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Evaluating Sustainability: A Social Cost-Benefit Analysis of Shrimp Aquaculture Practices in Kerala

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Abstract
Kerala is blessed with an abundance of freshwater and brackish water rivers, estuaries, backwaters, and interconnecting backwaters. These bodies of water add to the inland production and make the land lush and fertile. As per the 'State Wise Area Utilized and Production of Tiger Shrimp 2020-21' data of MPEDA Kerala has 2813.85ha area under culture in hectares and 1128.98 estimated production in tonnes. In the last decades its development has attracted considerable attention because of its export potential. During the study period (2017-18), Kerala produced an estimated 2,952.56 metric tonnes of farmed shrimp annually, out of which 26.34 percent were produced scientifically and the remaining 73.66 percent were produced traditionally. State fishery sector is also promoting 'one paddy one shrimp farming' project as it is suitable for coastal wetland economy like Kerala. Consequently, shrimp aquaculture sector plays a major role in the coastal wetland economy of Kerala, which has 234 prawn filtration fields covering 12873ha and 65213ha of brackish water area. 'Sustainable blue economy' states that shrimp aquaculture contributes to food security, social status, livelihood for the poor, women's empowerment through employment, increased family income, and purchasing power to the Kerala economy, it is necessary to question the sustainability of the Kerala shrimp aquaculture sector, particularly in light of the micro plastic pollution caused by current shrimp aquaculture practices. Kerala is a top producer of shrimp raised in aquaculture due to its abundant backwater and estuary water bodies. There are claims that the amount of shrimp consumed domestically is also rising. Exposure to Micro plastics poses a severe risk to the health and well-being of regular shrimp users. Using Soya Bean Meal (SBM), a reasonably priced and sustainable substitute for artificial fish feed becomes necessary. In light of this, this paper conducts a sustainability analysis based on social cost-benefit analysis of the feeding practices currently used by the shrimp aquaculture industry in Kerala.

Keywords: Sustainability Analysis, Kerala Shrimp Aquaculture Practices, Social Cost-Benefit analysis

1. Introduction

The 'blue economy' idea aims to ensure environmental sustainability while also fostering economic growth, social inclusion, and the maintenance or enhancement of livelihoods. Its main focus is the decoupling of socioeconomic development from environmental and ecosystem deterioration through ocean-related industries and activities. A crucial aspect of the blue economy is the need to balance the economic, social, and environmental aspects of sustainable development in connection to marine resources. Aquaculture is one of the major sectors of 'blue economy' which is expected to satisfy the food and protein needs of growing population. Seafood products supply a large portion of protein needs in many lower developed countries and under developed countries. Reviving the aquaculture industry can aid in achieving food security, social inclusion, and economic development for the under privileged and lowest rungs of society because it provides 58 percent of the fish sold in global markets. The aquaculture sector helps to reduce the local seafood imports, aids in catalyzing employment, boosting food security and nutritional needs.

Kerala is fortunate to have a 590-kilometer (km) coastline and a territorial sea that covers over 13,000 km^2.Shrimp aquaculture in locations with brackish water dates back many years in Kerala. However, a significant majority of the state's brackish water farming systems fall under traditional farming, which has low levels of productivity and production (Sahadevan, 2012). Even though shrimp aquaculture is contributing to various social benefits such as food security, social status, livelihood for the poor, women empowerment, increased family income and purchasing power to the Kerala economy, as stated in the concept of 'sustainable blue economy' some resent scientific studies are questioning the sustainability of traditional shrimp aquaculture, especially about the Micro Plastic (MP) pollution caused by shrimp aquaculture sector which includes: - i. Micro plastics in fishmeal (Sofi Uddin Mahamud et al.,2022), ii. Micro plastics created as a result of the deterioration and use of plastic fishing gear (Haodi Wu et al.) iii. Micro plastic from the packaging of aquaculture products (Haodi Wu et al., 2023), iv. The likelihood of ingesting micro plastics during aquaculture production increases in closed or semi-closed environments (Haodi Wu et al., 2023).

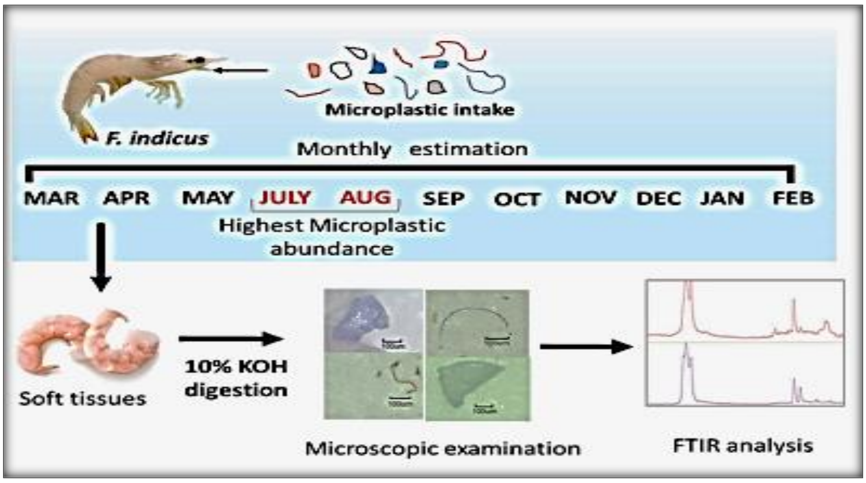
Many recent studies have found that fishmeal is the main way that MPs enter the aquaculture environment since some of it is wasted as aquaculture feed (partially returning removed MPs but also possibly adding new ones). A total of 180-310 million pieces of MPs or 10-1670 kg of MPs are thought to reach coastal water bodies annually as a result of the 2.5 million tonnes of fishmeal used annually for marine aquaculture (Thiele et al., 2021). Small marine fish directly consume the already present MP from the marine environment, and zooplankton indirectly consumes them after they have accumulated (Naidu et al., 2018). Fishmeal made from tiny marine debris fish is fed to the shrimp aquaculture system regularly, which is how MP are introduced into fish feed. MPs are released into the aqua cultured pond water and the shrimps are forced to intake this as it is a closed or semi-closed ecosystem. MP is also accumulated in the tissues and organs of shrimps. Humans who are at the highest tropic level consume these fish tissues which will eventually lead to physical complications (Sofi Uddin Mahamud et al., 2022). According to a study centered on the Cochin coast (Damaris Benny Daniel et al. 2020), all of this MP contamination, particularly that caused by fishmeal in the shrimp farming industry, is creating an alarming scenario where even traces of MPs are discovered in Indian White Shrimps (Fenneropenaeus indicus). Similar studies have discussed the negative impacts of MP injection at various tropical levels, how it is harming human health in particular, and the physical problems brought on by consuming seafood that contains MP (Sofi Uddin Mahamud et al., 2022). This massive MP pollution done by aquaculture industry is creating a question on the sustainability of the blue economy in general and aquaculture in particular. Sofi Uddin Mahamud's research has demonstrated how easily MP, which is pervasively present in the environment at all trophic levels, can enter the human food chain. Fisheries products are an important source of MPs in our food chain.

1.1 Conceptual Pathways through which MPs are transmitted from the Ocean to Humans: Small marine fish directly consume marine environment MP that are readily available or indirectly consume them after they have accumulated in zooplankton. MPs are introduced into the pond aquaculture system through routine feeding and then transferred into Fish Meal (FM) made from small marine garbage fish. MPs are released into pond water, where they interact with the ecosystem's native flora. Additionally, MPs build up in farmed shrimp tissues, which significantly alter fish's physiology. After consuming MPs including shrimps and being subjected to several bodily problems, humans are exposed to MPs (Sofi Uddin Mahamud et al., 2022).

1.2 Evidence of Micro Plastic in Shrimp Aqua Culture Practices in Kerala: A study conducted by S. Gündogdu et.al, 2021 identified the evidence of MP in 26 different FM products that is distributed globally. The study used 26 distinct FM products that came from four different continents and Antarctica, making up the great bulk of commercial FM products that are sold and traded around the world. FM imported from China had substantially higher plastics content (337.5–34.5 n kg-1) than FM from other countries (526.7–526.7 n kg-1).According to these findings; FM may be a significant entry point for plastics into the seafood supply chain. It also explains the FM production process and how marine plastic is up-cycled into the aquaculture system in the form of FM. (S. Gündogdu et.al, 2021).

Micro Plastic presence in regular Indian fishmeal used in Shrimp Aquaculture is analysed by Parichehr Hanachi et.al, 2019 by using a Fourier transform infrared (FTIR) spectroscopy, and this study examined the presence of MPs in four types of commercial FM originating from marine sources. The average size of the particles was 452 161 m (SD). Fish raised in aquaculture and FM levels of MPs were found to be positively correlated. This study shows that FM derived from marine sources may be a source of MPs that might contaminate fish raised in aquariums, raising questions about aquaculture (Parichehr Hanachi et.al, 2019). Damaris Benny Daniel et.al, 2020 examined the presence and seasonal change of MPs in Fenneropenaeus indicus, a species of commercially significant marine shrimp from Cochin, Kerala India. Over the course of a year, from March 2018 to February 2019, the soft tissues of 330 shrimp were evaluated. FTIR Spectroscopy revealed the presence of 128 MPs in all, 83 percent of which were fibers and the shrimp samples yielded an average (mean SD) of 0.39 0.6 MPs/shrimp (0.04 0.07 MPs/g wet weight) from the sampled shrimps. In comparison to other months, the MPs contamination was much higher in July and August (the monsoon season). (Damaris Benny Daniel et.al, 2020)

Figure 1: FTIR result of Kerala shrimp



Source: Microplastics in Indian white shrimps (Fenneropenaeus indicus) from coastal waters near Cochin, Kerala, India, abundance, features, and seasonal change. Damaris Benny Saly N. Thomas, P. Muhamed Ashraf, and Daniel A, 2020.

Therefore, present study assumes that shrimp meal contains an average of 0.39 to 0.6 MPs content per shrimp based on this findings.

1.3 Micro Plastic Exposure in Human Food Chain can lead to Colorectal Cancer: A study conducted by Meltem Etin, et al., (2022) determined whether MPs were present in the colon tissue samples (C, n=15) taken from subjects who had not yet been diagnosed with colo-rectal cancer as well as in the tumorous colon tissues (TCT, n=16) and non-tumorous colon tissues (N-TCT, n=16) of the patients with colo-rectal adenocarcinoma. (Meltem et al., 2022)

Figure 2: Results of Plastic Evidence in Affected Colorectal Cancer Patients

The number and size of the microplastic particles extracted from the colon tissues of all groups.

Groups	Number of microplastic particles (in per 1 g colon tissue)	Particle size (μm) (min.-max.)
TCT (n=16)	702.68±504.26	1-613
N-TCT (n=16)	207.78±154.12	1-743
C (n=15)	218.28±213.05	1-1299

TCT: Tumoral colon tissues from the patients diagnosed with colorectal adenocarcinoma; N-TCT: Non-tumoral colon tissues from the patients diagnosed with colorectal adenocarcinoma; C (Controls): Colon tissues from subjects not diagnosed with colorectal cancer.

Source: Meltem ETIN et al., Detection of Micro-plastics in Patients with Colo-rectal Adenocarcinoma Using Various Techniques, 2022

In 1 g of colon tissue, it was discovered that the TCT group had considerably more MPs removed than the N-TCT group did. Therefore, this study made the assumption that eating shrimp from aquaculture can increase the risk of developing colorectal cancer. So, using the feed conversion ratio (FCR) as the independent variable, present study investigates a partial societal cost benefit analysis, using regular FM in shrimp farming as a polluting input with negative externality. This study made the premise that the only source of MP in the human food chain is consumption of shrimp.

2. Review of Literature

The current aquaculture practices followed across the globe is proved to have dreadful effect on environment and human health especially due to the MP injection into the food chain (Wu, C et al., 2022). Hence use of sustainable farming methods which are cost effective and revenue yielding is the need of the hour. The major contaminator in the aquaculture food chain is the regular fishmeal which cycles up the marine MP from seaweeds and wild fish, which are the major raw materials in the regular fishmeal (Mahamud, A. S. U. et al., 2022).One of the main barriers to the adoption of sustainable fishmeal alternative in the shrimp aquaculture is the cost effectiveness of the sustainable methods. Private cost of an average shrimp farm in Kerala has been typically calculated using NPV and BCR (Sahadevan, 2022). Most of the recent literature on the MP exposure of shrimp aquaculture questions the sustainability of aquaculture industry in particular and shrimp aquaculture in general across the globe (Wu, H. et al., 2023) or on the assessment of health hazards caused due to MP injection to human body via food chain (Al Mamun, et al., 2023). Studies even suggest use of sustainable alternative fishmeal such as Soya bean meal (SBM), Moringa leaf powder etc (Yun. H, et al., 2017). There exists a research gap because, despite studies on sustainability and sustainable fishmeal alternatives have done rigorously, no study has conducted on the social cost-benefit analysis of health hazards caused by regular fishmeal, which is the primary input used in shrimp aquaculture.

3. Data and Methodology

This study is being carried out in Kerala, an Indian state. Low-lying coastal regions that are ideal for brackish water aquaculture are a bountiful source of brackish water resources for the maritime state of Kerala. Kerala has 65,213 hectares (ha) of brackish water regions, most of which are low-lying and suitable for commercial shrimp farming. Rice and shrimp farming are historically done on 12,873 acres of traditional prawn filtering fields in the state. This study is based on a wide set of theories extracted from disciplines like microbiology, analytical chemistry, medical science, marine science and aquaculture studies. Along with that, economic concepts such as social cost benefit analysis, benefit cost ratio, net present value, opportunity cost, rate of return and willingness to pay concept (WTP) etc. were also utilised. This study makes a comparative social cost benefit analysis of various sustainable and non-sustainable practices of shrimp farming (different fish feed replacement rates with SBM) with special reference to health.

Timeframe of this study is taken in annual form and the costs and benefits were calculated and expressed in 2017 -2018 prices due to the secondary data availability. Even though the incidence of colorectal cancer caused due to MP exposure can only be computed in an infinite timeline, so incident rate of new cases are assumed to be of one year for the easiness of estimation. In an eight-week feeding trial, various doses of dietary Soya bean meal (SBM) were tested as a FM (FM) substitute for white-leg shrimp. Eight experimental diets were tested, including a base diet that replaced no FM with SBM in a clear water system (S0SW), four diets that replaced FM with SBM at 0 percent, 33 percent, 67 percent, and 100 percent, and it was discovered that 33percent SBM replacement is best.

Table 1: SBM Replacement and Reduction in Actual Production (in percent)

Aqua Culture Methods	S0	S33	S67	S100
Replaced FM percent	0 percent	33 percent	67 percent	100 percent
percent of production	0 percent	8 percent	11.3 percent	39.7 percent

- The 1st alternative of 0 percent conversion shows there is maximum production but the aquaculture is fully unsustainable.
- 2nd alternative option of 33 percent conversion ratio shows that production will decrease to 92percent. And the aquaculture will become partially sustainable due to decrease in the amount of MP injection into the aqua cultured shrimp.
- 3rd alternative option of 67percent conversion ratio shows that production will decrease to 88.7percent and the production practice is partially sustainable.
- 4th alternative option of 100percent use of SBM shows that production will decrease to 60.3percent and the production practice is fully sustainable and organic.

Assumptions:

- Marine driven FM is the only source of MP pollution in the shrimp aquaculture industry.
- Aqua-cultured shrimp is the only source of MP in the human food chain.
- In an ideal situation in which 100percent of SBM is used the number of colo-rectal cancer patients will be nil. And 67percent use of SBM will result in the reduction in the number of colo-rectal

cancer patients by 67percent and so on. When there is only FM used, it will lead to a total number of 5.5 person out of 1000000 new cases of colo-rectal cases in 1 year.

- Health cost is the only cost borne by the society.
- The timeline is assumed to be 1 year (2017-18).
- The WTP (Willingness to Pay) is assumed to be Rs500 for all the 3 alternatives which uses SBM (33percent use of SBM, 67percent use of SBM and 100percent use of SBM).
- This study only considers partial health costs and benefits due to the limited time duration of the study period.
- The timeline showing the effect of MP is infinite but due to the insufficient secondary data and lack of time available the timeline is considered to be one year (2017-18) only consider.

A partial social cost and benefit of health variable is considered along with private cost and benefit in the entire state of Kerala. In our study the costs and benefits were calculated and expressed in 2017 -2018 prices. The NPV and BCR is calculated to assess the optimal fish feed replacement rate with SBM in Kerala aquaculture industry.

Benefit Cost Ratio (BCR) of shrimp aqua culture practice is calculated the ratio of benefit and cost per hectare based on 2017 -2018 prices.

$$BCR = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{C_t}{(1+i)^t}}$$

Net Present Value (NPV) is used to estimate the profitability by taking the difference between the present value of cash inflows and the present value of cash outflows over the project’s time period. If the difference is positive, it’s a profitable and if it is negative, then it’s not worthy. NPV is calculated and expressed in 2017 -2018 prices by using the formula,

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t}$$

The rate of return on Investment was calculated by representing the residual return to the Owner’s capital as a percentage of the initial investment. The rate of return based on average investment costs to the present farming units was calculated as:

Rate of Return on Investment = [(Market or Sales Value – Initial Cost)/ Initial Cost] * 100

Opportunity Cost: refers to the potential gain one forgoes while selecting an alternative over the next-best option. The potential advantages that are lost when a person, business, or investment chooses one option over another are known as opportunity costs.

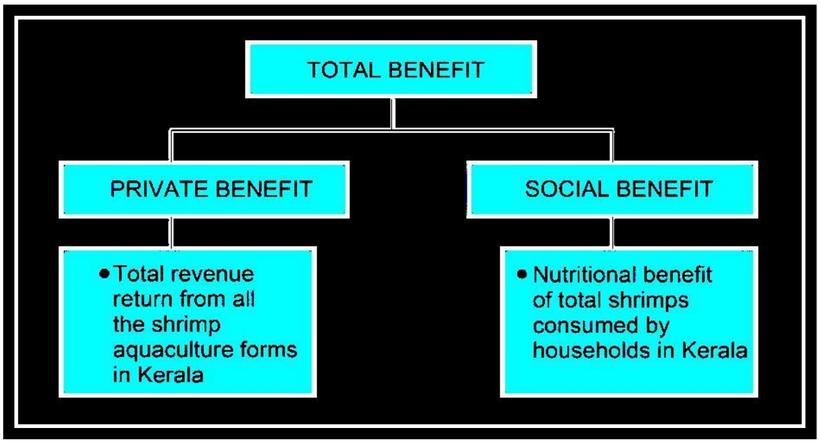
Opportunity Cost = FO (return on the best-forgone choice) – CO (return on the chosen)

Willingness to Pay (WTP): The maximum amount a client is willing to pay for a good or service is known as willingness to pay (WTP). WTP fluctuates according to the situation, various demographics, the particular client, and can change over time. The maximum sum of money a consumer would give up in exchange for a good or service is known as the willingness to pay.

4. Results and Discussion

The total benefit of shrimp aqua culture practices in Kerala can be divided into two, private benefit and social benefit. Private benefit is the total return from shrimp aquaculture by considering all the scientific and traditional shrimp farms in Kerala. Social benefit is calculated using willingness to pay (WTP) for nutrition from the entire quantity of shrimp consumed by rural urban household in Kerala.

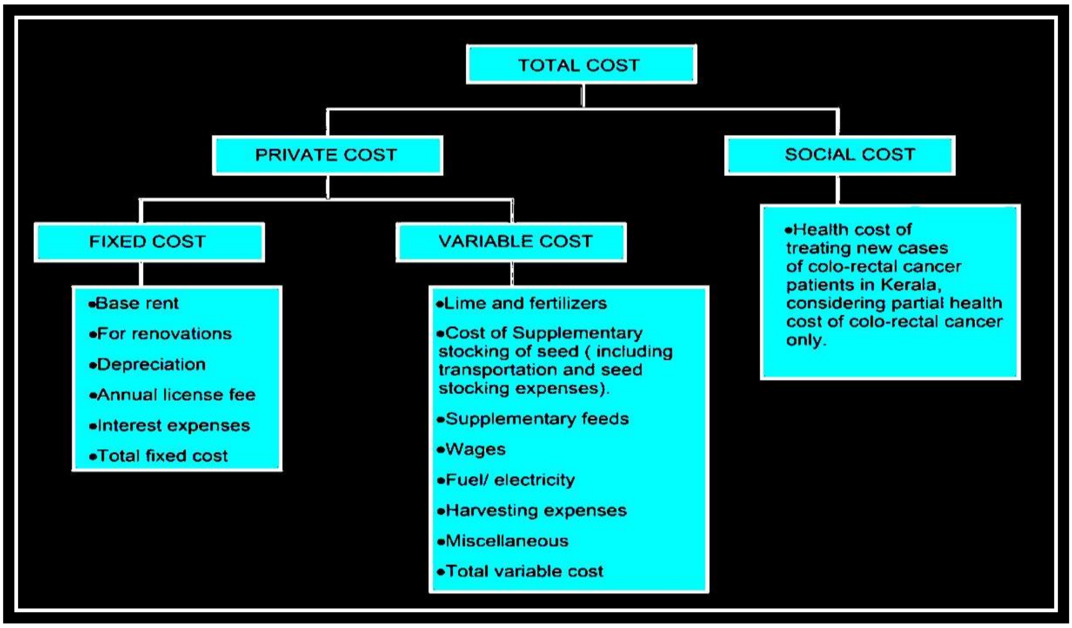
Figure 3: Classification of Total Benefits



Source: Created by Authors

The total cost can be divided into two private cost and social cost. Private cost includes fixed cost and variable costs in the shrimp aquaculture by considering all the scientific and traditional shrimp farms in Kerala. Social benefit is calculated using willingness to pay (WTP) for nutrition from the entire quantity of shrimp consumed by rural - urban household in Kerala.

Figure 4: Classification of Total Cost



Source: Created by Authors

Total Estimated Cost of Various shrimp aquaculture practices in Kerala is calculated by considering the total variable costs of shrimp aquaculture in Kerala such as fixed cost (Lease rent, Pond renovation, Depreciation, Annual license and Interest expenses) and variable costs (Lime and fertilizers, Cost of supplementary stocking of seed, Supplementary feeds, Wages, Fuel/ electricity, Harvesting expenses and Miscellaneous expenses). Total Cost Includes total cost of Traditional Shrimp Aquaculture Cost (TSAC), total cost of Scientific Shrimp Aqua culture Cost (SSAC) and Total Social Cost (SC). A partial social cost calculation is done one the basis of the expected cost of treatment for colorectal cancer. From the ICMR dataset per year, new cases of colorectal cancer cases are 5.5 out of 100000 populations. Using the dataset of ministry of fisheries the fish eating population affected with colorectal cancer can be computed as 1561.7 people. The average cost of treating colorectal cancer in rural urban area is Rs.60169.33.Hence the total social health cost of colorectal cancer caused due to MP injection from aqua cultured shrimp in Kerala in the year 2017-18 is calculated as Rs.93968449.41. An ideal situation assumed to be that of 100 percent use of SBM which will result in shrimp produced with no amount of MPs. Hence no new cases of colorectal cancer will be there. So Social Cost calculation on different alternatives will be calculated by the conversion rate and corresponding decline in number of cancer cases. So 33 percent conversion rate results in the decrease in cost by 33 percent. And 100 percent replacement, an ideal situation of 100 percent use of SBM which will result in shrimp produced with no amount of MPs. Hence no new cases of colorectal cancer and health cost are assumed to be zero here

Table 2: Annual Cost of various Shrimp Aquaculture Practices in Kerala (Based on 2017-18 prices)

Sl No	**TSAC/lakhs**	**S0**	**S33**	**S67**	**S100**
1	Total fixed cost	8102.17	8102.17	8102.17	8102.17
2	Total Variable cost	13590.74	13034.3	404.69	404.69
3	Total TSAC	21692.91	21136.47	20563.16	20006.71
Sl No	**SSAC/lakhs**	S0	S33	S67	S100
1	Total fixed cost	404.75	404.75	404.75	404.75
2	Total Variable cost	9840.09	8561.68	7244.52	5966.10
3	Total SSAC	10244.84	8966.43	7649.27	6370.85
Sl No	**SC/lakhs**	S0	S33	S67	S100
1	Healthcare cost	939.68	629.59	310.09	0
	Total Cost/lakhs	32877.43	30732.49	28522.52	26377.56

Source: Author's calculation

The total benefit is calculated by adding social benefit and private benefit. Total private benefit is calculated by computing the per hectare return from traditional and scientific farms to total number of scientific and traditional farming area. The nutritional benefit is monetized using WTP for nutrition (Rs.450) from the Case study from Kerala, south India: (Demand trends and willingness to pay for high-value fish consumption conducted by Shyam S Salim, 2020). The computation of consumer surplus from whole Kerala is done using the state wise household shrimp consumption data from ministry of fisheries government of India (table.3).

Table 3: Annual Benefit of Shrimp Aquaculture in Kerala in the year (2017-18)

Sl No	Benefit/lakhs	S0	S33	S67	S100
1	Private benefit	66536.29	64540.21	59017.69	40121.39
2	Social benefit	33690.89	67381.78	67381.78	67381.78
3	Total benefit	100227.18	131921.99	126399.47	107503.17

Source: Author's calculation

Net present value (NPV) of all the 4 alternatives (0 percent use of SBM, 33 percent use of SBM, 67 percent use of SBM and 100 percent use of SBM) are calculated for analyzing the best alternative. Similarly benefit cost ratio (BCR) is also calculated for all the 4 alternatives by dividing total benefit with total cost.

Table 4 : NPV and BCR of various alternative methods

	ALTERNATIVE 1(0% SM USED)	ALTERNATIVE 2(33% SM USED)	ALTERNATIVE 3(67% SM USED)	ALTERNATIVE 4(100% SM USED)
Net present value(NPV)	6734975106	10118951289	9787695734	8112560710
Benefit cost ratio (BCR)	3.048509622	4.292591734	4.431567206	4.075553259

Source: Author's calculation

The NPV is more in Alternative two which uses 33 percent SBM as fish feed followed by alternative 3 and 4. Alternative 1 that is the shrimp aquaculture using 0percent SBM is considered to be the least preferred. The benefit cost ratio BCR is more for alternative 3 followed by alternative 2 and 4. Alternative 1 has the lowest BCR. The NPV and BCR techniques of obtaining results yield slightly different findings, but overall, all alternative solutions provide a net positive conclusion. According to NPV, alternative 2 yields a superior result because its NPV of Rs. 10118951289 is higher than that of alternative 3's NPV of Rs. 97877695734. Alternative 3 would be selected if utilizing the BCR approach, though, as it has a BCR of 4.4 as opposed to 4.2. If we try to assess the overall outcome of the CBA by taking into account the overall, much greater benefits (in monetary terms) achieved by selecting Alternative 2, we may find that Alternative 2 has higher costs than Alternative 3 in this situation.

Table 5 : Total Costs and Benefits of all the alternatives

	ALTERNATIVE 1(0% SM USED)	ALTERNATIVE 2(33% SM USED)	ALTERNATIVE 3(67% SM USED)	ALTERNATIVE 4(100% SM USED)
TOTAL COSTS	3287743945	3073248100	2852252381	2637756536
TOTAL BENEFITS	10022719051	13192199389	12639948114	10750317246

Source: Author's calculation

As a result, it is clear that the outcomes of the cost-benefit analysis are not closed-ended. It may be best to present both types of analysis using various techniques so that the decision-makers can consider all

available information. Both techniques are used to determine CBA outcomes in CBA Builder Simple and Advanced. However, some researchers (and textbooks) contend that because the BCR is a ratio and ignores the total monetary value of the advantages connected with an alternative, it can be misleading and provide false information. The BCR is also more responsive to willingness-to-pay. For these reasons, some analysts contend that the most accurate way to get results is to ignore the BCR and concentrate on the NPV. Hence we consider the 2nd alternative with 33percent FM replacement with SBM as the best practice of shrimp aquaculture in Kerala as the NPV is Rs.10118951289.
An attempt is made to study a partial social cost benefit analysis of shrimp aquaculture in Kerala as the current practice is found to be threatening to the society in a socio-medical angle. The major concern was to find out the benefit on the farmers and the society at large and to suggest a sustainable alternative. So it is imperative to suggest an alternative or via media approach to be adopted by the shrimp farming community so as to benefit the farmers as well as the society at state. The socio-economic impact as well as the alternative measures were analyzed and interpreted for the year 2017-18 using the secondary data available.

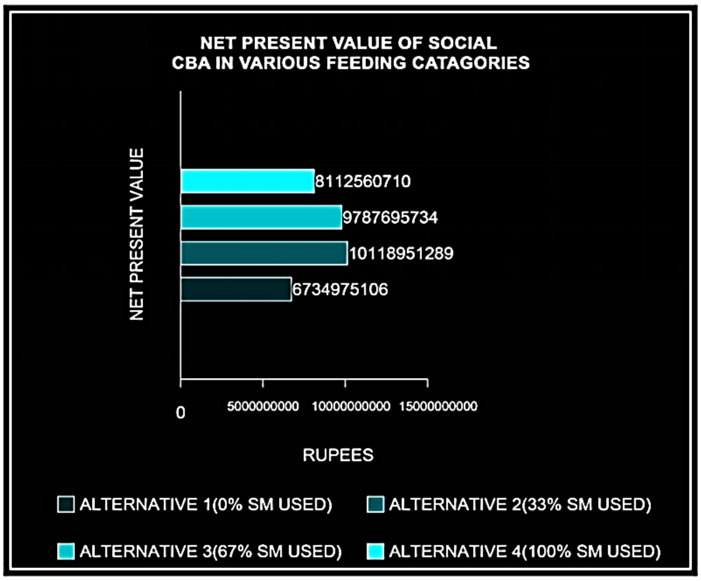
Table 6 : Partial Social Cost Benefit Analysis

	ALTERNATIVE 1(0% SM USED)	ALTERNATIVE 2(33% SM USED)	ALTERNATIVE 3(67% SM USED)	ALTERNATIVE 4(100% SM USED)
PRIVATE COST	3193775496	3010289239	2821242793	2637756536
PUBLIC COST	93968449.41	62958861.1	31009588.3	0
TOTAL SOCIAL COST	3287743945	3073248100	2852252381	2637756536
PRIVATE BENEFIT	6653629819	6454020924	5901769649	4012138781
PUBLIC BENEFIT	3369089233	6738178465	6738178465	6738178465
TOTAL SOCIAL BENEFIT	10022719051	13192199389	12639948114	10750317246
NET PRESENT VALUE (FARMERS VIEW)	3459854323	3443731685	3080526857	1374382245
NET PRESENT VALUE (SOCIETY IN TOTAL)	6734975106	10118951289	9787695734	8112560710

Source: Author's calculation

From the analysis a conclusion is derived that most beneficial farming practice for the shrimp aquaculture farmers in Kerala is the one that uses 100percent MP containing regular FM. But the most appropriate shrimp farming practice for the farming community and the society is identified to be alternative 2, which has high social NPV.

Figure 5: NPV of SCB of Various Feeding Varieties



The findings says that the present level of SBM application (0percent) in the shrimp aquaculture maybe altered to that of a much sustainable option (Alternative 2 with 33percent SBM replacement) and the reduction in the profit of farming community may be compensated by the society. There exists a gap in the case of private returns (benefits) between the practice that is advisable from the society's point of view and from the current practice (alternative 1) which is profitable to the farmers. And it has to be compensated by the society by adopting suitable policy measures.

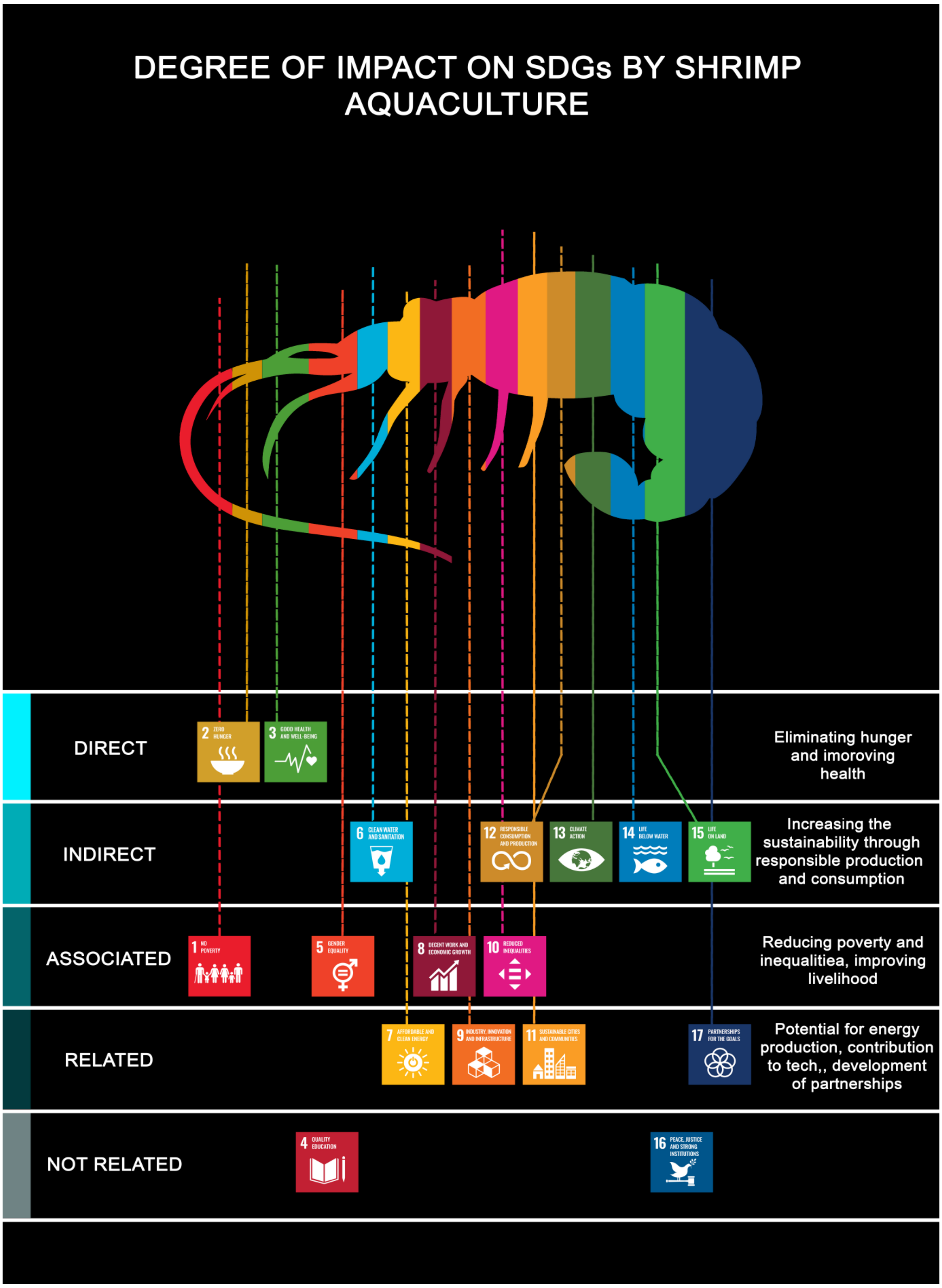
4.1 Sustainability Analysis of Various Shrimp Aqua culture Practices: Growth and development and the preservation of ocean resources are two discourses that are inherently at odds with one another, according to the blue economy notion. Aquaculture for shrimp is linked to the blue economy and the Sustainable Development Goals (SDGs). The degree of association is shown in the below diagram. In this the 17 SDGs are classified into five categories on the basis of their association with shrimp aquaculture as direct impact, indirect impact, associated impact, related impact and not related impact. They are denoted using different shades as shown in the figure 6.

The shrimp aquaculture has direct impact on SDG 2 and 3 of Zero Hunger and Good Health and Well-being. It has indirect impact on SDG 6, 12, 13, 14, 15. The impact is analysed to be associative in the case of SDGs 1, 5, 8, and 10. SDG 7,9,11 and 17 shows related impact. SDGs 4 and 16 don't have any significant impact due to shrimp aquaculture. Analysis of all these four types of farming practices influences 17 SDGs (figure.6).

- **1st alternative of using no SBM**

Among the SDGs with direct impact this farming practice has good impact on reducing hunger but shows bad impact in the case of good health and wellbeing. In the case of indirectly affecting SDGs it shows bad impact on responsible production and consumption, climate, life below water and relatively bad impact on life on land. The associated impact on gender equality, decent work and economic growth shows good impact. Hence we can conclude that even though this alternative has good impact on economic growth related SDGs but the environmental and health denoting SDGs are impacted in a bad way.

Figure 6: Relationship between Shrimp Aquaculture and 17 SDGs



Source: Created by Authors

- **2nd alternative of using 33percent SBM as a replacement to FM**

Among the SDGs with direct impact this farming practice has good impact on reducing hunger and shows relatively good impact in the case of good health and wellbeing. In the case of indirectly affecting SDGs it shows relatively good impact on responsible production and consumption, climate, life below water and life on land, the associated impacts on gender equality, decent work and economic growth shows relatively good, whereas sustainable cities and communities are impacted in a relatively bad way.

Hence we can conclude that even though this alternative has relatively good impact on economic growth related SDGs and the environmental and health denoting SDGs.

- **3rd alternative of using 67percent SBM as a replacement to FM**

Among the SDGs with direct impact this farming practice has relatively good impact on reducing hunger and good impact on health and wellbeing. In the case of indirectly affecting SDGs it shows relatively good impact on clean water, responsible production and consumption, climate, life below water and life on land. The associated impacts on gender equality, decent work, economic growth shows relatively good impact and sustainable cities and communities are impacted in a relatively good way. Hence we can conclude that even though this alternative has relatively good impact on all the relevant SDGs.

- **4th alternative of using 67percent SBM as a replacement to FM**

Among the SDGs with direct impact this farming practice has relatively bad impact on reducing hunger as it either reduces production or reduces affordability and good impact on health and wellbeing. In the case of indirectly affecting SDGs it shows relatively good impact on clean water, responsible production and consumption, climate, life below water and relatively good impact life on land. The associated impact on gender equality, decent work, and economic growth shows relatively good. Sustainable cities and communities are also impacted in a relatively good way. Hence we can conclude that even though this alternative has good impact on environmental and health denoting SDGs but the economic growth denoting SDGs are impacted in a bad way

5. Conclusion

Shrimp aquaculture is a major sector of the Kerala economy; this contributes to the income of the farmers and caters the protein and food security needs of the society at large. But the socio-economic angle of the current practice (alternative 1 using only factory made MP containing FM) has not been studied extensively in Kerala. This study analyses the partial social cost benefit analysis (SCBC) of four farming practices of replacing Soya Bean Meal (SBM) to regular FM (FM) in various rates (0 percent use of SBM, 33 percent use of SBM, 67 percent use of SBM and 100 percent use of SBM) in Kerala shrimp aquaculture sector. This study concludes that the second alternative to convert 33 percent of SBM to FM would be optimal for the farmers as well as the consumer's health. Alternative 2 is socially beneficial even though the 1st alternative is more profitable to the farmers. So this study states that 33percent conversion rate is suitable for the Kerala economy as it is a better sustainable option. The 100percent SBM use in the aquaculture system is not possible as it results in drastic fall in the overall production of the shrimp aquaculture sector.

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