TECHNOLOGICAL TRANSFORMATION AND ITS IMPACT ON MARINE FISH PRODUCTION IN KERALA

Dr. Asha Mathew[1]

[1]Associate Professor, Department of Economics, St. Joseph's College (Autonomous), Devagiri, (Affiliated to University of Calicut), Kozhikode, KERALA

ashamathew@devagiricollege.org[1]

Abstract: The marine fisheries sector of Kerala has undergone significant transformations over the past six decades, largely driven by technological advancements in harvesting and post-harvesting processes. This study analyses the impact of mechanization, motorization, and modernization of crafts and gears on marine fish production and market dynamics. Using secondary data from 1951 to 2010, the research identifies five distinct phases of growth influenced by technological shifts. Trend estimation through Ordinary Least Squares (OLS) with breakpoints, Chow's Break-point Test, and descriptive statistics are employed to assess structural changes in production. The findings reveal an overall positive growth trajectory despite fluctuations, with mechanized and motorized sectors emerging as dominant contributors, while the role of the non-motorized sector diminished drastically. The study highlights how technological interventions initially enhanced productivity but also triggered ecological stress, overfishing, and socio-economic challenges. This analysis provides insights into the dual role of technology in shaping both opportunities and threats for Kerala's marine fisheries, stressing the importance of sustainable exploitation strategies.

Keywords: Technology, marine fisheries, motorization, mechanization

INTRODUCTION

Marine fisheries have historically been a cornerstone of Kerala's economy, culture, and food security. The state's long coastline of over 580 kilometers, coupled with a highly productive continental shelf, provides an ideal environment for a wide variety of marine species. Fishing has not only served as a primary source of livelihood for the coastal communities but has also contributed significantly to domestic consumption and foreign exchange earnings through export trade. Over the decades, the sector has undergone profound changes, driven by technological advancements, policy interventions, and evolving market demands.The technological landscape of Kerala's marine fisheries has transformed remarkably since the mid-20th century. Initially, fishing was dominated by traditional, non-motorized crafts and indigenous gears, operated mainly by local communities with limited social and economic resources. Production during this period was primarily for subsistence and local markets, constrained by conventional methods and social structures. The advent of mechanization, coupled with policy initiatives under projects like the Indo-Norwegian Project, gradually introduced motorized and mechanized crafts, synthetic gears, and improved post-harvest infrastructure. These interventions not only expanded fishing capacity but also facilitated access to deeper waters and a wider range of species, significantly enhancing productivity.This evolution, however, has not been linear. The sector has experienced phases of rapid growth, stagnation, and ecological stress, influenced by overfishing, environmental changes, and socio-economic factors. Motorization and mechanization, while increasing efficiency and output, have also introduced challenges such as resource depletion and disruption of traditional fishing practices. Understanding these phases, their driving forces, and the contributions of different technological modes is crucial for framing sustainable fisheries management strategies.

The present study aims to provide a comprehensive analysis of marine fish landings in Kerala from 1951 to 2010, with a particular focus on technological contributions to production. By examining long-term trends, identifying structural breakpoints, and assessing the relative roles of mechanized, motorized, and non-motorized sectors, the study seeks to elucidate the complex interactions between technology, policy, and ecological constraints in shaping the state's fisheries sector. The findings are intended to inform policymakers, researchers, and stakeholders about the historical dynamics of marine fisheries and the implications for sustainable development and resource management in Kerala.

OBJECTIVES

1. To examine the growth trends in marine fish landings from 1951 to 2010.
2. To identify structural changes in production associated with technological interventions.
3. To analyze the contributions of mechanized, motorized, and non-motorized sectors.
4. To assess the implications of technological change for sustainability and livelihoods.

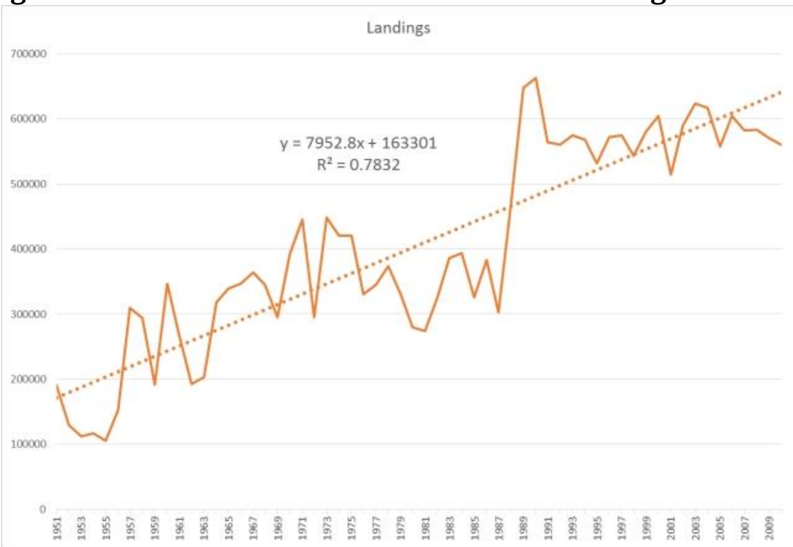
MATERIALS AND METHODS

- *Data Source:* Secondary data from CMFRI, government reports, and published studies (1951–2010).
- *Analytical Tools:*
  - OLS trend estimation with breakpoints.
  - Chow's Break-point Test to confirm structural shifts.
  - Descriptive statistics and comparisons across phases.
- *Phase Analysis*: Five periods identified based on technological shifts—Pre-mechanization, Mechanization, Decline & Motorization, Peak Motorization, and Stabilization.
- *Sectoral Focus*: Relative contributions of mechanized, motorized, and non-motorized sectors analyzed to understand long-term structural transformation.

RESULTS AND DISCUSSIONS

***Technology and Production* :** The fishing techniques practiced in Kerala are remarkably diverse, shaped by factors such as the nature of the coastline, climatic conditions, fish availability, the financial capacity of fisher-folk, and local traditions. A thorough understanding of these elements is essential for effective fishing, as even minor miscalculations in gear deployment can result in poor catches. Over the decades, technological advancements, supported by well-developed harvest and post-harvest infrastructure and growing domestic and international demand for seafood, have driven significant growth in Kerala's marine fisheries sector. Between 1951 and 1955, marine fish production fluctuated between 191,032 tons and 105,457 tons, rising to 152,213 tons in 1956. From 1957 onward, the sector expanded rapidly, with landings increasing from 309,926 tons to 448,269 tons by 1973. However, the period from 1975 to 1987 witnessed a decline, with output dropping from 420,836 tons to 303,286 tons. A dramatic surge occurred between 1988 and 1990, when production peaked at 662,890 tons, but subsequent years showed less impressive growth, and by 2010, total landings had fallen to 560,822 tons. These fluctuations reflect both the opportunities and limitations posed by technological change in Kerala's fisheries sector.

Figure 1: Trend in the Total Marine Fish Landings in Kerala

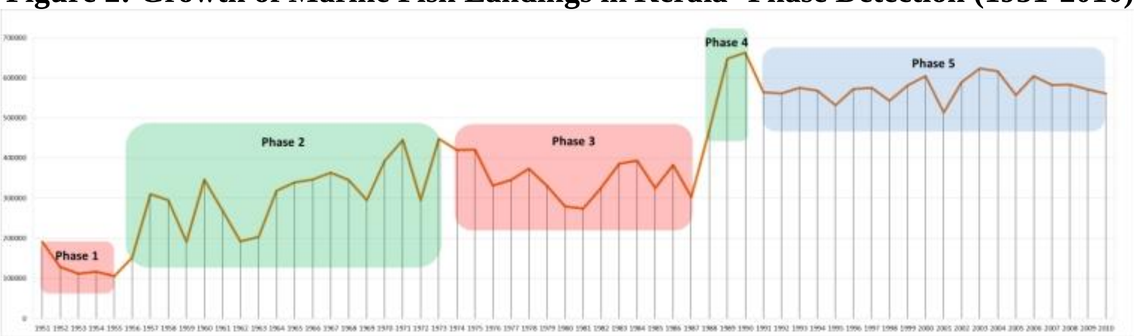


Source: Researcher's calculation based on CMFRI data

The figure depicts an overall upward trend in marine fish landings over the period, despite noticeable fluctuations. The trend line, estimated using the least squares method, shows a strong fit with an explanatory power of 78 percent. The high positive trend value (7,952.8) reflects several contributing factors, including improvements in harvesting techniques, increased fishing effort, and the expansion of fishing into deeper waters.

Identification of the Phases of Growth of Marine Fish Landings in Kerala :The figure indicates a general upward trend in marine fish landings over the period, despite fluctuations in different directions. The trend line, estimated using the least squares method, shows a strong fit, with a goodness of fit of 78 percent. The high positive trend value (7,952.8) can be linked to factors such as advancements in harvesting methods, increased fishing effort, and the extension of fishing into deeper waters. Based on these patterns, the phases of growth in total marine fish landings in Kerala over the last sixty years (1951–2010) have been identified and are illustrated in Figure 2. The key determinants in recognizing these phases were the technological shifts at specific points in time and the resulting changes in overall fish landings.

Figure 2: Growth of Marine Fish Landings in Kerala- Phase Detection (1951-2010)



Source: Researcher's calculation

On the basis of technological changes and fluctuations in total marine fish landings, five phases of growth has been identified. The details of the phases are furnished in table 1.

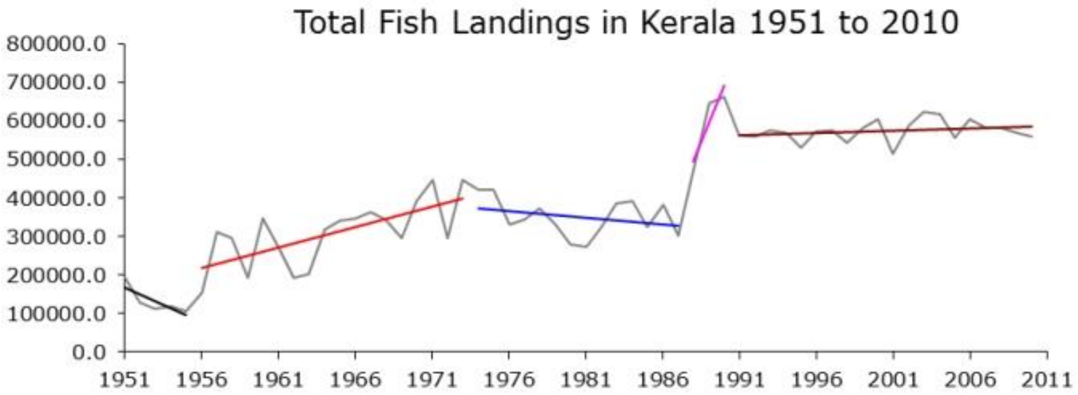
Table 1: Phases of Growth of Marine Fish Landings in Kerala (1951 – 2010)

Phase	Time Period (Inclusive of both years)
Phase 1 – Pre-mechanization phase	1951 - 1955
Phase 2 - Mechanization phase	1956 - 1973
Phase 3 - Phase of declining harvest	1974 - 1987
Phase 4 – Speedy Motorization and the pinnacle of production	1988 - 1990
Phase 5 – Inclination for stabilization	1991 - 2010

Source: Figure 2

Linear Regression Analysis Using Ordinary Least Squares Method with Break Points : Considering the marine fish landings in Kerala from 1951 to 2010, the overall growth trajectory can be analyzed by focusing on each distinct phase. A detailed examination of these phases is facilitated by assessing the linear trend values specific to each period. The growth pattern for each phase is clearly illustrated in Figure 2.

Figure 2:Trend Lines Portraying the Phases of Growth in Marine Fish Landings



The break points for the period 1951 to 2010, along with the trend values for the various phases of marine fish landings growth, were identified using EViews version 8.0. According to the software's convention, break years are considered as the starting year of each phase, which resulted in breaks occurring in 1956, 1974, 1988, and 1991. The detailed results of this analysis are presented in Table 2.

Table 2: Results of the Linear Regression Analysis Using Ordinary Least Squares Method with Break Points

Dependent Variable: TOTAL
Method: Least Squares with Breaks
Sample: 1951 2010
Included observations: 60
Break type: Fixed number of user-specified breaks
Breaks: 1956, 1974, 1988, 1991

Variable	Coefficient	Std. Error	t-Statistic	Prob.
1951 - 1955				
C	35938690	28716171	1.251514	0.2166
YEAR	-50.22454	40.27780	-1.246953	0.2182

1956 - 1973				
C	-20711874	4150384.	-4.990351	0.0000
YEAR	29.31059	5.787287	5.064651	0.0000
1974 - 1987				
C	7338996.	6106167.	1.201899	0.2351
YEAR	-9.667525	8.445615	-1.144680	0.2578
1988 - 1990				
C	-1.92E+08	65359758	-2.941600	0.0049
YEAR	265.6038	90.01460	2.950674	0.0048
1991 - 2010				
C	-2018004.	3607547.	-0.559384	0.5784
YEAR	3.548985	4.939781	0.718450	0.4758

R-squared	0.925509	Mean dependent var	405861.7
Adjusted R-squared	0.912101	S.D. dependent var	156935.9
S.E. of regression	46528.12	Durbin-Watson stat	2.089244
Sum squared resid	1.08E+11		
F-statistic	69.02459		
Prob(F-statistic)	0.000000		

The model demonstrates strong statistical significance, as confirmed by the probability level of the F-statistic. The R-squared value of 93% and the adjusted R-squared value of 91% highlight an excellent model fit. To assess potential issues of autocorrelation, the Durbin-Watson test was applied, producing a value close to 2, which indicates the absence of autocorrelation. Overall, the least squares estimation with breakpoints proves to be a reliable approach, offering a robust explanation. The key insights from this analysis can be summarized as follows.

Table 3: Trend Values in the Production Over Different Phases of Development of Marine Fisheries

Phase	Time Period (inclusive of both years)	Trend
1	1951 to 1955	Negative(-50.22)
2	1956 to 1973	Positive (29.31)
3	1974 to 1987	Negative(-9.67)
4	1988 to 1990	Positive(265.60)
5	1991 to 2010	Positive(3.55)

Source: Table 2

Having identified the phases of development and trends, each phase is examined as follows:

Phase 1 (1951–1955) – Pre-mechanization: Fishing relied on indigenous crafts and gears, primarily for subsistence, serving local needs. Operated by low-strata fishing communities, output declined from 1.91 lakh tons in 1951 to 1.05 lakh tons in 1955 due to traditional methods, social constraints, and limited exploitation. The Indo-Norwegian Project (1953) marked the beginning of modernization, but progress was slow.

Phase 2 (1956–1973) – Mechanization: Mechanized boats, synthetic gears, and export-oriented strategies led to a sharp increase in landings, from 1.52 lakh tons in 1956 to 4.48 lakh tons in 1973. Government investments, including mechanized gill net boats, nylon nets, ice plants, and curing yards, coupled with export-driven prawn harvest, transformed the sector. Caste barriers declined, allowing non-fishermen to participate, and demersal species contributed significantly to the growth.

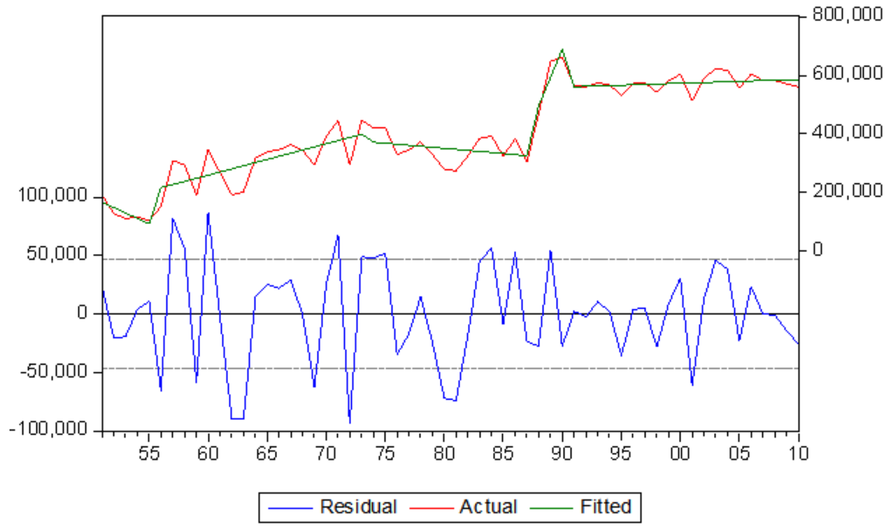
Phase 3 (1974–1987) – Declining harvest and motorization: Overfishing, ecological stress, and the introduction of purse-seine nets led to a negative trend. Landings fell to 2.74 lakh tons by 1981. Artisanal fishermen faced competition from mechanized boats, prompting protests and government interventions, including committees and the 1988 monsoon trawl ban. Motorization of country crafts began as a response, leading to partial recovery.

Phase 4 (1988–1990) – Rapid motorization and peak production: Motorization and ring seine adoption, along with extended fishing grounds and seasonal closures, drove landings to a peak of 6.63 lakh tons in 1990, dominated by oil sardine and mackerel. Government-imposed trawl bans helped regulate destructive practices, though environmental concerns persisted.

Phase 5 (1991–2010) – Stabilization and technological adaptation: Mechanized and motorized fleets operated alongside new techniques like echo sounders, mini trawlers, and multi-day fishing. Landings showed slow growth, peaking at 6.23 lakh tons in 2003 before declining. Overfishing, unregulated trawling, natural disasters like the 2004 tsunami, and unsustainable practices such as catching juveniles contributed to ecological stress and gradual depletion of several species. Conservation and management became critical concerns, with inboard canoes and selective fishing methods introduced to improve efficiency.

The results of the linear trend estimation with breakpoints are visually supported through graphs displaying the actual, fitted, and residual values.

Figure 4: Total Marine Fish Landings in Kerala – Graph Portraying the Actual, Fitted and Residual Lines



The upper section of the graph illustrates the actual values of total marine fish landings along with the fitted linear regression lines estimated across different breakpoints. The lower section depicts the distribution of regression residuals. Notably, the variability of the residuals decreases over time, indicating a stabilization process in the time series.

Chow's Break-point Test: The structural stability of the linear regression with breakpoints was assessed using Chow's Break-point Test. This test divides the data set into sub samples and estimates the same regression equation for each subsample separately, allowing for the detection of significant differences between the estimated equations. A significant difference indicates a structural change in the relationship.

The hypotheses for the test are formulated as follows:

- Null hypothesis (H_0): No structural breaks exist at the specified breakpoints.

- Alternative hypothesis (H_1): Structural breaks exist at the specified breakpoints.

The years 1956, 1974, 1988, and 1991 were selected as the breakpoints, and the results of the analysis are presented in Table 4.

Table 4: Results of Chow Break point Test

Chow Breakpoint Test: 1956 1974 1988 1991
Null Hypothesis: Absence of breaks at the specified breakpoints
Varying regressors: All equation variables
Equation Sample: 1951 2010

F-statistic	11.93618	Prob. F(8,50)	0.0000
Log likelihood ratio	64.08483	Prob. Chi-Square(8)	0.0000
		Prob. Chi-Square(8)	0.0000

Source: Researcher's Calculation

Chow's Breakpoint Test evaluates the null hypothesis, which assumes the absence ofbreaks at the specified breakpoints. Since the F-statistic shows a significance level below 0.05, the null hypothesis is rejected, indicating that structural breaks exist at the specified points and are statistically significant."

Descriptive Statistics of Total Marine Fish Landings in Different Phases: It is relevant to look at the average values of total marine fish landings in different phases.

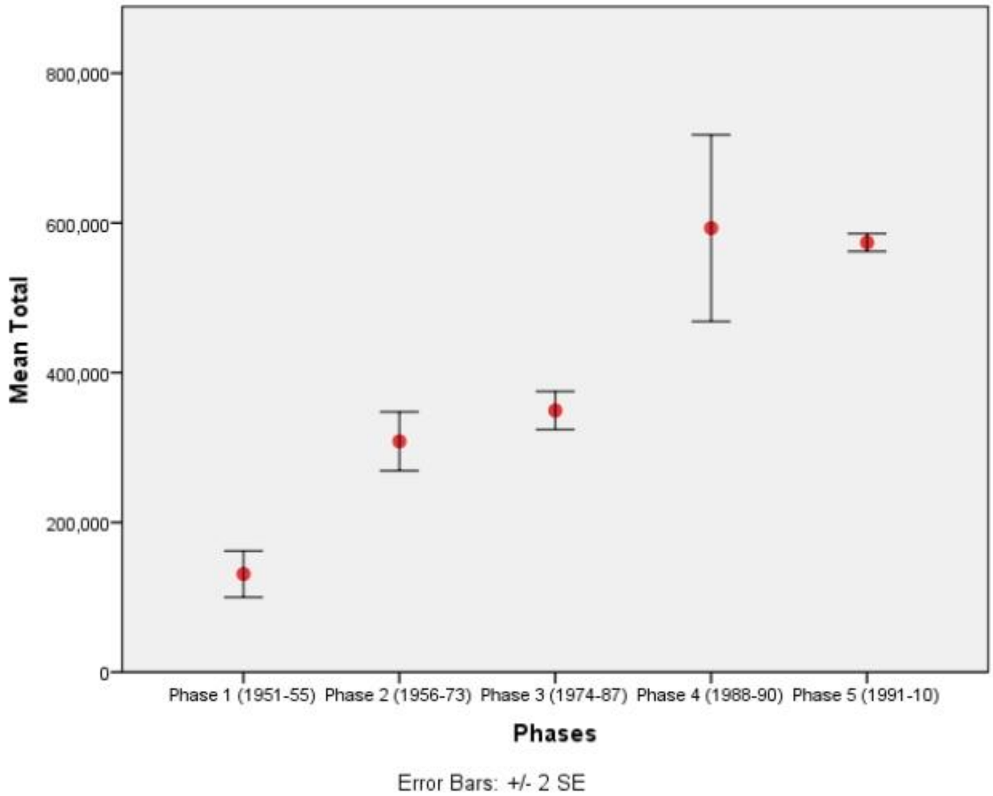
Table 5 : Descriptive Statistics of Total Marine Fish Landings in Kerala

	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Phase 1 (1951-55)	5	130973.40	34695.491	15516.295	105457	191032
Phase 2 (1956-73)	18	308300.67	83527.142	19687.536	152213	448269
Phase 3 (1974-87)	14	349404.21	47678.392	12742.586	274395	420836
Phase 4 (1988-90)	3	593074.67	107891.920	62291.429	468808	662890
Phase 5 (1991-10)	20	573827.00	26841.032	6001.837	514139	623293
Total	60	405861.70	156935.914	20260.339	105457	662890

Source: Researcher's Calculation

The analysis reveals that, although fluctuations are present in the trend values, the overall averages show improvement across all phases except the final one. To evaluate these averages, a One-Way Analysis of Variance (ANOVA) was conducted. This test assesses whether there are statistically significant differences among the means of two or more independent groups. As an omnibus test, one-way ANOVA can indicate the existence of such differences but does not specify the exact groups involved. Given that this study covers five distinct phases, identifying which phases differ is particularly important. The results confirmed that the variations in averages are statistically significant ($P < 0.001$). Figure 5 illustrates this outcome, presenting an error bar chart of the average values for each phase, with error bars representing ± two standard errors.

Figure 5: Error Bar Chart Representing the Average Values in Different Phases of Growth of Marine Fish

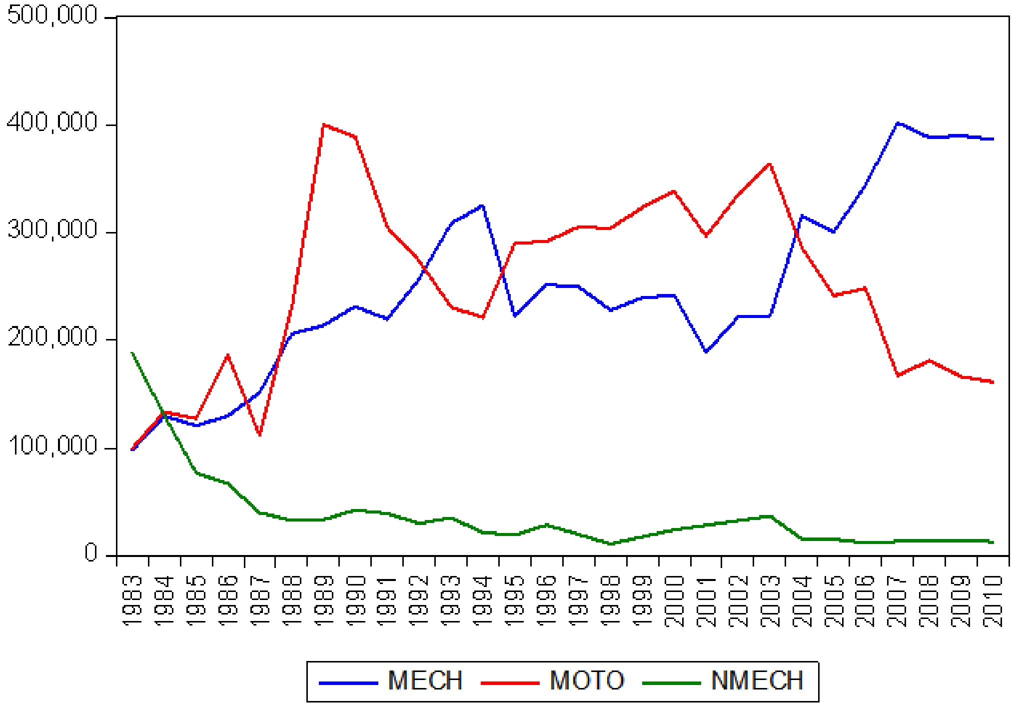


The error bar chart reveals that marine fish landings consistently increased across phases, except in the final phase where a decline is evident. The narrowing variation around the mean during the fifth phase suggests greater stability in landings, possibly reflecting technological interventions. This trend emphasizes the need to critically assess how technology has shaped productivity patterns in marine fisheries.

Technological Advancement and Marine Fish Production: Marine fish landings in Kerala can be better understood by examining the role of technological advancements, particularly the expansion of mechanized and motorized crafts. Over the past 18 years, the number of active crafts has grown significantly. Mechanized crafts increased from 4,042 in 1985 to 5,504 in 2007. Motorized crafts, which were relatively few at 5,337 in 1985, expanded rapidly to 29,395 by 2003, before declining to 14,151 in 2007. In contrast, the non-motorized sector steadily contracted, with the number of crafts falling from 25,363 in 1985 to 9,522 in 2007, indicating its shrinking role in the fisheries sector (Economic Review, 2007).

A comprehensive assessment of technological progress in Kerala's marine fisheries is constrained by the availability of data, which spans only from 1983 to 2010. This period covers part of the third phase, as well as the full fourth and fifth phases. Figure 6 illustrates the trends in total marine fish landings across mechanized, motorized, and non-motorized modes.

Figure 6 :Marine Fish Landings in Kerala – Contribution of Mechanized, Motorized and Non-motorized



Source: Based on the data, compiled from various administrative reports of CMFRI

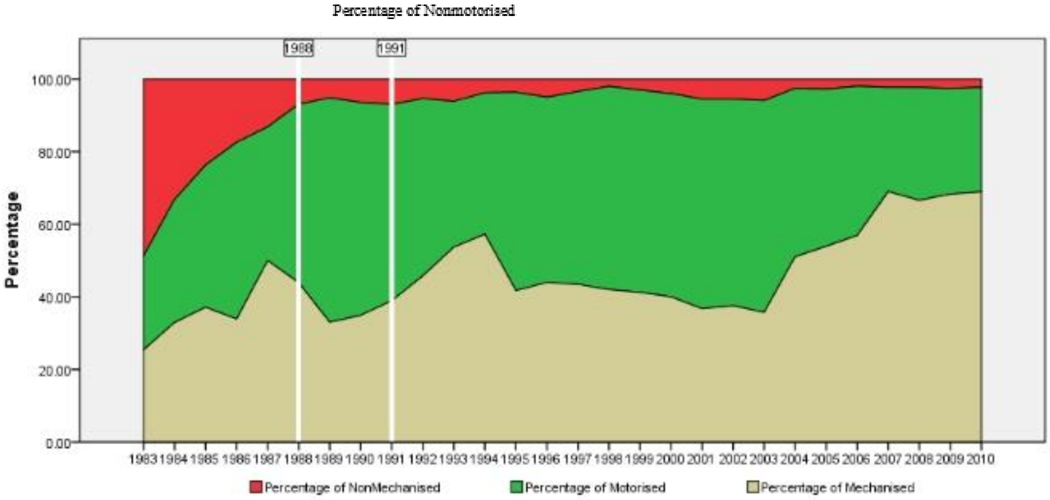
Figure 6 depicts the contributions of mechanized, motorized, and non-motorized crafts to Kerala's total fish catch. The data clearly show a steady decline in the share of the non-motorized sector, while the motorized sector rose to prominence during certain periods before experiencing a downturn. The mechanized sector, though marked by fluctuations, has sustained its significance and shows signs of continued growth.

Contribution of Mechanized, Motorized and Non-Motorized Sectors to the Total Output:

The contribution of each mode—mechanized, motorized, and non-motorized—to Kerala's total marine fish landings can be better understood by examining their percentage share. This information is presented in the Stacked Area Chart, which provides a clear visual representation of the relative importance of each mode over time. By focusing on the last three phases—Phase 3, Phase 4, and Phase 5—the chart enables a comparative assessment of how the balance among these sectors has shifted.

During Phase 3, the non-motorized sector still played a visible role, though its share had already begun to shrink with the increasing use of motorized crafts. In Phase 4, the motorized sector reached its peak contribution, reflecting the rapid adoption of this technology and its growing influence on the fishery economy. By Phase 5, however, the contribution of motorized crafts began to decline, while the mechanized sector gained further prominence, consolidating its position as the dominant mode of production. The non-motorized sector, meanwhile, continued its downward trend, underscoring its declining relevance in the face of technological advancements.The Stacked Area Chart thus provides a holistic view of the technological transition within Kerala's marine fisheries, highlighting the gradual replacement of traditional methods with more advanced modes of fishing.

Figure 7: Stacked Area Chart Showing the Percentage Contribution of Mechanized, Motorized and Non-motorized sectors



Phase-Wise Trends in Marine Fish Landings by Craft Type:

Phase 3 (1983–1987):This phase, though limited to the years 1983–1987 due to data availability, marks the beginning of a visible technological transition. The non-motorized sector, which once held a dominant share, declined drastically from 48.76% in 1983 to just 13.16% in 1987, signaling the gradual replacement of traditional fishing methods. In contrast, both mechanized and motorized crafts gained prominence. The mechanized share almost doubled, rising from 25.42% to 50%, largely fueled by the booming demand for prawn exports in international markets. The motorized sector also experienced a sharp rise, from 25.82% in 1983 to 48.66% in 1986, before slightly falling to 36.84% in 1987, reflecting early fluctuations in adoption and resource dependence.

Phase 4 (1988–1990):The fourth phase witnessed the rapid expansion of motorization, significantly supported by the widespread adoption of ring seine nets and seasonal trawl bans. Motorized crafts reached their peak contribution in 1989 at 61.81%, driven by exceptionally high landings of oil sardine and mackerel—two key species in Kerala's fisheries. However, the mechanized sector's share declined from 43.92% in 1988 to 34.93% in 1990, partly due to restrictions such as the 1988 monsoon trawl ban, which limited mechanized activity during peak fishing seasons. The non-motorized sector, by this time, had become marginal, falling from 6.93% in 1988 to just 5.18% in 1989, underscoring its diminishing importance in the production structure.

Phase 5 (1991–2010):The fifth phase represents a long period of technological competition between mechanized and motorized sectors. The motorized fleet initially dominated, contributing more than 50% in 1991, but its share soon became volatile—dropping to 38.96% in 1994, rising again to 58.39% in 2003, and eventually falling sharply to 28.79% by 2010. These fluctuations can be linked to issues such as overfishing, depletion of key stocks, and high juvenile catches, which undermined the sustainability of motorized fishing. On the other hand, the mechanized sector steadily consolidated its dominance. Its contribution rose from 38.94% in 1991 to a peak of 68.92% by 2004, supported by technological improvements such as the use of inboard canoes and the expansion of in-stay fishing practices. By the end of the phase, mechanized crafts clearly established themselves as the backbone of Kerala's marine fisheries. The non-motorized sector, meanwhile, was almost phased out, with contributions consistently below 5% and dropping further to just 2.29% in 2010.

Across these three phases, the trajectory of Kerala's marine fish production has been defined by technological transformation. Motorization initially acted as a catalyst, boosting production during its peak years, but its long-term sustainability was challenged by ecological pressures and stock decline. Mechanization, with its greater efficiency and adaptability, gradually emerged as the dominant force, shaping the modern fisheries sector. In contrast, the non-motorized sector steadily lost its relevance, reduced to a marginal role in the production system. Together, these shifts highlight how technological adoption, resource dynamics, and policy interventions have collectively influenced the structure and sustainability of Kerala's marine fisheries.

*Descriptive Statistics of Mechanized, Motorized and Non-Motorized Fish Production:*The average of the percentages of contribution to the total marine fish landings according to the modes are presented in table 6.

Table 6 : Descriptive Statistics for the Total Marine Fish Landings by Mechanized, Motorized and Non- Motorized Sectors

		N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Percentage of Mechanized	Phase 3 (1974-87)*	5	35.8842	8.98416	4.01784	25.42	50.00
	Phase 4 (1988-90)	3	37.2880	5.82653	3.36395	33.01	43.92
	Phase 5 (1991-10)	20	49.6499	11.51291	2.57436	35.72	69.01
	Total	28	45.8672	12.04072	2.27548	25.42	69.01
Percentage of Motorized	Phase 3 (1974-87)*	5	36.8722	8.29700	3.71053	25.82	48.66
	Phase 4 (1988-90)	3	56.5270	6.58738	3.80323	49.15	61.81
	Phase 5 (1991-10)	20	46.5038	10.60730	2.37186	28.70	58.39
	Total	28	45.8578	10.97721	2.07450	25.82	61.81
Percentage of Non - Motorized	Phase 3 (1974-87)*	5	27.2436	14.18865	6.34536	13.16	48.76
	Phase 4 (1988-90)	3	6.1850	.90112	.52026	5.18	6.93
	Phase 5 (1991-10)	20	3.8463	1.59073	.35570	1.96	6.96
	Total	28	8.2750	10.64473	2.01167	1.96	48.76

Source: Researcher's Calculation

Note: * Phase 3 includes data from 1983-87 only.

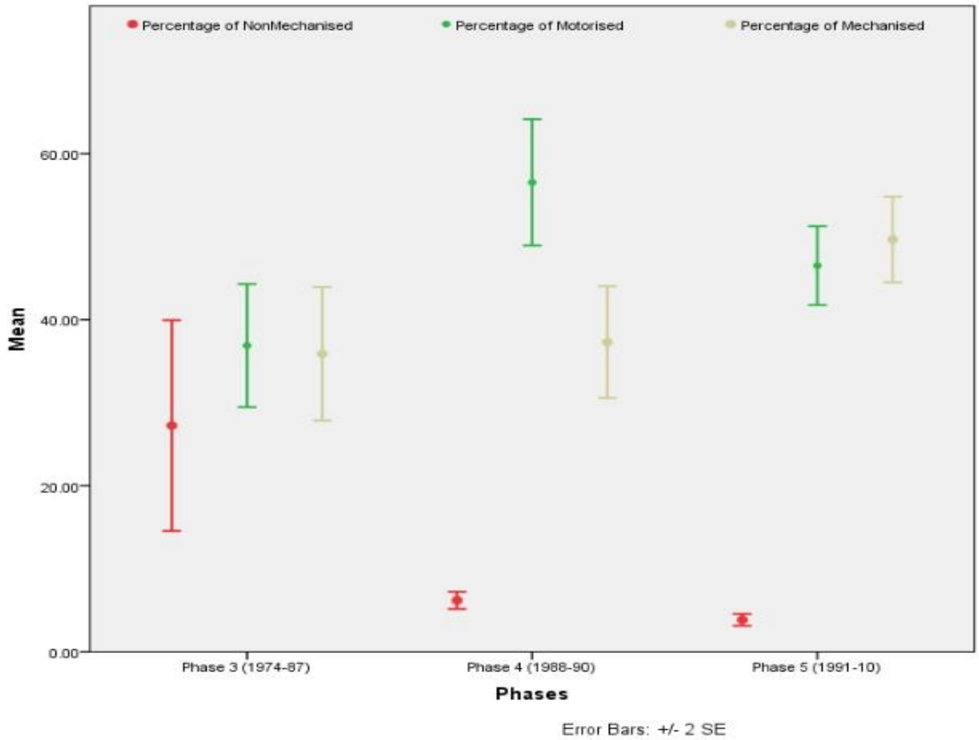
When the average percentage contributions of the three sectors are considered, distinct patterns of technological transition become evident. The mechanized sector demonstrates steady improvement across all phases, reflecting its increasing dominance in Kerala's marine fisheries. This sustained growth highlights the sector's adaptability, efficiency, and capacity to respond to both market demand and policy interventions.The motorized sector, on the other hand, shows a different trajectory. Its share records a sharp increase during the fourth phase, largely due to the rapid expansion of motorized crafts and the widespread use of ring seines. However, this momentum was not maintained in the long run, as its contribution declined in the subsequent phase. The fall can be attributed to ecological pressures such as overfishing and juvenile exploitation, as well as the growing competitiveness of mechanized crafts.Meanwhile, the non-motorized sector follows a consistent and steep downward trend throughout all phases. Once the backbone of Kerala's marine fishing economy, this sector gradually lost its significance with the advent of more advanced technologies, eventually becoming marginal in the overall production structure.To assess whether these observed differences in mean contributions across phases were statistically meaningful, a one-way ANOVA test was applied. The results confirmed that the differences are indeed significant ($P < 0.05$), indicating that technological changes have had a measurable impact on the composition of marine fish landings. The mean values, along with their variability represented by ± two standard errors, are visually presented in the error bar chart, which offers a clear comparison of sectoral contributions across the phases.

The error bar chart demonstrates that the average percentage contribution of the non-motorized sector has shown a continuous decline across the different phases of Kerala's marine fisheries. This steady reduction highlights the diminishing role of traditional fishing methods, which were once the backbone of coastal livelihoods but gradually lost ground as new technologies emerged. The variability around its mean contribution, represented by ±2 standard errors, decreased in the fourth phase and became almost negligible in the fifth when compared to the third phase. This suggests that not only did the non-motorized sector lose its share, but its contribution also became highly predictable and uniformly low, reflecting its near-complete marginalization in the modern era of fisheries.

For the mechanized sector, the pattern is markedly different. The variation around the mean steadily declined across all phases, pointing to increasing stability in its contribution. This indicates that mechanized fishing, with its advanced vessels and efficient harvesting methods, established itself as a consistent and reliable component of total production. The narrowing error margins suggest that mechanization reached a stage of maturity, where its role in the fisheries economy was less prone to fluctuations and more dependable in meeting production demands.

The motorized sector displayed more fluctuation in its trajectory. During the fourth phase, variability increased, indicating instability in its share of contribution. This could be linked to the uneven adoption of motorized technologies, differences in access to resources, or the transitional pressures faced by small-scale fishers shifting away from non-motorized practices. However, by the fifth phase, this variation declined, showing that the motorized sector had eventually stabilized. This points to its successful adaptation, as many traditional fishers embraced motorization as a way to remain competitive while avoiding the higher costs of full mechanization. Overall, these findings emphasize that technological advancement has fundamentally reshaped Kerala's marine fisheries. The non-motorized sector has been progressively marginalized, losing both significance and variability, while the mechanized sector has grown into a stable pillar of production. The motorized sector, after a period of adjustment, has also found a more consistent position. Together, these patterns underline a broader transformation in the fisheries landscape, where modernization has not only shifted production shares but also determined the stability and resilience of different sectors over time.

Figure 8: Error Bar Chart of Mechanized, Motorized and Non-Motorized Fish Production



CONCLUSION

The analysis of Kerala's marine fisheries between 1951 and 2010 reveals a period of remarkable transformation, shaped by technological innovations, policy interventions, and shifting socio-economic conditions. Five distinct phases can be identified, each defined by specific technological and institutional changes.

Pre-mechanization phase (1951–1955): Fishing during this period remained subsistence-oriented, dependent on traditional crafts and gears operated largely by marginalized coastal communities. Production was limited, inconsistent, and constrained by social practices as well as the underutilization of marine resources.

Mechanization phase (1956–1973): A significant breakthrough occurred with the introduction of mechanized crafts, synthetic gears, and the expansion of the prawn export trade. Government support—including the provision of mechanized gill net boats, supply of nets, and establishment of curing yards and ice plants—greatly enhanced production. Landings displayed a clear upward trend, with notable gains in demersal and prawn resources.

Third phase (1974–1987): This period was characterized by ecological stress and declining catches due to overfishing. At the same time, the motorization of traditional crafts began, partly in response to competition from mechanized fleets. Government interventions, such as policy reviews by expert committees and the introduction of the monsoon trawl ban, were implemented to reduce resource depletion.

Fourth phase (1988–1990): A period of rapid motorization, supported by the widespread adoption of ring seines and longer fishing hours. Seasonal closures also contributed to stock recovery, leading to exceptionally high levels of production. This short phase marked the peak of total landings in Kerala's marine fisheries.

Fifth phase (1991–2010): The sector entered a stage of relative stabilization rather than rapid growth. Technological innovations—such as motorized country crafts, inboard-fitted canoes, echo sounders, and multi-day fishing—contributed to sustaining productivity. However, overall gains were modest, constrained by overfishing, environmental degradation, and natural disasters such as the 2004 tsunami. Mechanized crafts gradually consolidated their dominance, while the motorized sector fluctuated, and the non-motorized sector became almost irrelevant.

The combined results of trend and variance analyses, including linear trend estimation with breakpoints, Chow's test, and one-way ANOVA, confirm that the technological modes of fishing significantly shaped production outcomes. Mechanized and motorized sectors emerged as the key drivers of growth, while traditional, non-motorized fishing steadily lost its relevance.In summary, the evolution of Kerala's marine fisheries reflects a dynamic interplay of technology, policy, and ecology. Although the sector has shown resilience and adaptability, the findings stress the urgent need for sustainable resource management. Safeguarding marine biodiversity, regulating fishing practices, and promoting responsible technological use will be essential for sustaining productivity and securing the long-term livelihoods of Kerala's fishing communities.

REFERENCES

1. Achari, T.R.T. (1969). *The Impact of Indo-Norwegian Project on the Growth and Development of Fisheries.* Agricultural Division, State Planning Board, Government of Kerala, Trivandrum.
2. Achari, T.R.T. (1989). *Socio-Economic Impact of Motorisation.* National Workshop on Technology for Small Scale Fish Workers, 27 and 28 February and 1 March 1989, Trivandrum.
3. Achari, T.R.T. (1993). *Impact of Motorisation of Traditional Craft on Coastal Fishing and Fisherman Community – Kerala": Development of marine Fisheries for Higher Productivity and Export.* Central Institute of Fisheries and Nautical Engineering Training, Cochin.
4. Achari, T.R.T., & Menon, Devadasa, M. (1963). *A report on the assessment of INP on the socio-economic conditions of the fishermen in INP area*. OSLO, NOEAD.
5. Alexandratos, N. (2000). *World Agriculture towards 2010: An FAO study*. Rome and Chichester, U.K: Food & Agricultural Organization of United Nations and John Wiley.
6. Ammini, P.L., Srinivasan., Ramani,J., Beena,k., and Seynudeen, M.B.(2010). Marine Fisheries in Kerala. *Marine Fisheries Information Service T&E, Ser: No. 204*
7. Anderson, A.M. (1974). Expansion of domestic markets in developing countries in fishing products. *Fishing News*: UK.
8. Anderson, G. Lee. (1977). *Economics of fisheries management*. Baltimore: John Hopkins Press.
9. Aravindhakshan, N. (2000). Fishery regulations in Kerala. *Kerala Calling. October 20* (12).
10. Bailey, C., & Pomeroy, C. (1996). Resource dependency and community stability in coastal fishing communities of South East Asia. *Society and Natural Resources 9* (2). 191-199.
11. Barbier, E.B. (2005). *Natural resources and economic development*. New York: Cambridge University Press.
12. Baumann, P. (2002). *Improving access to natural resources for the rural poor: A critical analysis of central concepts and emerging from a sustainable livelihoods perspective*. LSP working paper 1. Rome: FAO.

13. Bavinck, M. (2001). *Marine resource management: Conflicts and regulations in the fisheries of the Coromandel Coast*. New Delhi: Sage publishers.
14. Bensam, Pathrose. (1999). *Development of marine fisheries science in India*. New Delhi: Daya Publishing House.
15. Berkes, F. (2001). *Common property resources: ecology and community based sustainable development*. London: Belhaven press.
16. Bhata, R., & Prabhakar, S. (1990). *A study of seasonal fluctuations of fish catch and prices along Dakshina Kanada Coast*. New Delhi: Sterling Publishers private Limited.
17. Bhushan, Bharat. (1979). *Technological change in fishing in Kerala, 1953-1977*. Unpublished M.Phil Dissertation, Centre for Development Studies, Thiruvananthapuram.
18. Cherunilam, F. (1993). *Fisheries: Global perspective and Indian development*. Delhi: Himalaya Publishing House.
19. Christy, Francis, T. (1982). Territorial use rights in marine fisheries: Definitions and conditions. *FAO Fisheries technical paper No.227*.
20. CMFRI. (1978). All India Marine Fisheries Census Frame Survey – 1973-77. *Marine Fisheries Information Service, T & E Ser., No.3*.
21. CMFRI. (2011). *Marine fisheries statistics*. Cochin, Statistical Cell.
22. D'cruz, Titto. (1998). *The ringseine - Evolution and design specification*. Thiruvananthapuram: SIFFS.
23. Day, F. (1989). *The fishes of India*. London: William Dawsons and Sons.
24. Devaraj, M., & Vivekanandan, E. (1999). Marine capture fisheries of India: Challenges and opportunities. *Current Science, 76* (3). CMFRI.
25. Devaraj, M.R., Sathiadhas, R., & Reghu, R. (1998). Techno – economic assessment of marine fish production, marketing and capacity utilization of processing plants in Gujarat. *Marine Fisheries Information Service, T & E ser., No. 18*.
26. FAO. (1994). *Socio-economic issues in coastal fisheries management*. Proceedings of the IPFC symposium, Italy; Rome.
27. Felice, Annie. (1980). *Traditional and Modernity in a fishing community – A study of technological innovation in fishing on the fishermen of Vypeen island, Kerala*. Ph.D thesis (unpublished), submitted to University of Kerala. Thiruvananthapuram.
28. Gopalakrishnan, P.K. (1974). *Keralathinte Samskarika Charithram* (Malayalam). Thiruvananthapuram: Kerala Language Institute.
29. Gopalakrishnan, P.K. (1979). *Aryasamudayathinte Navothanam*. Kerala Charithram (Malayalam). Thiruvananthapuram: Kerala History Association.
30. Gopalan, U.K. (1980). *The Fishery Resources of Kerala and Their Exploitation,- Fisheries Crises and Policy Approach in Kerala*. Proceeding of State level seminar held at Trivandrum on August 27, 28, 1987, PCO Centre, Trivandrum.
31. Gopalan, U.K. (1987). *The fishery resources of Kerala and their exploitation*. Kerala proceedings of the state level seminar held at Thiruvananthapuram.
32. Government of India. (1971). *Evaluation of the programs of mechanization of fishing boats*. New Delhi: The Planning Commission.
33. Government of India. (1988). *Report on marine fisheries*. National Sample Survey Organization.
34. Government of India. (2005). *Marine Fisheries Census – 2005*. Ministry of Agriculture, Department of Animal Husbandry, Dairying and Fisheries. New Delhi.
35. Government of India. (2008). *Hand book on fisheries statistics – 2008*. Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, New Delhi.

36. Government of India. (2009). *Handbook on fisheries statistics – 2009*. Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture. New Delhi.
37. Government of India. (2009). *Statistics of marine products, 2009*. MPEDA, Ministry of Commerce and Industry. New Delhi.
38. Government of India. (2011). *Statistics of marine products*. MPEDA, Ministry of commerce and Industry. New Delhi.
39. Government of India. (2013). *Annual Report: 2012-13*. Department of animal Husbandry, Dairying and Fisheries, Ministry of Agriculture. New Delhi.
40. Government of Kerala. (1969). *The impact of Indo-Norwegian project on the growth and development of Indian fisheries agricultural division*. State Planning Board, Kerala.
41. Government of Kerala. (1990). *Kerala Fisheries – facts & figures*. Department of Fisheries, Thiruvananthapuram.
42. Government of Kerala. (2004). *Kerala Fisheries, facts and figures*. Department of Fisheries. Thiruvananthapuram.
43. Government of Kerala. (2004). *Socio-techno economic survey of fisher folk in Kerala*. Department of Fisheries.
44. Government of Kerala. (2005). *District profile*. Directorate of Fisheries. Thiruvananthapuram, Statistical Cell.
45. Government of Kerala. (2005). *Economic review*. State Planning Board, Thiruvananthapuram.
46. Government of Kerala. (2007). *Marine fisheries census*. Department of Fisheries. Thiruvananthapuram.
47. Government of Kerala. (2007). *Marine fisheries statistics of Kerala – 2007*. Department of Fisheries, Thiruvananthapuram.
48. Government of Kerala. (2009). *Data on district wise distribution of fishermen population in Kerala*. Directorate of Fisheries. Thiruvananthapuram Statistical cell.
49. Government of Kerala. (2010). *Kerala Fisheries, facts and figures*. Department of Fisheries. Thiruvananthapuram.
50. Government of Kerala. (2010). *Marine fisheries census*. Department of Fisheries. Thiruvananthapuram.
51. Government of Kerala. (2010). *Statistics on marine fisheries infrastructure*. Harbour Engineering Department. Thiruvananthapuram.
52. Gulati, Leela. (1979). *Women and Technological Change; A Case Study of Three Fishing Villages,* Working Paper No.99 Centre for Development Studies Thiruvananthapuram.
53. Ibrahim, P. (1992). *Fisheries development in India*. New Delhi: Classical Publishing Company.
54. Ibrahim, P., & D'Silva, Stanley. (1994). *Economics of mechanized boats and motorized crafts*. New Delhi: Daya Publishing House.
55. Iyer, Krishna., Rajendran., & Chaudary Roy. (1983, March). Comparative economic efficiency of fishing trawlers of 9.82 m (32 ft) and 11m (36 ft) OAL operating along the Kerala coast. *Fishing Technology Newsletter*, *3* (7).
56. Iyer, Krishna., Rajendran., & Choudary, Roy. (1968). Comparative fishing ability and economic efficiency of mechanized trawlers operating along the Kerala coast. *Fishery Technology, 5* (2).
57. Kalawar., Devaraj., & Parnlekar. (1985). *Report of the expert committee on marine fisheries in Kerala*. Bombay: Central Institute of Fishery Education.

58. Klausen, A.M. (1968). *Kerala fishermen and the Indo-Norwegian pilot project*. London: Allen and Unwin.
59. Korakkandy, Ramakrishnan. (1994). *Technological change and the development of marine fishing industry in India*. New Delhi: Daya Publishing House.
60. Kurien, J., & Achari, T.R.T. (1989). *On ruining the commons and the commoner- The political economy of overfishing.* Centre for Development Studies, Working Paper No.232 Trivandrum.
61. Kurien, John. (1978). Entry of big business into fishing – Its impact on the fish economy. *Economic and Political weekly, 13* (36).
62. Kurien, John. (1978). *Towards an understanding of the fish economy of Kerala*. Working paper No.68. Centre for Development Studies, Thiruvananthapuram.
63. Kurien, John. (1987). *The Impact of New Technology Introductions into Fishing in Kerala. Fisheries Crises and Policy Approach.* Proceedings of the State level seminar held at Trivandrum on August 27-28, 1987, Seminar Committee Fisheries Research Cell, PCO Centre, Trivandrum.
64. Kurien, John., and Willmann, R. (1982). *Economics of Artisanal and Mechanized Fisheries in Kerala: A Study on Costs and Earnings of Fishing Unit*. FAO/UNDP Publication, Working Paper No.34, Madras.
65. Kurien, John., Jayakumar.(1980). *Motorisation of traditional canoes - The Purakkad experiment.* Fisheries Research Cell, Thiruvananthapuram.
66. Menon, T.R. (1985). *Traditional crafts and gears – A systems framework of the marine foods industry in India*. Ahmedabad: IIM.
67. Panikar, P.A., Sivan, J.M., & George, N.A. (1985). *A new fishing gear for traditional craft-Harvest and post-harvest technology of fish*. Symposium on harvest and post harvest technology of fish. Cochin.
68. PCO & SIFFS. (1991). *Motorization of fishing units. Benefits and burdens*. Thiruvananthapuram.
69. Rajasenan, D. (1996). Resources depletion and fishery management – the Kerala experience. *India Manager. 22* (1), Cochin.
70. Rajasenan, D. (2001). Technology and labour process in marine fishery: the Kerala Experience. *India Journal of Labour Economics 4*(2).
71. Rao, P.S. (1983). *Fishery Economics and Management in India*. Bombay: Pioneer Publishers & Distribution.
72. Rao, P.S. (1990). *Fish marketing system in the South and South East Asian countries*. An article prepared for the V conference of International Institute of Fisheries Economics and trade, Santiago.
73. Sathiadas, R., & Venkataraman. (1981). *Impact of Mechanized Fishing on the socio economic condition of fishermen of Sakthikulangara-Neendakara, Kerala* . CMFRI, Cochin.
74. Sathiadhas, R., & Venkataraman, G. (1981). Impact of mechanized fishing on the socio-economic conditions of the fishermen of Sakthikulangara – Neendakara, Kerala. *Marine Fisheries Information Service, T & E ser., No.29*.
75. Whitmarsh, David. (1990). Technological change and marine fisheries development; Marine Policy. *The International Journal of Ocean Affairs, 14(1)*.
76. Yohannan, T. M., & Sivadas, M. (1993).Marine fisheries in Kerala. *Marine Fisheries Information Service No. 160.*