, temperate countries like Norway have higher BUA certainly reflecting their proper species selection and aquaculture development. The crude BUA of China has increased over the years by the farming of aquatic animals in addition to fishes (Li *et al*., 2011). Some countries had registered a lower BUA compared to 1996 (Kutty, 2000). This is because of species diversification in China which is used as the reference country for BUA estimation. India's score has increased when compared to 1996 (Kutty, 2000), however, the major contributing species in terms of volume remains very few, namely, major Indian carps and *L. vannamei* (Mishra *et al*., 2017) This indicates the un-exploited opportunities in aquaculture species diversification in India (Sundaray *et al*., 2017; Kasozi *et al*., 2017).

Manpower

Fisheries and aquaculture sectors were sources of income and livelihood for 59.6 million people, engaging 40.3 million and 19.3 million people, respectively, in 2016 (FAO, 2018). Though the workforce is found to increase with years, the vigorous growth in aquaculture production depends not only on the number of farmers employed but also on their efficiency and technological developments to sustain the highly competitive foreign markets (Subasinghe *et al*., 2003).

The population and the number of fish farmers in selected important producer countries are given in Table 3. It could be observed that Norway exhibits the highest aquaculture productivity per farmer (162.5 tonnes/ farmer). Though being a small country in terms of landscape and population, the highest productivity is because of species group (marine finfishes) cultured under sophisticated farming systems (FAO, 2019). Norway is followed by China (12.66 T) and Indonesia (4.98 T). Besides being the second most populous country in the world, the productivity per farmer in India stands out to be 3.9 T. Hence, more focus should be given on increasing the productivity of labour in India by the attraction of skilled manpower in aquaculture and improvement of technologies.

Market and infrastructure

Fish marketing system, a critical driving force for sustainable aquaculture is highly inefficient in India (Ayyappan, 2009). Ravindranath (2008) had identified the reasons for this to be the heterogeneous nature of commodity, perishability, cost of storage and transportation, uncertainties in quality and quantity, dominance of private sectors inviting large number of intermediaries and the high price spread. Fishery, being a state subject under the Constitution of India, is vested with the states to draw policies for fish marketing (Planning Commission, 2019). According to Kumar *et al*. (2010), The West Bengal Fish Dealer's Licensing Order (1975) is the only legislation for fish marketing in India and Kerala Government is to soon impose the 'Auctioning, Marketing and Quality Control Bill.' Moreover, since fish is not a notified commodity under the Agricultural Products Marketing Commodity Act of 1966, all commission charges are paid by fishermen which demands Government's intervention (Kumar *et al*., 2008). There is a clear species and sector specific demarcation in fish marketing in India. While marine fishes are sold in nearby local markets, freshwater fishes are transported to markets spread across states. Similarly, crustaceans like shrimps are intended for exports by fish processing industries while finfishes like carps end up in domestic trade (Sathiadhas and Narayanakumar, 1994).

However, the Kolleru lake area in Andhra Pradesh, the carp pocket of India has an efficient marketing system for carps which could be adopted in other states also (Kumar *et al*., 2010). According to Roy *et al*. (2008), the reasons for their success are as follows:

- Standardized scientific culture harvesting techniques,
- Awareness on the cost of culture and wholesale market prices across the country,
- Entrepreneurship of the traders and
- Development of Forward and Backward Linkages like ice plants, rice husk, thermocol boxes, poultry manure, etc.

These market and infrastructure facilities ensure that the fishes from Kolleru basin are supplied at a price lower than those in Howrah, Guwahati, Dadar, Bhubaneswar, Coimbatore and Trippur markets (Kumar *et al*., 2010).

Shrimp export industry is an inevitable fraction in the marketing and trade in Indian aquaculture. Since 2009, Indian shrimp exports have grown considerably due to the following reasons (MPEDA, 2018). Early Mortality Syndrome (EMS) was a major setback for shrimp production in Thailand and southeast asian countries while the unaffected Indian production supported its boom in exports (Radhakrishnan *et al*., 2018). Simultaneous introduction of Pacific white shrimp (*Penaeus vannamei*) in 2009 added fuel to the fire (Vinay *et al*., 2016). There was a paradigm shift from the black tiger (*Penaeus monodon*) to vannamei farming due to the availability of specific pathogen free (SPF) broodstock, increased disease resistance, shorter culture duration and

Table 3: Productivity of work force in major producer countries

S.No	*Country*	*Population (millions)*	*No. of fish farmers (million)*	*% of fish farmers in the country*	*Total production including aquatic plants (million tonnes)*	*Production per farmer (tonnes)*
1	China	1413.479	5.022	0.355294	63.58	12.66029
2	Norway	5.123	0.008	0.156159	1.3	162.5
3	Indonesia	256.329	3.334	1.300672	16.631	4.988302
4	India	1339.2	1.46	0.1090203	5.703	3.906164

(Source: FAO, 2018; FAO, 2019)

Table 4: Production of P. monodon, L. vannamei & Scampi in India

Species		*2008-09*	*2009-10*	*2010-11*	*2011-12*	*2012-13*	*2013-14*	*2014-15*	*2015-16*
P. monodon	AUC	108788.7	102259	113853	114370	93110.4	72177	71400	68846
	EP	75996.54	95919	118575	135466	123303	76798	73155	81452
	PUD	0.699	0.938	1.041	1.184	1.324	1.064	1.025	1.183
L. vannamei	AUC	0	283	2931	7837	22715.7	57267	50240	59116
	EP	0	1731	18247	80717	147516	250507	353413	406018
	PUD	0	6.117	6.226	10.299	6.494	4.374	7.034	6.868
Scampi	AUC	18421.14	8154	5511.72	6244	3432	9175	9307.49	12706
	EP	12806.25	6568	3721	4269	3625	3545	7989	10152
	PUD	0.695	0.805	0.675	0.684	1.056	0.386	0.858	0.799

AUC - Area Under Culture in hectares; EP - Estimated Production in tons; PUD- Productivity in tonnes/ha

(Source: MPEDA, 2018)

affordability (Mishra *et al*., 2017). The concurrent devaluation of Indian Rupee increased the exports, especially during 2014. However, in the recent years, Indian exports are suffering due to oversupply and overstocking, rejections due to antibiotics and Free Trade Agreements between major importers (Fathima *et al*., 2006).

Productivity of Indian Aquaculture:

Carp farming is the mainstay of aquaculture in India contributing about 90% of the culture production satisfying the domestic need. Instead, coastal aquaculture of shrimps with only 5% share in production contributes much of the export earnings (Kumar *et al*., 2015). However, carp farming suffers huge difference in the yield obtained from experimental stations, farm experiments and the average farm yield (Katiha *et al*., 2005). In India, average fish yields at experimental and farm trials were 8.0 tonnes/ha/yr and 5.5 tonnes/ha/yr, respectively, making gap of 2.5 tonnes/ha/year while the same at the actual farm was 1.93 tonnes/ha/yr escalating gap to 3.57 tonnes/ha/yr. The reasons for this difference are due to smaller pond size, higher stocking density, a lower percentage of desired seed stock, a considerable reduction in the use of fertilizers and feed ingredients, financial constraints, improper management practices, issues with ownership of ponds and inadequate extension services (Katiha *et al*., 2005).

The productivity of different crustacean species across the various coastal states of India is shown in Table 4. The production of *P. monodon* has shown a declining trend in 2006-2009 during which most of the well-established hatcheries remained idle. However, the sector regained its potential with the development of good management practices and disease management and now has an average productivity of 1.18 tonnes/ha (MPEDA, 2018). Among the states, Gujarat has registered higher productivity of 3.12 tonnes/ha because of the best management practices followed in the state. As regards the *L. vannamei* farming, the average pond productivity lies at 6.8 t/ha with Gujarat being the most productive state with 7.9 tonnes/ha. An interesting point to note is that the average productivity of all the states was at its peak during 2011-12 which has gradually declined and keeps sustaining at an lower rate (when compared to 2011-12), due to poor quality seeds, disease incidence and poor feed management (Yaligar, 2019). As noticed in Table 4, the productivity of *L. vannamei* culture is higher than that of *P. monodon* due to its faster growth rate and hardiness when compared to the latter.

Conclusion

It is clearly evident that India is bestowed with diverse water, biodiversity, manpower, and infrastructure resources for aquaculture. However, the sector faces challenges due to climate change, competition from other food production sectors, shortage of raw materials, issues of compliance with international standards which need to be addressed. Hence, proper strategies should now be framed and implemented to harness its full potential and achieve a targeted production of 15 MT by 2020. Besides expansion of culture and species diversification, a holistic approach encompassing skill development of the workforce, strengthening of marketing policy regulations, improving extension activities along with financial assistance for marginal farmers is essential to increase and sustain aquaculture productivity in the long run.

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