

Technological innovations and fishing effort: Paradigm shifts in the trawl fishery of Munambam Fishing Harbour, Kerala, South India

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Abstract

Technological advancements and modernisation have greatly transformed the Indian fisheries sector, especially with the rising human population, urbanisation, and shifts in the country's macroeconomic environment. The present study focuses on the technological innovations, fishing effort and the resulting paradigm shifts in the trawl fishery of Munambam Fishing Harbour, one of the major fish landing centres located on Vypin Island in Ernakulam District, Kerala, by comparing conditions during 2013, 2018 and 2023. Mechanised trawl fisheries constitute a significant portion of the fish landings at this harbour. The study documents substantial changes in operational practices, fishing effort, and labour dynamics during the study period. Both single-day and multi-day trawlers operate from this harbour, with multi-day vessels engaging in fishing trips lasting from 8-12 days with 6-16 crew members, including the skipper, engine driver, and deckhands. A notable shift in labour composition was observed during the study with a decline in the availability of native labour owing to better opportunities elsewhere, leading to an influx of migrant workers into the sector. Economic analysis indicated marked increase in operational costs, with the average expenditure per fishing trip rising from ₹1.59 lakhs in 2013 to ₹4.98 lakhs in 2023, mainly due to increased crew share and fuel costs. The crew share accounted for 62.96% of the total operating cost in 2013, whereas fuel cost accounted for 33.06% of the total operating cost in 2023. The operating ratio was 0.73 in 2023, indicating that only 27% of the total income is available to cover the capital costs and generate profit for the vessel owner. The study also identified that mechanisation and resultant modern fishing methods have enhanced vessel efficiency, increasing harvesting capacity, while contributing to the socio-economic well-being of fishing communities. However, given the increased fishing power associated with mechanisation, the study emphasises the need for effective fisheries management strategies to maintain a sustainable balance between harvesting capacity and resource availability.

Introduction

Technology and modernisation have undoubtedly revolutionised the fisheries sector due to the rising human population, urbanisation and changes in macroeconomics of the country (Platteau, 1989). Marine fisheries has undergone a perceptible change due to continuous increase in fishing activities involving introduction of different advanced fishing technologies, gears and fishing fleet (Infantina, 2016). Technological interventions have brought about significant changes in the everyday lives of fishing communities,

transforming their economic and social well-being. Fishing has been the main occupation of the people of the coastal belt from time immemorial and the fishing sector is a unique source of animal protein to the population, employment and income for the rural poor and a source of valuable foreign exchange for the country (Shyam *et al.*, 2012).

Among the maritime states of India, Kerala is one of the most prominent fish producing state (GoI, 2023). Among the maritime states of India, Kerala recorded marine fish landings of 6.33 lakh t in 2023 ranking second in the country and contributing 17.9% to the

total marine fish production of India (CMFRI, 2023). Trawl fishing is one of the major mechanised fishing operations in Kerala, and contributes significantly to the marine fish landings, which comprises small and large pelagic as well as demersal finfishes, shrimps and cephalopods. The total number of trawlers operating in India are 35,228 of which 71.2% operate on the west coast and the rest along the east coast. The number of trawlers has increased by 20.5% during the last decade (Madhu, 2018). In a related study, Sehara (1991) investigated the economic performance of trawlers at national level, while Sathiadhas (1998) and Hassan *et al.* (2009) analysed the economics of trawl fisheries in Kerala. Similarly, Rajool Shanis *et al.* (2014), investigated the economics of deep-sea shrimp trawlers in the state and reported that fuel cost constituted the dominant component of operational cost, accounting for 53-56%.

Over the years, there has been a steady increase in the vessel size and the installed engine capacity in India's mechanised trawl sector. (Hassan *et al.* (2009) examined the economic performance of trawlers operating from the Neendakara-Shakthikulangara belt of Kollam District and Munambam in Ernakulam District, and reported that trawlers with an overall length of (OAL) 9-11.5 m engaged in single-day fishing trips generated annual profit of ₹10.15 lakhs, whereas trawlers having an OAL of 11.7 m undertaking multi-day fishing trips earned an average annual profit of ₹36.71 lakh. The historical evolution of the mechanised trawling sector of India, highlights significant structural and technological transformations over time (Edwin *et al.*, 2014). In 1998, there were about 30,979 trawlers along the Indian coast, ranging from 9 to 17 m OAL and powered by engines of 40–150 HP (Ravi *et al.*, 2014), in addition to small number of offshore registered trawlers measuring 17-30 m OAL and 150–400 HP engine capacity (Vivekanandan, 2003). Studies on the economic performance of mechanised trawlers in Kerala have also highlighted the consequences of rapid fleet expansion. The number the mechanised trawlers increased from 769 units in 1979 to 3,500 units in 1980, resulting in severe overcapitalisation and a significant decline in annual net profits, dropping from ₹5,37,500/- in 1976 to ₹5,805/- in 1980. This overcapitalisation resulted in reduced profitability and economic viability for many fishing units. (Unnithan *et al.*, 2005).

Despite the significant contribution of mechanised trawling to Kerala's marine fish production and the continuous technological advancements in the sector, there exists a growing concern regarding its economic sustainability and operational efficiency. The increasing operational costs, particularly fuel and labour expenses, coupled with overcapitalisation, fluctuating catch rates, and resource depletion, have raised questions about the long-term viability of trawler operations. Moreover, the structural transformations in fleet size, engine capacity, and fishing practices necessitate a comprehensive and updated economic assessment to evaluate the current status and future sustainability of the mechanised trawl sector.

This study therefore aims to evaluate the current economic performance and viability of mechanised trawlers, analyse their cost and return structures, and examine the challenges faced by stakeholders in the sector. The findings will provide critical insights for policymakers, fisheries managers, and fishers to formulate strategies for sustainable resource utilisation, efficient cost management, and improved livelihood security for fishing

communities. Ultimately, the findings of the study are expected to support the balanced development of the fisheries sector by aligning economic profitability with ecological sustainability. By analysing the evolving dynamics of trawler operations, the study aims to generate insights that can guide policymakers, fisheries managers, and stakeholders in framing strategies for sustainable resource utilisation, equitable income distribution, and improved livelihoods of coastal populations.

Materials and methods

Study area and background

Munambam Fishing Harbour is one of the most prominent among the nine fishing ports along Kerala's coastline, covering a land area of about 7.15 acres, with an auction hall of 3,123 m² and a parking area of 3,750 m². Known as a model harbour with Export Inspection Agency approval and one of the busiest fishing ports in the state, Munambam Harbour is home to over 800 fishing vessels. The primary types of crafts operating from Munambam include trawlers, purse seiners, and gill netters. In 2023, trawlers contributed 77% of the total landings (CMFRI, 2023). The harbour handles a wide variety of fish, including sardines, mackerels, Jthreadfin breams, ribbon fish, carangids, perches, and others. Additionally, it serves as a key source of raw material for fish processing industries producing value-added products like fish oil and poultry feed

Sampling method

The study was conducted at Munambam Fishing Harbour, a major landing centre located on Vypin Island in Ernakulam District, Kerala. The primary aim of the survey was to examine the changes that have occurred in the trawl fishing operations of Munambam Fishing Harbour over the years 2013, 2018, and 2023. Data pertaining to these years were collected using a retrospective (recall-based) survey approach, thereby generating a panel-type dataset suitable for temporal analysis.

Data collection was carried out using a structured schedule and primary data was collected through personal interviews and informal discussions with fishermen and trawl boat owners, using this pre-tested questionnaire. Information was gathered on various aspects, including investment, expenses, and revenue from trawlers, as well as labour share costs, wages, fuel expenses, maintenance costs, auction charges, berthing fees, taxes, and capital investment in fishing crafts and gear. A total of 60 respondents/key informants were selected through random sampling for in-depth interviews, all of whom had been involved in fishing operations for at least 10 years during the period from 2013 to 2023. The changes in species composition in trawl landings was analysed based on the data on estimated fish landings in Munambam Fishing Harbour from the National Marine Fisheries Data Centre (NMFDC) of ICAR-CMFRI.

The economic performance of fishing techniques was evaluated by working out the operating expense, gross income and net income per fishing trip. The labour productivity was worked out by utilising crew share and catch per person per trip. Net income, operating ratio, labour productivity, input-output ratios, Gross Value Added and Gross Value Added as a percent to Gross Revenue

(Narayanakumar *et al.*, 2009; Raju *et al.*, 2022) were worked out as the indicators of economic performance of various fishing units.

The essential information was gathered on operating expenses per trip, which incorporated the expenses of fuel, labour charges, food costs, auction charges, upkeep and other miscellaneous expenses for completing the fishing tasks. The operating expense per trip was calculated as follows:

Operating ratio = Total operating costs / Total revenue.... (i)

Operating ratio relates variable expenses to gross revenue.

Operating cost per trip = (Fuel + Labour charges + Food costs + Auction charges + Upkeep charges + other expenses) (ii)

Input-output ratio is the ratio of all inputs (excluding labour cost) to the total revenue. Operating ratio relates variable expenses to gross revenue.

Input-Output ratio = Input cost/Total revenue.....(iii)

The total revenue per trip was determined from the quantities of different species in the total catch and value per species.

Labour productivity = Catch (kg) / Number of crew..... (iv)

Net cash flow=Total revenue-Total costs.....(v)

The net cash flow is regarded as a reward for entrepreneurship.

Gross profit=Net cash flow-Fixed costs.....(vi)

Net profit = Total revenue – Total operational costs(vii)

Profitability ratios=Net profit/Operating cost..... (viii)

Net profit ratio= Net profit / Total revenue..... (ix)

The net profit ratio is a proportion of benefit after the sum total of what expenses have been represented and mirrors the level of income that a vessel proprietor holds as benefit.

Return on Investment (ROI) = Net profit/ Total costs..... (x)

The return on investment is the most commonly used indicator for financial performance.

Gross Value Added (GVA) = Net profit + Labour costs.....(xi)

The GVA reflects the economic contribution of fishing vessel operations to the economy, and serves as an important indicator for guiding future investments and expenditure decisions in the fisheries sector.

GVA to revenue = GVA / Total revenue from landings.....(xii)

The GVA to revenue figure is expressed as percentage and provides for the portion of income that adds to the economy through the production (Carvalho *et al.*, 2019).

Results and discussion

A fishing system comprises the fishing vessel, gear and associated operational practices. Based on the survey conducted, the technical specifications of trawlers, including vessel length, engine power, crew size, duration of operation, fish holding capacity, number of hauls per trip, construction materials used, endurance, and communication aids are presented in Table 1. A comparative analysis of these parameters over the years 2013, 2018, and 2023 reveals a marked transformation in the technical, operational, and socio-economic characteristics of the trawl fleet.

Technical profile of trawlers

Trawlers, are fishing vessels specifically designed to operate trawl nets and can be classified based on the mode of operation, and the number of vessels involved in fishing operation. In Kerala, experimental trawl fishing started in 1955, off the coast of Malabar, using a 6.6 m overall length (OAL) vessel equipped with a 10 HP engine (Kristjonsson,1967). Subsequently, commercial trawling was introduced as part of Indo-Norwegian project (INP) in 1953 (Klausen *et al.*,1964), marking the beginning of mechanised trawl fisheries in the region. At present trawlers operating in central Kerala range from 9.8 to 21.6 m OAL, with no very large trawlers in active operation (Gibinkumar *et al.*, 2012). Trawling has long been recognised as one of the most efficient and economically viable methods for catching shrimps, which attracted more fishermen and entrepreneurs to the sector which resulted in earning an industrial status to the sector. Since its introduction, trawlers dominated the mechanised fishing fleet of Kerala.

During 2013, trawlers with a maximum OAL of 25 m were in operation, whereas by 2023, vessels exceeding 40 m OAL had become operational, reflecting a substantial increase in vessel size since the introduction of mechanised trawling. Earlier studies also reported an increase in the maximum length of trawlers in Kerala from 28.0 m to 33.5 m i within a four year period (Ravi *et al.*, 2014). This trend indicates a growing preference among fishers for larger vessels that offer greater endurance, increased fish-holding capacity and improved operational efficiency. Rather than investing in a large number of smaller vessels, fishermen prefer fewer numbers of larger more powerful vessels, capable of undertaking extended fishing voyages. Consistent with this trend, Vivekanandan (2003) reported a declining trend in number of mechanised vessels below 40 feet in Kerala coast, largely due to their poor economic performance. The present study similarly observed a shift towards larger vessels equipped with high powered engines in the mechanised sector, reflecting the industry's emphasis on maximising endurance.

The comparative analysis indicated that the maximum overall length (OAL) of vessels increased significantly from 23 m in 2013 to 33.5 m in 2018 and further to 40 m in 2023, indicating a clear trend towards the expansion of vessel size. This structural shift is also reflected in the transition of construction materials from a combination of wood and steel to exclusively steel-hulled vessels, suggesting improved durability, higher capital investment, and modernisation of the fleet.

Material of construction

Around 2010, both steel and wood were used as construction materials for trawlers in Kerala, but a gradual shift from wooden to steel-hulled vessels was observed. Ravi *et al.* (2014) reported that 20% trawlers in Kerala during 2012-13 were wooden and they also observed a declining trend in number of wooden trawlers. This shift towards steel construction can be attributed to the scarcity of quality timber at reasonable price, issues related to labour and maintenance of wooden vessels and ease of availability of optimum grade steel. In addition, steel vessels offer advantages such as improved safety, longer life, greater durability and enhanced endurance at sea. The findings of the present study are consistent with earlier reports indicating a growing preference for steel trawlers

Table 1. Technical profile of trawlers and fishing operations at Munambam Fishing Harbour, Kerala during 2013, 2018 and 2023

Parameters	Multi-day trawlers		
	2013	2018	2023
Maximum length overall (OAL) (m)	23	33.5	40
Materials used	Wood, Steel	Steel	Steel
Maximum engine horse power (HP)	150	550	591
Endurance	Multiday	Multiday	Multiday
Navigational and other equipment	Echo sounder SONAR, Magnetic Compass, GPS, Wireless, Mobile, TV, DVD	Echo sounder, SONAR, Magnetic Compass, Autopilot, GPS, Wireless, Seaphone, TV, Mobile	Echo sounder, SONAR, Magnetic Compass, Autopilot, GPS, Wireless, Seaphone, TV, Mobile
Crew size (No.)	6-8	10-12	14-16
Labourers	80% Natives 20%-Migrants	60%-Natives 40%-Migrants	10% -Natives 80-90%-Migrants
Engine make	Indian (80%)	Chinese (60%)	Chinese (70%)
Average engine cost (₹ lakhs)	3-5	10-12	15-25
Distance of fishing ground (km)	20	100	125
Depth of fishing (m)	< 80	>80	>80
Average fish holding capacity (t)	2	7.5	15
Average no. of fishing trips per month	6	4	4
Average no. of hauls per trip	4	6	6
Type of gears used	Trawl net and Hook and line	Trawl net and Hook and line	Trawl net and Hook and line

over wooden trawlers in Central Kerala and Quilon coasts (Gibinkumar, 2008; Sabu *et al.*, 2008). Presently, approximately 95% of trawlers operating in Kerala are steel trawlers, reflecting the widespread adoption of steel as the preferred boat-building material.

Engine details

A substantial increase in engine power is evident, rising from a maximum of 150 HP in 2013 to 550 HP in 2018 and 591 HP in 2023. This increase corresponds with enhanced vessel capacity, enabling operations in distant and deeper fishing grounds. Accordingly, the distance to fishing grounds expanded from 20 km in 2013 to 100 km in 2018 and 125 km in 2023, while the depth of operation shifted from less than 80 m to deeper waters exceeding 80 m. These changes indicate a move towards offshore and deep-sea fishing practices, driven by resource depletion in nearshore areas and the need to sustain catch levels.

The engine power of trawlers in Kerala has increased substantially over time in parallel with vessel size. In 2013 engine power of trawlers ranged from 90-140 HP which got increased up to 300-590 HP in 2023. The average engine power of trawlers in Kerala was 7.5 HP in 1980s (Sabu *et al.*, 2008). It can be stated that the engine power of trawlers in the state has increased 59 times since 1955. In the present study, trawlers with OAL of more than 40 m were equipped with 591 HP engine. The maximum engine power for a 23 m trawler in 2013 was 150 HP, which increased to 550 HP for 33.5 m vessels in 2018 and further to 591 HP for 40 m vessels in 2023. Commonly used imported marine engines in trawl sector in the state include Weichai, Yuchai, Sinotruk and Cummins, while Ashok Leyland is the only Indian manufacturer of marine diesel engines. Ravi *et al.* (2014) reported was a significant increase in the engine horsepower in the Kerala trawl fleet, with lower representation of 60-80 HP (5.6%) and 80-100 HP (16.7%) engines and higher representation of 100-120 HP (33.3%) and 120-140 HP (44.4%) engines. The present findings, together with earlier studies (Kurup *et al.*, 2007), indicate that fishing capacity has increased significantly owing to

higher installed engine horsepower, larger vessel sizes, improved navigation systems, enhanced fish detection capabilities and improved efficiency of fishing gear systems. According to Ravi *et al.* (2014) engine power in Kerala trawlers previously ranged from 76 HP in small vessels to 450 HP in very large trawlers. However, by 2017, mechanised trawlers operating in the state generally employed engines exceeding 116 HP, with lower-powered engines being confined mainly to the motorised trawling sector.

The consistent rise in engine power alongside vessel size reflects a clear trend of technological intensification and modernisation in the mechanised trawling sector. While this transformation has enhanced fishing efficiency and operational capabilities, it also indicates increasing capital investment and operational costs, particularly fuel consumption. Such developments point towards possible overcapitalisation and raise concerns about the long-term economic viability and sustainability of the sector.

The source and cost of engines further highlight the increasing capital intensity of the sector. While Indian-made engines dominated in 2013 (80%) (Aswathy *et al.* 2013), there is a clear shift towards Chinese engines, accounting for 70% by 2023. Simultaneously, the average engine cost rose sharply from ₹3-5 lakhs in 2013 to ₹15-25 lakhs in 2023, reflecting increased investment requirements and higher operational risks.

Moreover, the shift towards high-powered engines and larger vessels may intensify pressure on marine resources and create disparities among fishing operators. Therefore, there is a need for balanced and regulated growth in engine capacity and fleet size to ensure sustainable fisheries management and economic stability in the sector.

Endurance of fishing

Mechanised trawlers started undertaking multiday fishing trips from 1997 onwards. Both single day and multiday fishing is carried out by trawlers in Kerala. Multiday trawlers were classified into

medium sized multiday trawlers which undertook fishing trips of 2-5 days duration and large multiday trawlers undertaking fishing trips of more than six days duration (Aswathy *et al.*, 2011). In 2013 most multiday trawlers carried out fishing operations ranging from 4-5 days which got enhanced up to 8-16 days. In 2013, the average number of fishing trips per month was 6 which declined to 4 trips in 2018 and 2023, since duration increased in large multiday trawlers. The transition towards longer multiday fishing trips indicates an adaptive strategy to enhance operational efficiency and economic returns. However, the reduced frequency of trips alongside increased trip duration highlights changing fishing dynamics that may have implications for resource use and cost management.

Navigational aids

Technological advancement is also evident in the adoption of improved navigational and communication equipment. While basic tools such as echo sounders, SONAR, magnetic compass, and GPS were present in 2013, later years show the inclusion of advanced systems like autopilot and seaphones, enhancing operational efficiency, safety, and fish detection capabilities. This technological upgradation has contributed to an increase in fishing efficiency, as reflected in the rise in the average number of hauls per trip from 4 in 2013 to 6 in subsequent years.

All the trawlers surveyed were equipped with modern electronic navigation, fish finding as well as communication equipment such as echo sounder, SONAR, magnetic compass, Global Positioning System (GPS) and wireless communication devices and mobile phones. Many vessels were also fitted with onboard entertainment systems such as TV and DVD. Many of these equipment are used to locate fishing grounds, identify fish shoals, determine water depth, and assess seabed characteristics. GPS facilitates accurate navigation and precise positioning of fishing locations. Installation of fish finder, GPS and radio communication systems has enabled mechanised vessels to extend their operations to offshore waters. Most of the multiday trawlers use these advanced facilities for reaching the fishing ground and for finding fish shoals. Navigational instruments, such as autopilot and GPS, are used for manoeuvring the vessels both in harbours and at sea. Radar systems facilitate safe navigation and in operations such as pair trawling, help maintain the correct distance between the two vessels. Communication devices, including sea phones enable effective coordination and communication while at sea. Adoption of these advanced technologies has significantly enhanced operational efficiency, navigational safety, and fishing performance. In a related study Shyam *et al.* (2024) developed a Fisher Development Index (FDI), and demonstrated that fisher well-being is closely linked to resource sustainability, technological advancements and infrastructure support; all of which led to substantial positive externalities across fisheries production and distribution systems.

Crew size

The labour dynamics of the sector have also undergone a significant shift. Crew size increased from 6–8 members in 2013 to 14–16 in 2023, reflecting the need for more manpower in larger and technologically advanced vessels. More notably, there is a drastic change in labour composition, with a decline in the proportion

of native fishers from 80% in 2013 to about 10% in 2023, and a corresponding increase in migrant labour, particularly from states like Tamil Nadu, West Bengal, Odisha, and Assam. This indicates growing dependence on migrant labour due to labour shortages, rising costs, or reduced local participation in fishing activities.

Large trawlers having OAL between 15 and 25 m, powered with imported engines of 90 to 150 HP engaged in multiday operations accommodate 6-8 crew labourers including skipper, engine driver and deck hands and rarely up to 10 depending upon the season. Aswathy *et al.* (2011) reported a maximum of 10 crew in large vessels with LOA more than 16 m during 2007). Previous studies reported that small trawlers operating along Kollam coast employed 5 crew members, whereas medium and large trawlers had six to eight crew (Gibinkumar, 2008). Ravi *et al.* (2014) documented 4 crew members in small trawlers and up to 12 in very large trawlers. The present study indicates a further increase in crew size, with multiday trawlers accommodating up to 14 crew members including the skipper, engine driver and deck hands. The number of crew onboard has increased progressively over time, from 4 in 1996 to 10 in 2008, 12 in 2014 and 14 in recent years for large trawlers. During the early stages of mechanised trawling, fishing operations were completely manual. However, increased demand for seafood in both domestic and international markets, accelerated mechanisation in marine fishing sector of the state which resulted in overall increment in fishing vessel size, size of gear and extension of fishing grounds as well as crew size. During 2013, majority of crew *i.e.* 80% were natives of Kerala especially from southern parts of Kerala, particularly from Kollam and Karunagapally and only 20% were migrants, mainly from Tamil Nadu. Subsequently in 2018, the native fishers involved in fishing got declined to 60% whereas the migrants started marginally dominating (40%) in fishing operations. Eventually in 2023, the native fishers started moving out from the fishing operations especially the younger generation. The native fishers became least interested in involving their future generation in fishing activity due to risk factors in the fishing field. Thus, migrant labourers from the state of Tamil Nadu as well as from the northern parts of India such as Assam, West Bengal, Bihar and Odisha became dominant in the trawl fishing sector of Kerala.

Fishing capacity and depth of operation

In Kerala, both single day and multiday trawlers are prevalent, but single day trawlers constitute only 5% of the total trawl fleet and the remaining 95% are multiday trawlers. Multiday trawlers conduct fishing throughout the year from August to middle of June, except during monsoon trawl ban period. Depth of operation of trawlers in the state varied from 10 m to beyond 800 m. The targeted resources include fish, shrimps, cephalopods and gastropods. In 2013, the depth of fishing ground was less than 80 m which got increased to more than 80 m (up to 400-700 m) in 2023. According to Jyothilal (1998) were 4000 trawlers in Kerala contributing 55% to the mechanised fishing fleet of the state and they were operating within 50 m depth zone. Kurup *et al.* (2007) reported that during 2000-2001, maximum depth of operation by Kerala trawlers was 300 m targeting cephalopods and deep-sea shrimps, while Hassan *et al.* (2009), reported 420 m as maximum depth of fishing ground for trawlers in the state.

Fishing capacity and operational efficiency have also improved considerably. The average fish holding capacity increased from 2 t in 2013 to 15 t in 2023, indicating enhanced storage facilities and longer fishing durations. However, the average number of fishing trips per month declined from 6 to 4, which can be attributed to the increase in trip duration and expansion of fishing areas. Despite fewer trips, the increase in hauls per trip and storage capacity suggests an overall intensification of fishing effort.

The size of trawlers also showed an increasing trend, particularly the storage capacity of trawlers showed a momentous growth over the past few years due to increase in duration of trip, number of hauls per trip, depth of fishing operations as well as number of labourers. Gear characteristics remained broadly consistent, with trawl nets and hook-and-line methods being used throughout the period.

Overall, the findings indicate a clear trend of technological advancement, increased capital investment, expansion of fishing operations into deeper and distant waters, and significant changes in labour composition. While these developments have enhanced fishing capacity and efficiency, they also point towards increasing operational costs, dependence on external inputs, and potential sustainability concerns in terms of resource exploitation and socio-economic equity within the sector.

Species composition

The marine fisheries of the Munambam Fishing Harbour exhibited seasonal variations to a great extent and the quantity-wise landings of major species in mechanised fishing exclusively using trawl nets to the total landings during the period 2013, 2018 and 2023 is presented

in Table 2. Trawlers form the major contributors to fish landings in the harbour. The trawl nets which were originally designed to exploit the bottom-dwelling fishes and shrimps have evolved extensively over the years and are now operated to catch bottom as well as the column and surface-dwelling fishes (Rohit *et al.*, 2024).

The analysis of total fish landings by trawl netters for the years 2013, 2018, and 2023 reveals notable shifts in species composition, catch volume, and resource dynamics. The total fish production during the period 2013 and 2023 exclusively by trawl netters showed an increase from 47,072 t in 2013 to 71,056 t in 2023. The contribution by trawl nets were 60% of the total landings in 2013 and 77% of the total landings in 2023 (CMFRI 2023).

The species-wise share showed that the trawlers land huge quantities of pelagic fishes such as mackerels, sardines, ribbonfishes and carangids and demersal fishes such as threadfin breams, penaeid shrimps and squids, in which threadfin breams contribute the highest share of 13.23% followed by ribbon fishes contributing 5.76%. The contribution of Indian mackerel, penaeid ps shrimps, lizard fishes and oil sardines were 5.29%, 3.76%, 3.34%, 2.25% and 2.05% respectively. Along with the major marine fish resources, landings of miscellaneous species showed an outrageous growth from .59% in 2013 to 19.72% in 2023, probably as a result of introduction of highly powered fish trawlers in the sector.

The overall increase in trawl fish landings over the years indicates improved fishing capacity and effort; however, significant fluctuations and declining trends in major commercial species highlight changing resource dynamics. The shift towards a more diversified catch composition, especially the rise in miscellaneous

Table 2. Total landings and share of different finfish/shellfish groups in mechanised fishing (exclusively trawl netters) in Munambam Fishing Harbour for the years 2013, 2018 and 2023

Group	Total fish landings (t)		
	2013	2018	2023
Pelagic finfish			
Anchovies	157 (0.20)	575 (0.66)	1,404 (1.52)
Barracudas	251 (0.32)	417 (0.48)	1,290 (1.40)
Carangids	3,539 (4.54)	4,297 (4.96)	2,268 (2.46)
Other carangids	186 (0.24)	1,921 (2.22)	1,869 (2.02)
Indian mackerel	1,329 (1.70)	1,865 (2.15)	3,475 (3.76)
Oil sardines	4,124 (5.29)	394 (0.45)	1,894 (2.05)
Ribbon fishes	13,867 (17.77)	11,402 (13.15)	5,322 (5.76)
Tuna	13 (0.02)	69 (0.08)	339 (0.37)
Demersal finfish			
Lizard fishes	1,380 (1.77)	3,039 (3.50)	2,078 (2.25)
Perches	184 (0.24)	268 (0.31)	1,306 (1.41)
Other perches	281 (0.36)	2,743 (3.16)	4,518 (4.89)
Threadfin breams	7,997 (10.25)	21,883 (25.24)	12,217 (13.23)
Crustaceans			
Penaeid shrimps	1,717 (2.20)	2,190 (2.53)	3,081 (3.34)
Crabs	83 (0.11)	234 (0.27)	823 (0.89)
Molluscs			
Squids	4,039 (5.18)	8,428 (9.72)	4,882 (5.29)
Cuttlefish	5,018 (6.43)	4,970 (5.73)	2,530 (2.74)
Octopus	1,496 (1.92)	3,244 (3.74)	1,548 (1.68)
Miscellaneous	462 (0.59)	8,289 (9.56)	18,212 (19.72)
Total	78,030	86,710	92,342

Figures in parenthesis indicate quantity share (%) of trawl landings to the total landings

Source: NMFDC, ICAR-CMFRI

species, suggests possible overexploitation of traditional stocks and adaptation by fishers to sustain their livelihoods.

Economic performance of trawl operations

The economic performance assessed using conventional economic and financial performance indicators during the period 2013, 2018 and 2023 is presented in Table 3. The total operating cost per trip shows a substantial increase from ₹1,59,299 in 2013 to ₹2,79,236 in 2018 and further to ₹4,98,875 in 2023, indicating a sharp escalation in the cost of fishing operations (Fig. 1). Among the various components, fuel cost emerged as the most significant contributor, increasing from 19.41% in 2013 to 47.52% in 2023. This reflects increased engine power, longer fishing durations, and expansion into distant fishing grounds.

Fuel cost varied among different length class of trawlers depending on rate of fuel consumption and fishing time. Sumaila *et al.* (2008) reported that fuel prices have recently seen significant increases and fuel constitutes a significant component of fishing costs. In many fisheries around the world like purse seine and gillnetting, fuel cost is the second largest contributor to the operational cost after crew wages (Lam *et al.*, 2011) But in case of trawlers, fuel cost accounted a major portion in operational expense higher than wages. In contrast, the share of crew wages declined from 62.96 to 33.06%, although the absolute amount increased, indicating a shift from labour-intensive to fuel-intensive operations. Crew-related aspects such as crew size (from 8 to 14) and bata also increased, reflecting the growing scale of operations.

The capital investment increased significantly with introduction of high-speed engines. The average cost of indigenous engines (Ashok Leyland or Tata make) of capacities 160-200 HP during 2013 was ₹3-5 lakhs, which increased to ₹15-25 lakhs for high-speed engines imported mainly from China, US and Japan. Higher catch, high cruise speed and species diversification were the major reasons for conversion into Chinese engines.

Other costs towards ice, provisions, and maintenance have also risen steadily, with provision costs showing a notable increase due to longer fishing trips. Auction charges and other miscellaneous expenses, though increasing in absolute terms, have declined in

percentage share, suggesting that major cost increases are driven primarily by fuel and labour.

The catch per trip increased from 2,180 kg in 2013 to 3,385 kg in 2023, indicating improved fishing efficiency. However, this increase is relatively modest compared to the steep rise in costs. The annualised fixed cost per trip also increased significantly, reflecting higher capital investments in vessels, engines, and equipment.

Total revenue rose from ₹3,45,574 in 2013 to ₹6,80,994 in 2023. However, when profitability is assessed, the net returns show that profit slight decline from ₹1,86,275 in 2013 to ₹1,75,949 in 2018, and then increased to ₹1,82,119 in 2023. This indicates that despite higher revenues, profitability has not improved proportionately due to escalating costs. The benefit-cost ratio (BCR) also reflects this trend, declining from approximately 2.17 in 2013 to 1.63 in 2018 and further to 1.36 in 2023, suggesting reduced economic efficiency over time.

The analysis clearly indicates that although mechanised trawlers have experienced an increase in catch and revenue over the years, the rapid rise in operational and capital costs, particularly fuel expenses, has significantly reduced profitability and economic efficiency. This trend highlights growing concerns regarding the financial sustainability of trawling operations, emphasising the need for cost optimisation, efficient resource utilisation, and policy interventions to ensure long-term viability of the sector.

Profitability of fishing operations

Profitability ratios and efficiency indicators provide a comprehensive understanding of the economic viability of mechanised trawlers. By examining changes in profit margins, input-output relationships, and productivity measures over time, it is possible to assess the sustainability and performance of fishing operations. Table 4 presents key profitability and efficiency ratios for the years 2013, 2018, and 2023.

As trawling one of the most energy intensive fishing methods, fuel cost forms a major component of the operational expenditure of mechanised trawlers. The present study showed that fuel

Table 3. Average cost and earnings of mechanised trawl fishing operations (per trip) in Kerala for the years 2013, 2018 and 2023

Components	2013	2018	2023
Fuel cost (₹)	30,923 (19.41)	1,11,978 (40.10)	2,37,070 (47.52)
Crew share (₹)	1,02,302 (62.96)	1,22,299(42.01)	1,76,911 (33.06)
Crew bata (₹)	2,000(1.26)	5,000 (1.79)	12,000 (2.41)
Crew size (No.)	8	10	14
Ice cost (₹)	1,875 (1.18)	7,500 (2.69)	12,750 (2.56)
Provisions (₹)	3,000 (1.88)	7,500 (2.69)	25,000 (5.01)
Auction charges (₹)	17,279 (10.85)	22,759 (8.15)	34,050 (6.83)
Other charges (including repairs, maintenance, interests) (₹)	3,921 (2.46)	7,200 (2.58)	13,094 (2.62)
Total operating cost (₹)	1,59,299	2,79,236	4,98,875
Catch (kg)	2,180	2,535	3,385
Annualised fixed cost per trip	12,744	22,339	39,910
Total revenue (₹)	3,45,574	4,55,185	6,80,994

Figures in parenthesis indicate % to total operating cost

costs accounted for 19% of total operational expenses in 2013, increasing to 44% in 2018 and 47% in 2023. This substantial rise is attributable to the increase in the average duration of multiday fishing trips from 4-5 days in 2013 were to 6-8 days in 2018 and 2023, as vessels increasingly undertake extended voyages, to distant fishing grounds and use energy intensive active fishing methods. Maintenance and operating expenses generally increase with engine power and vessel size. Several studies have reported that the profitability of fishing operations is influenced by factors such as vessel characteristics, gear type, engine capacity and other operational variables. Increased fuel consumption together with hike in fuel prices has a substantial negative impact on the profitability of mechanised fisheries (Unnithan *et al.*, 1985; Narayanakumar *et al.*, 2009, Aswathy *et al.*, 2011, Xavier, 2013; Rajool Shanis *et al.*, 2014). The present study further demonstrates that the higher fuel consumption associated with multiday trawlers in 2023, resulted in input costs accounting for about 58% of the operational costs, leading to a higher input-output ratio. In contrast, in 2013, input costs formed only about 25% of the operational costs, primarily because of lower fuel requirements and shorter fishing trips, resulting in a comparatively lower input-output ratio.

The analysis reveals a declining trend in gross profit, which decreased from ₹1,60,787 in 2013 to ₹1,31,271 in 2018 and further to ₹1,02,300 in 2023. A similar declining pattern is observed in net profit before taxes, indicating increasing operational pressures and reduced surplus generation. Although net profit shows only a marginal fluctuation (₹1,86,274 in 2013 to ₹1,82,120 in 2023), the overall trend suggests stagnation in profitability despite increased scale of operations (Table 4).

Labour cost is another major contributor to the operational cost of mechanised trawlers in Kerala. Components included under the labour cost are crew wages, daily allowance and cost of food.

Though the labour requirement is definite, the labour flow into the sector is dynamic, a share system of income distribution is followed in which the income is shared between the owner(s) and crew. The income from a fishing unit that is available for distribution is after deductions for operational expenses, including fuel. The expense of mechanised trawlers in the form of crew share varied between single day and multi day trawlers.

As the vessel size increase, a larger workforce is required, resulting in higher expenditure towards crew wages, provisions and other labour related costs. Sayana *et al.* (2018), in their study on the growth and fuel consumption of mechanised trawlers of Kerala, reported that the average annual expenditure incurred on crew wages increased with vessel size, amounting to `0.069 million in small single day trawlers, `0.25 million for small multiday trawlers, `0.64 million for medium trawlers, `0.99 million for large trawlers and `1.1 million for very large trawlers. The present study similarly observed a progressive increase in crew strength over time. The average crew size increased from eight members in 2013 to 10 in 2018 and further to 14-15 labourers including skipper in 2023. This increase reflects the adoption of larger trawlers equipped with high-powered engines and designed for longer fishing voyages to distant fishing grounds. Consequently, the demand for additional crew has risen to support extended operations, handle larger catches and manage increased onboard activities, thereby contributing to higher labour costs.

Traditionally crew members received 35% of the net revenue as their share, in addition to daily allowances (bata). This share increased to 40% in 2018 and further to 40-50% in 2023, reflecting the increasing costs associated with fishing operations. The average catch per fishing trip also exhibited a steady upward trend. Mean landings increased from 2180 kg in 2013 to 2535 kg in 2018, registering an increase of 16.3%, which again increased to 3385 kg with an average increase of 33.53%.

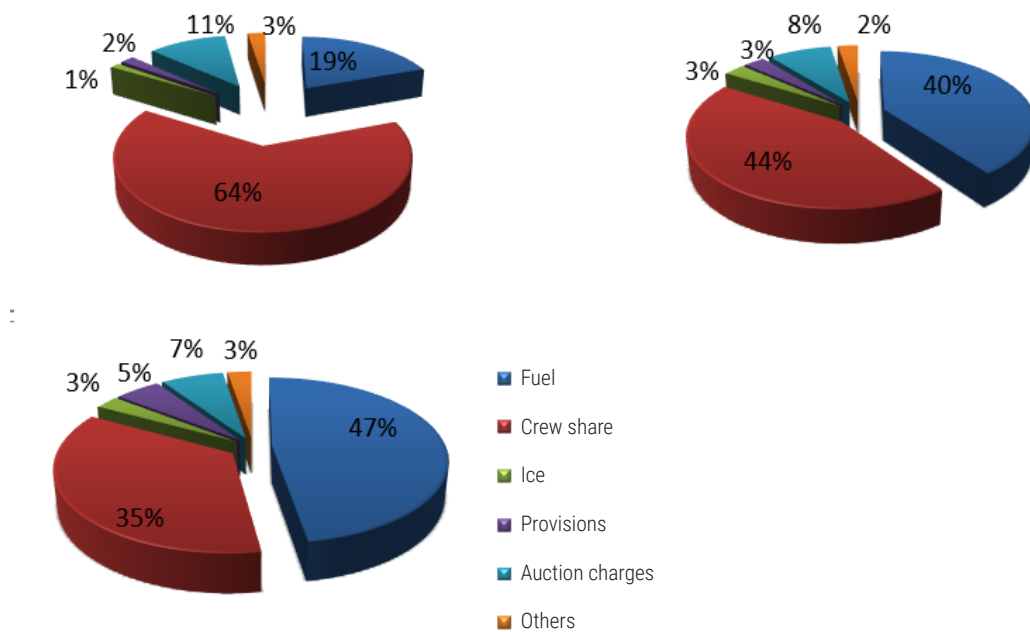


Fig. 1. Percentage contribution of total operating cost of multiday trawlers operated during 2013, 2018, and 2023

Table.4. Revenue profitability metrics

Components	2013	2018	2023
Gross profit (₹)	1,60,787	1,31,271	1,02,300
Labour productivity (kg crew ⁻¹ trip ⁻¹)	273	254	242
Net cash flow (₹)	1,73,531	1,53,610	1,42,210
Net profit (₹)	1,86,274	1,75,949	1,82,120
Input/Output ratio	0.11	0.29	0.42
Net profit before taxes (₹)	1,60,787	1,31,271	1,02,300
Operating Ratio	0.46	0.61	0.73
GVA (₹)	2,88,976	3,00,248	3,64,030
GVA as percent to total revenue	83.62	65.96	53.46

Similarly, Net Profit ratio of trawlers in 2023 was found to be low compared to multiday trawlers of 2013, since capital investment for multiday trawlers were high when compared with the multiday trawlers in 2013. Similar to Net Profit ratio, Rate of Return was also higher in 2013 signifying it to be the best in terms of financial performance. For mechanised trawlers of 2013, the average cost of assets or capital investment was very low as the crafts were manufactured mainly using wood which utilises least energy and is the most efficient material; however, due to higher maintenance cost and lower durability, fishermen preferred to use steel subsequently, which is easily available and has longer durability as well as safety. Therefore, the capital investment was higher for multiday trawlers during 2018, which is mainly incurred for vessel construction, followed by cost of engine, cost of gears, and cost for modifications after procurement. Wooden trawlers are an exception, where cost of trawl nets constitutes major share in capital investment followed by cost of vessel, cost of engine and modifications.

The analysis of operational costs and revenues of trawlers indicated that the total operating cost was ₹4.98 lakhs for mechanised trawlers in 2023 followed by ₹2.79 lakhs in 2018 and ₹1.59 lakhs for trawlers in 2013. The increase operational costs could be attributed to crew share and fuel costs. The crew share accounted 62.96% of the total operating cost in 2013 whereas 33.06% of the total operating cost was incurred as fuel cost during 2023. The input-output ratio increased significantly from 0.11 in 2013 to 0.42 in 2023, indicating that higher inputs are required to generate the same level of output, thereby reducing operational efficiency. This is further supported by the increase in operating ratio from 0.46 to 0.73, suggesting that a larger proportion of revenue is being absorbed by operational costs, leaving less margin for profit. Operating ratio was 0.73 in 2023, followed by 0.61 in 2018 and 0.46 in 2013 which indicates that only 25% of the total income is available with the owner to cover the capital costs and the remaining was the profit in 2023. While in 2013, 60% of the total income was available with the owner to cover the capital costs and the remaining towards profit. (Narayanakumar, 2014) reported that fuel and labour costs accounted for 54 and 25% respectively of the total operating cost of mechanised single day trawlers in Andhra Pradesh. Similar observations were made in a study by Sayana *et al.* (2018), who found operating ratio to be higher for very large trawlers (0.68), followed by small multiday trawlers (0.64), large trawlers (0.60), small single day trawlers (0.59) and medium trawlers (0.55). While considering operating ratio, medium trawlers were found to be more economical in the present scenario of Kerala. The operating ratio for mechanised fishing operation in Andhra Pradesh was 0.62, while for motorised and non-motorised fishing operations it ranged from 0.54 to 0.60 and 0.54 to 0.59, which indicated that across all sectors, a minimum of 40% of the

total income is available with the owner to cover the capital costs and the rest is profit (Raju *et al.*, 2022)

The study reveals that labour productivity declined steadily from 273 kg per crew per trip in 2013 to 242 kg in 2023, indicating reduced efficiency of labour, possibly due to resource depletion or overcapacity in fishing effort. The observed decline in labour productivity suggests that trawl fishing operations have become more labour intensive, despite technological advancements. The introduction of high-powered engines and the employment of larger crews had enhanced fishing capacity and increased fish landings, but have not translated into proportional gains in labour productivity. The economic and financial performance indicators implies that multiday trawlers during the study period (2013 to 2023), remained profitable, irrespective of engine type. However, vessels equipped with high-speed engines, received higher catches and generated greater revenues when compared to trawlers powered by conventional indigenous engines. Despite these technological improvements, net cash flow decreased from ₹1,73,531 in 2013 to ₹1,42,210 in 2023, reflecting increasing operational costs and tightening liquidity conditions in mechanised trawl operations.

Mechanised trawl fisheries made a substantial contribution to the economy, as reflected by their high GVA. The study showed that the GVA increased from ₹2,88,976 in 2013 to ₹3,64,030 in 2023, indicating that the sector continues to contribute economically. However, the GVA as a percentage of total revenue declined sharply from 83.62% to 53.46%, suggesting that the share of value addition is decreasing due to rising intermediate costs and operational expenses. The share of the revenue that contributed to the economy was high for mechanised trawlers in 2013, because of low input costs as compared to the trawlers in 2023. The results of GVA to Gross Revenue are comparable to that of EU fleets (60%) (Carvalho *et al.*, 2019). Overall, the findings indicate a decline in economic efficiency and productivity of mechanised trawlers over time, despite an increase in total value generated. Rising input costs, declining labour productivity, and reduced value addition highlight growing concerns regarding the profitability and long-term sustainability of trawling operations.

The analysis of multi-day trawling operations from 2013 to 2023 reveals a phase of rapid transformation in the fisheries sector, marked by the adoption of larger, technologically advanced vessels with higher engine power, increased fish-holding capacity, and longer fishing durations. These developments have significantly expanded fishing grounds, enhanced catching capacity, enabling fishers to optimise effort and, in some cases, reduce operational intensity without compromising output. Such technological progress has

contributed positively to production and the broader economic growth of fishing communities. However, these gains have been accompanied by a substantial rise in capital and operating costs, particularly fuel, placing increasing pressure on profitability. Despite growth in total landings and revenue, declining labour productivity, rising input-output ratios, and reduced gross profit, indicate a gradual erosion of economic efficiency at the unit level.

Simultaneously, the sector has experienced notable socio-economic shifts, including increased mechanisation and a growing dependence on migrant labour, altering traditional workforce structures in what remains a labour-intensive industry. While technological advancements have improved efficiency, they have also intensified competition and fishing pressure on marine resources. The expansion of fishing into deeper waters, coupled with increased fleet size and capacity, has contributed to declining catch per unit effort, thereby affecting fisher incomes. Additionally, rising fuel costs and fluctuating or declining market values of catches have further constrained economic viability.

Ecologically, the changing species composition, characterised by a decline in high-value traditional species and an increase in miscellaneous and low-value catches, signals potential overexploitation and shifts in marine ecosystem dynamics. The non-selective nature of trawl nets exacerbates this issue by capturing non-target and endangered species, including sensitive fauna such as sea turtles, thereby posing serious threats to biodiversity and sustainability. Although trawling is recognised for its flexibility and high production efficiency, these environmental concerns cannot be overlooked.

In this context, ensuring the long-term sustainability of the fisheries sector requires a balanced and strategic approach to management. This includes enforcing stricter regulatory frameworks, aligning fishing capacity with resource availability, and promoting the adoption of selective and resource-conserving technologies. Measures such as rationalising fleet size, improving access to credit and training for technological upgradation, and strengthening monitoring, control, and surveillance systems are essential. Furthermore, enhancing value addition, stabilising market mechanisms, and supporting livelihood diversification can help mitigate economic risks while safeguarding ecological resilience and the future of marine fisheries.

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References

Aswathy, N. and Shyam, S. S. 2013. Impact of Chinese engines in the marine fishing sector of Kerala. In: *International Symposium on Greening Fisheries: Towards green technologies in fisheries*, 21-23 May 2013, Kochi, India.

- Aswathy, N., Shanmugam, T. R. and Sathiadhas, R. 2011. Economic viability of mechanized fishing units and socio-economics of fishing ban in Kerala. *Indian J. Fish.*, 58(2): 115-120.
- Carvalho, A. R., Bellido-Millán, J. M., Pennino, M. G. and Olavo, G. 2019. Small-scale shrimp fisheries bycatch: A multi-criteria approach for data-poor situations. *Mar. Policy*, 110: 103613. <https://doi.org/10.1016/j.marpol.2019.103613>.
- CMFRI 2023. *Annual report 2022-23*. ICAR-Central Marine Fisheries Research Institute, Kochi, India.
- Edwin, L., Pravin, P., Madhu, V. R., Thomas, S. N., Remesan, M. P., Baiju, M. V., Ravi, R., Das, D. P. H., Boopendranath, M. R. and Meenakumari, B. 2014. *Mechanised marine fishing systems: India*. ICAR-Central Institute of Fisheries Technology, Kochi, India, 276 p.
- Gibinkumar, T. R. 2012. *Investigations on hard bycatch reduction devices for trawling*. LAP LAMBERT Academic Publishing, Saarbrücken, Germany, 236 p. <http://dyuthi.cusat.ac.in/xmlui/purl/1934>.
- Gol 2023. Basic animal husbandry statistics 2023. Department of Animal Husbandry and Dairying, Ministry of Fisheries, Animal Husbandry and Dairying, Government of India, New Delhi, India, 172 p.
- Hassan, F. and Sathiadhas, R. 2009. An appraisal of trawl fishery of Kerala. *Asian Fish. Sci.*, 22(1): 277-284.
- Infantina, J. A., Jayaraman, R., Umamaheswari, T., Viswanatha, B. S. and Ranjith, L. 2016. *Governance of marine fisheries in India: Special reference to Tamil Nadu*.
- Jyothilal, K. R., 1998. Status of marine fisheries development in Kerala. In: *Proceedings of the Experience Sharing Workshop on Fisheries Sector Development for the State of Gujarat*, 22-23 September 1998. Indian Institute of Management, Ahmedabad, India
- Klausen, A. M. 1964. Technical assistance and social conflict: A case study from the Indo-Norwegian fishing project in Kerala, South India. *J. Peace Res.*, 1(1): 5-18. <https://doi.org/10.1177/0022343364001001>.
- Kristjonsson, H. 1967. Techniques of finding and catching shrimp in commercial fishing. In: *Proceedings of the FAO World Scientific Conference on the Biology and culture of shrimps and prawns*, 12-24 June 1967, Ciudad de Mexico, Mexico, pp. 1-69.
- Kurup, M. B. and Rajasree, R. 2007. Status of bottom trawl fishery in Kerala. *Fish. Technol.*, 44(1): 99-108.
- Lam, V. W., Sumaila, U. R., Dyck, A., Pauly, D. and Watson, R. 2011. Construction and first applications of a global cost of fishing database. *ICES J. Mar. Sci.*, 68(9): 1996-2004. <https://academic.oup.com/icesjms/article/68/9/1996/668065>.
- Madhu, V. R. 2018. A review of trawl selectivity studies carried out along Indian coast. *Fish. Technol.*, 55(1): 1-18.
- Narayanakumar, R. 2014. Economic performance of marine fishing methods in India. *Indian J. Fish.*, 61(1): 31-35
- Platteau, J. P. 1989. The dynamics of fisheries development in developing countries: A general overview. *Dev. Change*, 20(4): 565-597. <https://doi.org/10.1111/j.1467-7660.1989.tb00358.x>.
- Rajool Shanis, C. P., Shyam, S. S., Manjebaykath, H., Ganga, U., Manjusha, U. and Pillai, N. G. K. 2014. Deep-sea shrimp fishery operations in Kerala coast: Problems and prospects. *Int. J. Fish. Aquat. Stud.*, 1(6): 237-242.
- Raju, S. S., Narayanakumar, R., Ghosh, S., Pattnaik, P. and Roul, S. K. 2022. Economic performance of marine fishing operations in the state of Odisha, India. *Indian J. Fish.*, 69(2): 111-118.
- Ravi, R., Vipin, P. M., Boopendranath, M. R., Joshy, C. G. and Edwin, L. 2014. Structural changes in the mechanised fishing fleet of Kerala, South India. *Indian J. Fish.*, 61(2): 1-6. <https://doi.org/10.21077/ijf.2014.61.2.31118-01>.

- Rohit, P., Abdussamad, E. M., Margaret Muthu Rathinam, A., Ganga, U., Ghosh, S., Rajesh, K. M., Koya, K. P., Koya, M., Chellappan, A., Nakhawa, A. D. and Surya, S. 2024. Pelagic fisheries of India—An overview. *Indian J. Fish.*, 71(1): 12-28. <https://doi.org/10.21077/ijf.2024.71.1.131154-02>.
- Sabu, S. and Boopendranath, M. R. 2008. *Studies on soft bycatch reduction devices for selective trawling*. Doctoral dissertation, Cochin University of Science and Technology, Kochi, India.
- Sathiadhas, R. 1998. Marine fisheries in Indian economy. In: *Advances and priorities in fisheries technology*. Society of Fisheries Technologists (India), Kochi, India, pp. 463-472.
- Sayana, K. A. and Remesan, M. P. 2018. *Profiling growth and fuel consumption of mechanized trawlers of Kerala and investigations on efficiency of low drag trawl*. Doctoral dissertation, Cochin University of Science and Technology, Kochi, India.
- Sehara, D. B. S., Karbhari, J. P. and Salini, K. P. 1991. Economic feasibility of trawling in Maharashtra. *Mar. Fish. Inf. Serv. T & E Ser.*, 114: 8-15.
- Shyam, S. S., Geetha, R. and Sathiadhas, R. 2012. Low value fishes for nutritional security: The case with trawl landings in Kerala. *Mysore J. Agric. Sci.*, 46(2): 339-344.
- Shyam, S. S., Sathianandan, T. V., Mohamed, K. S., Narayankumar, R. and Athira, N. R. 2024. A Fisher Development Index (FDI) for assessing human development in marine fishers of Kerala, India. *Environ. Dev. Sustain.*, 1-20. <https://doi.org/10.1007/s10668-024-04923-9>.
- Sumaila, U. R., Teh, L., Watson, R., Tyedmers, P. and Pauly, D. 2008. Fuel price increase, subsidies, overcapacity, and resource sustainability. *ICES J. Mar. Sci.*, 65(6): 832-840.
- Unnithan, G. R., Gopal, N., Nair, V. R. and Nasser, M. 2005. Fuel consumption pattern by the mechanized fishing sector in Kerala. *Fish. Technol.*, 42(1). <https://doi.org/10.56093/ft.v42i1.1690>.
- Unnithan, G. R., Iyer, H. K. and Rao, P. S. 1985. Economic analysis of 22 m and 23 m deep sea trawler. *Fish. Technol.*, 22(2): 79-82.
- Vivekanandan, E. 2003. Marine fisheries and fish biodiversity in India. In: Venkataraman, K. (Ed.), *Natural aquatic ecosystems of India*. The National Biodiversity Strategy and Action Plan (NBSAP), India, pp. 71-185.
- Xavier, S. 2014. Economic sustainability of the trawl fishery of Kerala. *J. Fish. Life Sci.*, 2(1): 46-52. <https://www.fisheriesjournal.com/vol2issue1/Pdf/33.1.pdf>.
- Yadav, S., Mehta, P., Singh, A. and Yadav, S. L. 2024. Advancements in fish harvesting technology: Toward sustainable fisheries management. In: *Handbook of sustainable aquaculture and fisheries*. Elite Publishing House, New Delhi, India, pp. 299-315.