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# Estimation of farmed shrimp production in Kerala

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**Abstract**
Aquaculture of shrimps and prawns has made significant advances during the last four decades in India. Kerala (in South India) is one of the important states contributing to farmed shrimp production in the country. However, in spite of its importance, the quantity of shrimp produced through aquaculture in the state is not recorded with certainty. Marine Products Export Development Authority (MPEDA) publishes information on the farmed shrimp production of the various states of the country including Kerala, annually. But the information published is more or less restricted to the production of only two species *Penaeus monodon* (Fabricius, 1798) and *Litopenaeus vannamei* (Boone, 1931) which are exported from the country. In Kerala majority of the shrimp farms undertake traditional farming in which, other species of shrimps like *Penaeus indicus*, H. Milne Edwards, 1837, *Metapenaeus monoceros* (Fabricius, 1798) *Metapenaeus dobsoni* (Miers, 1878) etc. are also harvested. The data published by MPEDA does not reflect the production of these species. Similarly, the productivity figures published are limited to scientific farms alone. Thus, there is a need to estimate the species-wise total shrimp production of the state from the farming (both traditional as well as the scientific farming) sector. The present study was undertaken to estimate the total farmed shrimp production of Kerala adopting a slightly modified version of the sampling design developed by the Central Inland Capture Fisheries Research Institute (Indian Council of Agricultural Research), Barrackpore, West Bengal and recommended by the Fisheries Division of Department of Agriculture and Co-operation, Government of India and to assess the productivity of shrimp farms. The total area under shrimp farming in Kerala during 2017-2018 was estimated to be 10, 599.26 ha. of which 8,430.98 ha. was under traditional farming and 2,168.28 ha was under scientific farming. In the study the annual farmed shrimp production of the state was estimated to be 2,952.56 metric tonnes (t). Of this, the contribution of traditional sector was 2,174.80 t (73.66%) and that of the scientific sector was 777.76 t (26.34%). The productivity of shrimp farms in the state was calculated to be 932.08 kg $ha^{-1}$ $year^{-1}$ which is very low compared to that of other states in the country.

**Keywords:** Aquaculture, traditional shrimp culture, productivity

## 1. Introduction
Aquaculture of shrimps and prawns has made significant advances during the last four decades in many parts of the world, including India [1]. In the year 2018, the world produced around 4 million metric tonnes (t) of farmed shrimp which represents around 54% of the total global shrimp production [2]. During 2017-2018, India produced 6.80 lakh t of shrimp through farming [3]. During the last decade (2008- 2018) the country registered an unprecedented average annual growth rate of 27.60% in farmed shrimp production.

Kerala is one of the important states contributing to farmed shrimp production in India. However, information on the quantity of farmed shrimp produced in the state is not known with certainty. Marine Products Export Development Authority (MPEDA) publishes information on the farmed shrimp production of the various states in the country, including Kerala, annually [4]. However, the information on shrimp production published is more or less restricted to the production of only two species *Penaeus monodon* (Fabricius, 1798) and *Litopenaeus vannamei* (Boone, 1931). In Kerala majority of the shrimp farms undertake traditional farming in which, other species of shrimps like *Penaeus indicus*, H. Milne Edwards, 1837, *Metapenaeus monoceros* (Fabricius, 1798), *Metapenaeus dobsoni* (Miers, 1878) etc. are also harvested [5]. The data published by MPEDA does not reflect the production of these species. Similarly, the productivity figures published are limited to scientific farms alone. It is well known that crop yields in pond aquaculture vary depending on the culture intensity. According to Tucker and Hargreaves [6], yields in ponds vary by at least two orders of

magnitude, from 200 kg $ha^{-1}$ in lightly fertilised fish ponds to over 20 tons $ha^{-1}$ in intensively managed crops with feeding and continuous aeration.

The Food and Agriculture Organization (FAO) is publishing global statistics on farmed fish provided by FAO member countries [7]. However, according to Campbell and Pauly [8] only one-sixth of low-value, domestically-traded and small-scale aquaculture production is officially reported, which have a great impact on the accuracy of the aquaculture status. Many countries and national agencies lack the means to directly collect aquaculture data [8]. There is also an absence of locally adaptable statistical methodology for the collection of production data, in some parts of the world. However, robust estimates of current and potential yields are essential for evolving effective food security and environmental conservation measures.

In the context, there is a need to estimate the species wise farmed shrimp production (from traditional and scientific farming sectors) of the state with great accuracy. Estimation of farmed shrimp production with accuracy is required for meaningful evaluation of the contribution of the sector to the economy and nutritional security of the state. The information is also important for assessing the impact of different developmental schemes implemented by the Governments and other agencies. The present study was undertaken to estimate the total farmed shrimp production of the state and to assess the productivity (the average weight of shrimp harvested per unit area per year) of shrimp farms.

The term shrimps and prawns are used synonymously in the present paper due to the absence of systematic basis to mark a distinction as opined by Wickins [9] and Holthuis [10].

## 2. Materials and Methods

The present study was part of a larger study which was meant for investigating various aspects of shrimp farming in the state of Kerala. The study was conducted in the shrimp farming belt of the state *viz*., coastal areas of Thiruvananthapuram, Kollam, Alapuzha, Ernakulam, Thrissur, Malappuram, Kozhikkode, Kannur and Kasargod districts and the low-lying areas which lie adjacent to the backwaters in Kottayam district (fig. 1).

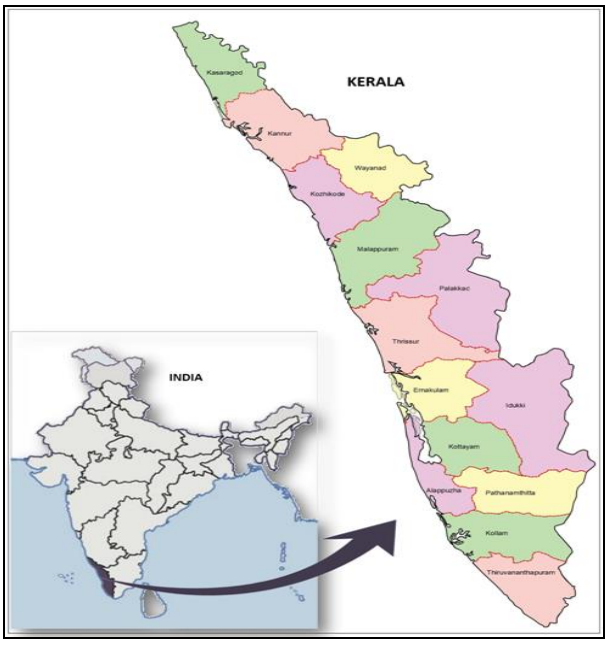


**Fig 1:** Study area

Prior to the actual study, a survey was conducted in all the shrimp farming districts of the state to estimate the total area under shrimp farming. Experience coupled with the information collected in the survey enquiry revealed that in Kerala, two types of shrimp farming are in practice. They are traditional prawn farming and scientific prawn farming. In traditional farming, stocking is done when the salinity builds up after the South-West monsoon (October- December), and final harvesting of prawn is done just before the monsoon (April- May). In scientific tiger shrimp (*P. monodon*) farming, crops are taken in different farms either as summer crop (January/ March – April/ June) or as monsoon crop (April/ May- July/ August). In farming of white legged shrimp (*L. vannamei*), the trend is for year- round culture with no distinct crop season.

Lists of all shrimp farms belonging to each of the above category was collected from the offices of the Fish Farmers' Development Agencies (FFDAs) functioning in various districts under the Department of Fisheries, Kerala and from the office of the Marine Products Export Development Authority (MPEDA), Government of India. Two consolidated lists of farms (one list consisting of farms undertaking traditional farming and another one undertaking scientific farming), containing details of location, total area and water spread area were prepared avoiding duplications. These lists formed the basis for the present study. The lists so prepared was validated in the pre survey which is mentioned above.

For the estimation of shrimp production, a slightly modified version of the sampling design developed by the Central Inland Capture Fisheries Research Institute (Indian Council of Agricultural Research) Barrackpore, West Bengal[11] and recommended by the Fisheries Division of Department of Agriculture and Co-operation, Government of India was adopted. The sampling design adopted was a multistage stratified random sampling design. All farms contributing to shrimp production formed the population and each farm therein constituted the sampling unit. Each shrimp farming district was divided into revenue blocks which formed the strata. For the sake of convenience, the areas coming under the coastal municipalities were included in contiguous revenue blocks. All farms within a stratum were classified into two groups *ie.*, farms with areas up to one hectare and farms with areas above one hectare. Separate sampling was done in these two groups of farming units.

Farms falling in each stratum (revenue block) were listed serially without omission or duplication and with one to one correspondence with serial numbers. The area of each of the farms was indicated in the list against the serial number of the farm. This listing was done separately for units with areas up to one hectare and for units above one hectare. From the serial numbers of the list prepared, farms were sampled with the help of a random number table until the total area of the sampled units crossed 10 percent of the total area of the farms in the stratum. The same procedure was followed for farms of areas above one hectare in the stratum.

The selected sample units were visited once after the normal stocking period to record information on stocking, expected period of harvesting etc. The information on the likely date/period of harvesting in each month was obtained from the farmer. The visits were scheduled to cover all farms during the last week of the month. As far as possible, an attempt has been made the visit on the day of harvesting to assess the weight on that day of the catch and also that of different species in the total catch. Information regarding the

catch for other days of the month was also collected by enquiry. When it was not possible to be present on the harvest time, the sampled units were visited on any day in the last five days of the month to assess the production during the month including species wise break up. In this way, the information regarding the catch for each of the sampled units for the whole month was obtained. In case there was no harvesting or catch in a particular month, 'nil' information was recorded. The estimation of shrimp production was done, as explained below. Total shrimp production of the state ($Y$) was calculated as:

$$Y = \sum_{r=1}^{10} \sum_{s=1}^{nr} X_{rs}$$

Where $X_{rs}$ is the total production of shrimp in the $s^{th}$ revenue block of $r^{th}$ district. Here $r$ = 1,2, 3……...,10 and $s$ = 1,2, 3,……$nr$, where $nr$ is the number of revenue block in $r^{th}$ district.

$$X_{rs} = \sum_{i=1}^{2} \sum_{j=1}^{2} \sum_{k=1}^{m} \left( \frac{(x_{rs})_{ijk}}{(a_{rs})_k} \right) (A_{rs})_k$$

Where $(x_{rs})_{ijk}$ is the total production of $k^{th}$ species of shrimp reported from the $j^{th}$ size- class of farm of the $i^{th}$ type of farming in the $s^{th}$ revenue block of $r^{th}$ district. $(a_{rs})_k$ is the sampled area of $k^{th}$ species in the $s^{th}$ revenue block of $r^{th}$ district. $(A_{rs})_k$ is the total area of production of $k^{th}$ species in the $s^{th}$ revenue block of $r^{th}$ district.

The study was conducted during the 24-month period from January 2017 to December 2018, and the average for one year was taken.

## 3. Results

### 3.1. The area under shrimp farming

The area estimated to be under shrimp farming in the year 2017-2018 in Kerala is 10,599.26 ha., the details of which are presented in table 1. The percentage distribution of traditional and scientific farming units in Kerala in terms of number and extent is provided in figure 2.

**Table 1:** Area under shrimp farming in Kerala.

| Traditional farms | | Scientific farms | |
|---|---|---|---|
| Number | Water spread area (ha.) | Number | Water spread area (ha.) |
| 1,576 | 8,430.98 | 412 | 2,168.28 |

The traditional system of prawn farming is practised in the low lying coastal brackish water fields in Central Kerala and North Kerala. The former is popularly known as *pokkali* prawn farming and the latter as *kaipad* prawn farming. *Pokkali* fields lie mostly in the coastal villages of Thrissur, Ernakulam, Alleppey and Kottayam districts. *Kaipad* lands are located in Kannur, Kasargod and Kozhikkode districts.

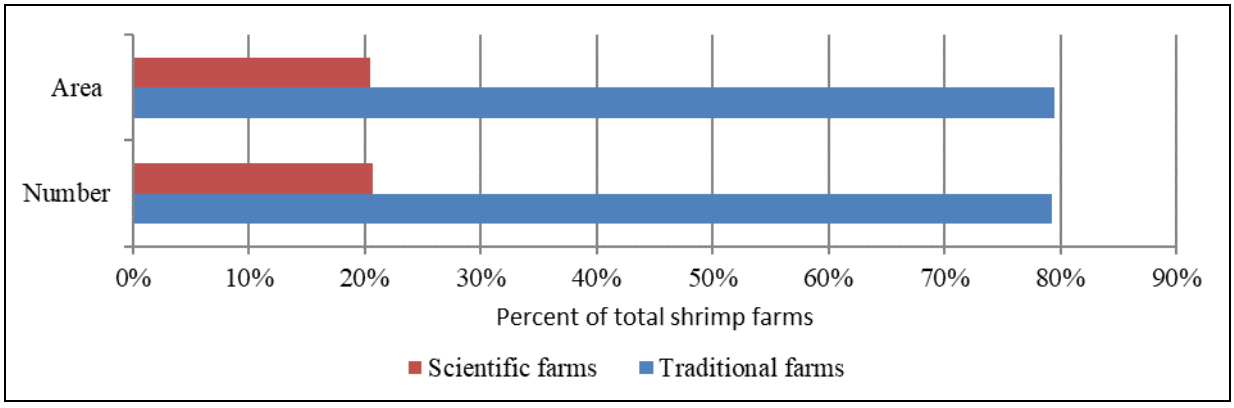


**Fig 2:** Percentage distribution of traditional and scientific shrimp farming units.

In both the systems soon after the paddy harvest, if shrimp farming is not done by the owners themselves, the fields are leased out to prawn farmers for a period of five months *ie.*, mid-November to mid-April. The lease value varies depending on the productivity of the field which is decided by the location and proximity of the field to the bar mouth. The farmer prepares the fields for the operation by repairing the bunds, fixing sluice gates for regulating the flow of tidal water and such other work. Paddy stumps and straw left out in the field are not removed but are allowed to decay there, to form good organic manure which promotes the growth of algal pasture including the periphyton.

Seed stocking is done by letting in tidal water into the fields at high tide. Along with the tidal water juveniles of prawns from the adjoining backwater areas enter the field. They are attracted into the field by keeping a light at the sluice gate during the night. When the tidal water starts receding during the low tide, a closely tied screen made of split bamboo or areca nut tree (nowadays mostly nylon nets) is inserted across the sluice gate and water alone is let out trapping the juvenile prawns that have entered the field. This sort of entrapment is continued at every high tide through out the period of operation. Of late, obviously, on account of the scarcity of juvenile prawn in the adjoining waters and consequent failure in the natural stocking of shrimp seeds, farmers undertake supplementary stocking with hatchery-produced seeds of black tiger prawn in the field at a low density @ 1-2 seed per square metre.

Harvesting, known as filtration, begins from mid- December. This is done during the low tide by operating a conical net fixed at the sluice gate. Sluice net operation (filtration) is done at dawn and dusk for five to eight days around every new moon and full moon period (locally known as *thakkom*) during which the maximum tidal amplitude is experienced. The final harvesting locally known as *kalakki pidutham* or *kettu kalakkal* is done at the end of the season by operating

sluice net, cast net and also by handpicking.
Shrimp feed on natural foods that enter the pond regularly with the tides and are subsequently enhanced by organic or chemical fertilisers. If available at a lower cost, fresh fish or molluscan meat are used as supplementary feed. Due to the low stocking densities, larger-sized shrimp are commonly harvested primarily during the last month.

### 3.2. Production and productivity

The total annual farmed shrimp production of Kerala during the study period was estimated to be 2,952.56 metric tonnes. The relative share of traditional and scientific farming sectors to total farmed shrimp production of the state is presented in Figure 3.

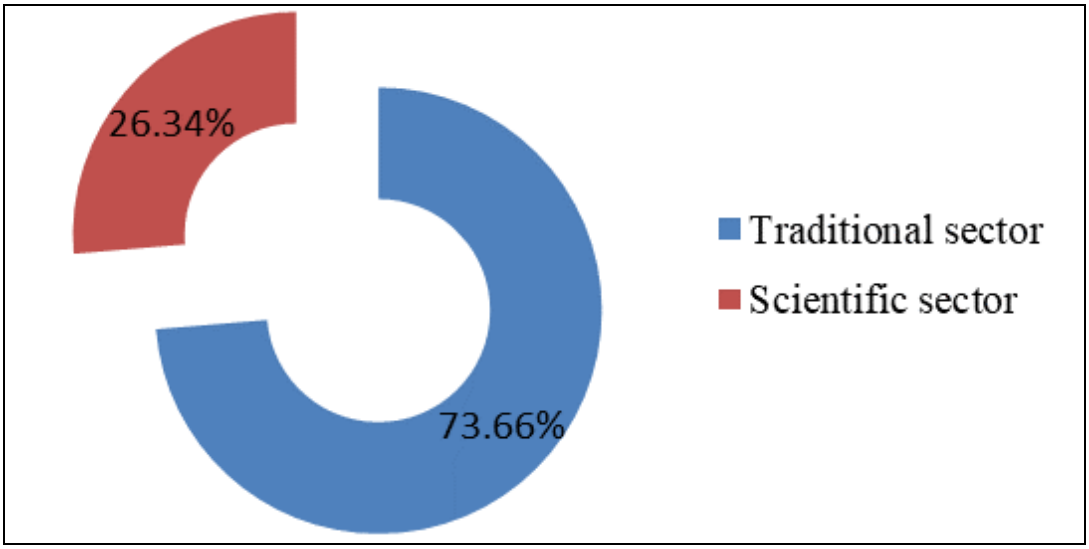


**Fig 3:** The relative share of traditional and scientific farming sectors to total farmed shrimp production.

In traditional farms, *P. monodon, P. indicus, M. monoceos, M. dobsoni, L. vannamei, P. semisulcatus,* and *M. affinis* were harvested. The percentage composition of the different species of shrimps in the harvest from traditional farms is provided in Figure 4. Indeed, the species composition of traditional farms was expected to be significantly influenced by the supplementary stocking. In the context, to have a comparison, an attempt was also made in the present study to understand the species composition of those traditional farms which did not undertake any supplementary stocking, details of which are provided in Figure 5.
Tiger shrimp (*P. monodon*) accounted for 70.56% of the total shrimp production from the scientific farming sector. Indian white prawn (*P. indicus*) and Pacific white shrimp accounted for 0.55% and 28.89, respectively. Species wise estimated total farmed shrimp production (traditional and scientific sectors) in Kerala is presented in Table 2.

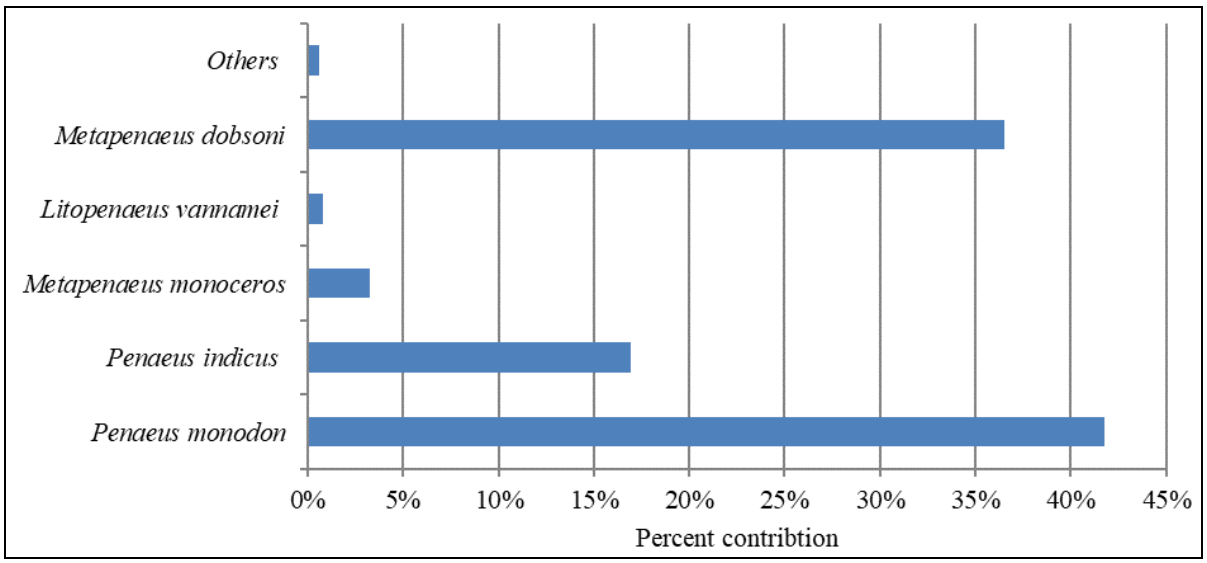


**Fig 4:** Percentage contribution of different species of shrimps in the harvest (weight) in traditional shrimp farms.

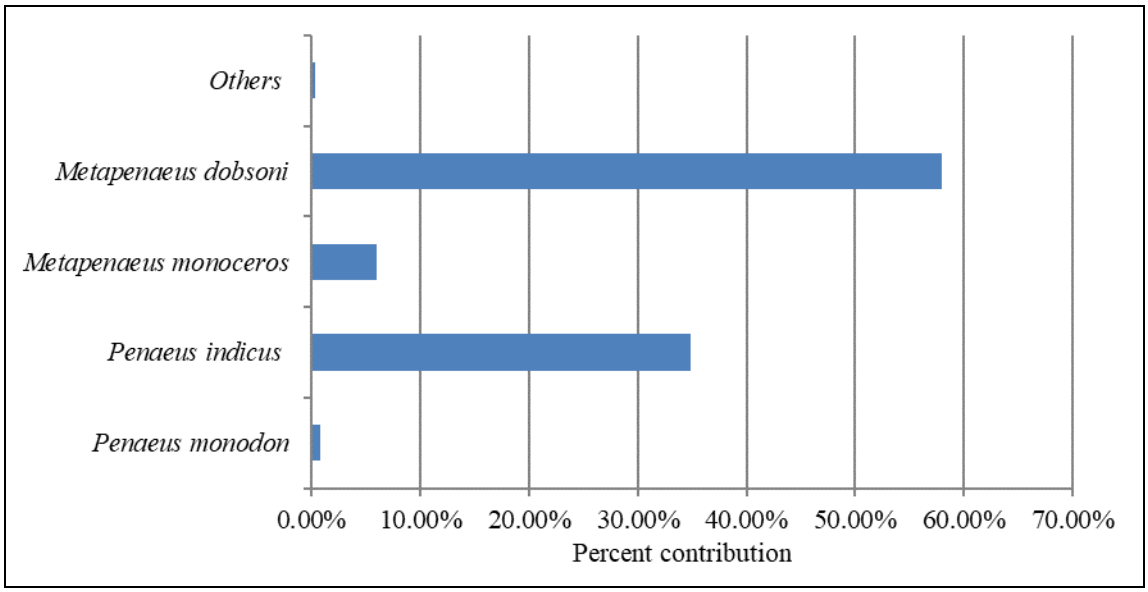


**Fig 5:** Percentage contribution of different species of shrimps in the harvest (weight) in traditional shrimp farms that do not undertake supplementary stocking.

**Table 2:** Estimated farmed shrimp production

| Farming system | Shrimp production in metric tons | | | | | | |
|---|---|---|---|---|---|---|---|
| | *P. monodon* | *P. indicus* | *M. monoceros* | *M. dobsoni* | *L. vannamei* | Other species of shrimp* | Total |
| Traditional farms | 908.52 | 368.66 | 71.28 | 794.94 | 18.11 | 13.29 | 2,174.80# |
| Scientific farms | 548.80 | 4.29 | 0.00 | 0.00 | 224.67 | 0.00 | 777.76 |
| Total | 1,457.32 | 372.95 | 71.28 | 794.94 | 242.78 | 13.29 | 2,952.56 |

*mainly *P. semisulcatus* and *M. affinis*
#in addition, 3,448.28 t of finfishes and 497.42 t of crabs were harvested from the traditional shrimp farms.

The productivity of shrimp refers to the average weight of shrimp harvested per unit area (hectare) per year. The productivity of traditional and scientific farms is presented in Figure 6. Productivity has also been calculated for various other situations like traditional farms (with supplementary stocking): 881.40 kg $ha^{-1}$ $year^{-1}$; traditional farms (without supplementary stocking): 605.46 kg $ha^{-1}$ $year^{-1}$; Scientific farms (overall): 1233.83 kg $ha^{-1}$ $year^{-1}$; *P. monodon* (traditional and scientific): 468.99 kg $ha^{-1}$ $year^{-1}$; *P. indicus* (traditional and scientific): 146.56 kg $ha^{-1}$ $year^{-1}$ and *L.vannamei* (traditional and scientific): 1916.02 kg $ha^{-1}$ $year^{-1}$. The overall productivity of shrimp farms in Kerala (traditional and scientific farms) was found to be 932.08 kg $ha^{-1}$ $year^{-1}$.

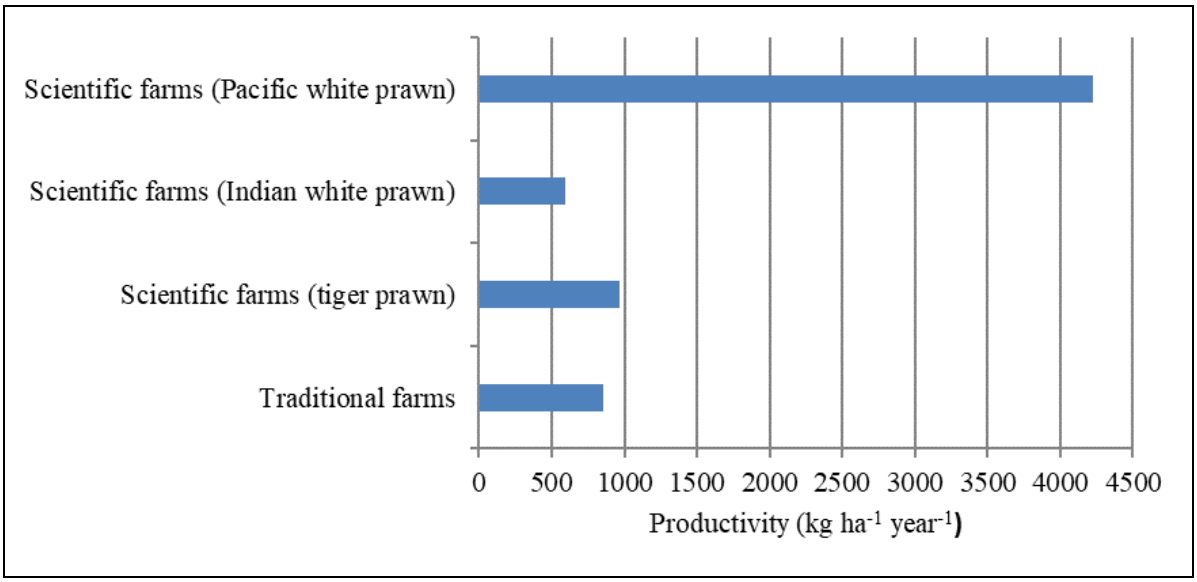


**Fig 6:** Productivity (kg $ha^{-1}$ $year^{-1}$) of shrimp farms.

## 4. Discussion

The state of Kerala has 65,214 ha. of brackish water areas amenable for brackish water aquaculture [12]. In addition, the state has 12, 873 hectare of prawn filtration fields which are utilised for rice cum shrimp farming [12]. However, in the present study, the total area under shrimp farming in Kerala was estimated to be 10,599.26 ha. of which 8430.98 ha. was under traditional farming and 2,168.28 ha was under scientific

farming. It means that only 13.57% of the total area available for brackish water aquaculture is at present being utilised, revealing the great potential of the state for further development of shrimp aquaculture.

The major portion of the shrimp farming units in Kerala is under traditional farming wherein production and profitability are low. These farm units fall under the subsistence farming system. These are low input systems which are conducted in tidal areas and are tide fed. The ponds are irregular in shape according to land boundaries and are generally larger and easily constructed by manual labour for cost reduction [13].

Many authors gave detailed accounts of various aspects of traditional shrimp farming practices in Kerala [14-26]. These included aspects like the technology of farming, physicochemical parameters of the fields, economic analysis of farming and other aspects. Gayathri and Raveendran[27] explored the untapped potential of coastal paddy fields of Kerala.

Unnithan [28] discussed the demerits of the traditional system of prawn farming in detail. According to him in the traditional system, the yield would be a mix of essential and less important species of prawns. Since no sufficient time is allowed for the growth of the prawns trapped inside, the catch would contain undersized prawns to a considerable extent. Predatory organisms entering the field along with the tidal water would eat away a good number of the prawns. Since stocking is entirely dependent on nature, no control over the stocking density with regard to the extent, and productivity of the field is possible, and the fields may be some times over-stocked and under-stocked. Over-stocking leads to poor growth of prawns, because of competition for food and space. Under-stocking hinders the full exploitation of the field. The above author advocated the adoption of scientific shrimp farming over the traditional system of farming.

The brackish water scientific shrimp culture in Kerala is at present more or less restricted to the tiger prawn (*P. monodon*) and to a very limited extent to the Indian white prawn (*P. indicus*) and the white legged prawn (*L.vannamei*). Sahadevan[29] made a similar observation. According to him, commercial farming of finfishes like milkfish, sea bass (*Lates calcarifer*), mullets (*Mugil cephalus, Liza* spp.) and pearl spot (*Etroplus suratensis*) and that of the white legged prawn (*L. vannamei)* was not attempted to any appreciable level in brackish water farming in the state. The author attributed the reluctance of farmers for a shift in species, acute shortage of seed of the milkfish, mullets, sea bass and the white legged prawn in the state as the principal reasons for the 'tiger prawn- centric' brackish water aquaculture development in the state.

It is of interest to note that in India as a whole *L. vannamei* is farmed in 61.27% of the total area under shrimp farming [4]. Further, except in Kerala and to some extent in West Bengal (7.47%), in all other states, *L. vannamei* occupies most areas under shrimp farming. Thus *L. vannamei* is farmed in 97.07% of the total area under shrimp farming in Andhra Pradesh, 99.28% in Gujarat, 99.89% in Tamil Nadu, 100% in Maharashtra, 97.07% in Odisha, 100% in Goa and 56.92% in Karnataka, in the year 2017-18 [4].

Kerala is the only state in India which relies almost entirely on *P. monodon* for farming. As per the statistics published by Government of India [3] *L. vannamei* is the dominant species of shrimp farmed in the country as a whole and accounts for 91.52% of the total shrimp produced through farming, in the year 2017-18. Further, *L. vannamei* is the most predominant species of shrimp in all other shrimp farming states of the country. The species accounted for 99.41% of the total farmed shrimp production in Andhra Pradesh, 99.71% in Gujarat, 99.94% in Tamil Nadu, 100% in Maharashtra, 90.55% in Odisha, 100% in Goa, 96.13% in Karnataka and 31.03% in West Bengal, in the year 2017-18 [3]. It may further be pointed out here that in the year 2016, globally 54 species of crustaceans were cultured commercially of which *L. vannamei* and *P. monodon* together constituted 61.78% of the total crustacean production [30]. In the year 2018, the contribution of the former was 52.90% whereas that of the latter was 8.1% [7]. The balance was contributed by crawfish, crabs, freshwater prawns and other crustaceans.

The failure of the state to shift from *P. monodon* to *L. vannamei* is one of the principal reasons for the low-profile performance of the shrimp farming sector of the state as the latter can be farmed at higher density and the production achieved is relatively very high [31, 32]. Modern prawn farming is a dynamic process in which optimum per unit area production depends on highly manipulatable population density adjustable with the quantum of feed and the conversion ratio of the species concerned.

The present study revealed that in traditional prawn farms *M. dobsoni* (49.78%), *P. monodon* (38.11%), *P. indicus* (7.90%) and *M. monoceos (3.01%)* were the predominant species harvested. *P. semisulcatus* and *M. affinis* were also harvested, though to a minimal extent. The observation on the percentage composition of different species in the present study is in variance with the observations made by many previous researchers.

George *et al.* [33] reported *P. indicus, M. affinis, M. dobsoni* and *M. monoceros* as the principal species of shrimps in the *pokkali* prawn filtration fields. The authors found *M. dobsoni* to contribute to more than 50% of the catch. George [34, 35] observed that more than 50% of the catch was represented by *M. dobsoni*. George [34] reported a declining trend of the fishery of *M. dobsoni* and *M. monoceros* and the increased contribution of *P. indicus* in *pokkali* fields. George [16, 36] and Unnithan [28] reported 36-43% of *P. indicus*, 0.7-1% of *P. monodon*, 53-57% of *M. dobsoni* and 3.5- 6% of *M. monoceros* in the catch. According to Mathew[18] the shrimp catch in traditional farms is chiefly composed of *M. dobsoni* (65-80%), *P. indicus* (15-30%) and *M. monoceros* (5-10%).

Studies conducted by Pillai *et al.* [37] indicated the dominance of *P. indicus* over *M. dobsoni* in a *pokkali* field. A gradual shift from this trend was noticed in the catches as the practice of supplementary stocking of the *pokkali* fields with *P. indicus* seed caught up with the farmers in the late 1980s. According to Pillai [38] the shrimp fishery of the *pokkali* fields was contributed mainly by four species of penaeids, *P. indicus, P, monodon, M. dobsoni and M. monoceros.* He observed that in the year 1996-97, the major share (59%) was contributed by *P. indicus* followed by *M. dobsoni* (28.6%), *M. monoceros* (1.9%) and *P.monodon* (0.5%) in their order of dominance. In the subsequent year, the same author reported *M. dobsoni* to dominate the catch (37.9%) followed by *M. monoceros* (31.1%) and *P. indicus* (30.7%). *P. monodon* contributed only 0.3% to the total catch. In the same study, in another field, the author found *M. dobsoni* (44.6%) to dominate the harvest. The next dominant species was *P. indicus* (33.8%) followed by *M. monoceros* (21.6%). In yet another field, the catch was found to be contributed mainly by *M. dobsoni* (57%). The shares of *P. indicus, M. monoceros* and *P. monodon* to the total fishery were 27.1%, 14.2% and

1.7%, respectively. The author attributed the observed difference in the species composition to reduced recruitment of certain species during certain seasons and to the supplementary stocking of hatchery-produced seeds in some fields. Purushan [23] reported *M. dobsoni* (53-57%), *P. indicus* (36-42%) and *M. monoceros* (3-6%) to contribute to the shrimp harvest from *pokkali* fields.

Cheruvat [39] reported the percentage composition of shrimps in the *kaipad* fields. According to the author *M. dobsoni* constituted 50-53% of the total shrimp harvest, followed in order by *P. indicus* (30-31%), *M. monoceros* (15%) and *P. monodon* (2-3%). Sudhan *et al.* [40] recently reported *M. dobsoni, M. monoceros, P. indicus, P. monodon, P. semisulcatus* and *M. affinis as* the principal species harvested from *pokkali* fields.

The observed difference in percentage composition of various species in the present study with that reported earlier is principally attributed to the practice of supplementary stocking of hatchery-produced seeds of *P. monodon* and *L vannamei*. Many of the earlier reports related to the species composition of the harvest when there was no supplementary stocking of shrimp seeds in the fields. Stocking of hatchery-produced seeds will obviously shift the relative percentage in favour of the species stocked. The spatial and temporal variation in recruitment of different species may also be responsible for the observed difference, at least to some extent. It may be pointed out here that the various studies indicated above were conducted at different points of time and in farms located at different distances from the sea. It may also be pointed out here that there existed no unanimity in the values of the percentage species composition reported by the various earlier workers, too.

The production and productivity of shrimp farms recorded in the present study is relatively low when compared to the values reported from other states of the country. As per the latest statistics published by Marine Products Export Development Authority (MPEDA) [4] the production of shrimp by other Indian states is relatively very high. The considerable difference in the production figures is primarily because these states have more areas under shrimp cultivation. The higher productivity of shrimp farms in these states has also contributed to the higher production values reported from these states. Further, in most of these states *L. vannamei* whose yields are higher is being cultivated but in Kerala *P. monodon* is the prime species. The productivity of shrimp farms reported in the present study is higher than the figures reported by MPEDA [4]. This is obviously on account of the fact the productivity figure reported by MPEDA includes the harvest of *P. monodon* and *L. vannamei* only. In comparison, the present estimate includes other species also, though a sizeable part of which may not have much export value and are destined to be consumed domestically. The productivity figure reported for the country [4] as a whole is 4450 kg $ha^{-1}$. It reveals in unambiguous terms the scope for further improvement of the production and productivity of shrimp farms in Kerala. Enhancing the productivity of the existing farms and extending culture to new areas could be considered as the ways to enhance shrimp production of the state of Kerala as has been suggested by Kutty *et al.* [42]. Sahadevan [31] has discussed the various reasons for the low productivity of shrimp farms of Kerala. He [32] has also given a detailed account of the strategies to be adopted for improving the shrimp production of the state through aquaculture.

It may be pointed out here that the production figures of tiger prawn and white legged prawn estimated in the present study are quite comparable to the figures reported by MPEDA [4] indicating the reliability for the use of the sampling method suggested. The successful conduct of the study as well as the meaningful results obtained, revalidate the methodology adopted for the estimation of farmed shrimp production. The sampling methodology with modifications to suit the local conditions is recommended for use for the estimation of aquaculture production in other parts of the country and elsewhere in the world.

## 5. Conclusion

Information on the quantity of farmed shrimp production is required for meaningful evaluation of the contribution of the sector to the economy and to the nutritional security of the state. The information is also important for assessing the impact of different schemes implemented by the Governments and other developmental agencies. In the present study, the yearly (2017-2018) farmed shrimp production of Kerala was estimated to be 2, 952.56 t., of which the shares of tiger prawn, pacific white prawn and Indian white prawn were found to be 49.36, 12.63 and 8.22%, respectively. The productivity of shrimp farms in Kerala was estimated to be 932.08 kg $ha^{-1}year^{-1}$ which is very low compared to that of other states in the country. The total area under shrimp farming in Kerala was estimated to be 10,599.26 ha. of which 8,430.98 ha. was under traditional farming and 2,168.28 ha was under scientific farming. The present study revealed that the total shrimp production and the area under shrimp farming in Kerala are relatively low. The sampling methodology used in the present study with modifications to suit the local conditions, if any required, is recommended for use for the estimation of aquaculture production.

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