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Livelihood challenges of traditional fishing units operating large modified ring seines: Climate variability perspective in Kerala, south west coast of India

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Original Article

Abstract

The modified artisanal marine fishing sector in Kerala, dominated by ring seine, is currently facing competition from the mechanized category of purse seine vessels. Communities have adopted new livelihood strategies by intensifying the usage of modified crafts and gears. This study aimed to analyze the livelihood challenges of the modified artisanal fishing sector in central Kerala adhering to the Department for International Development (DFID) livelihood framework. Data on the artisanal ring seine fisheries in the Ernakulam, Alappuzha, and Kollam districts, which are revenue boundaries of central Kerala during the period from 2010 to 2022 were analyzed. The livelihoods of modified artisanal fishing vessels with large ring seines are threatened by climate variability in terms of loss of fishing days, repercussions in employment, etc. The adoption of participatory disaster governance strategies and the formulation of marine fisheries disaster policies can play a crucial role in addressing the emerging challenges in traditional fishing communities. Implementation of resource/catch sharing, regulation of physical inputs and credit reimbursement systems are also suggested as management measures for addressing the livelihood challenges of traditional coastal fishers.

Keywords: *Livelihood, vulnerability, ring seine fishery, climate variability, policy suggestions*

Introduction

Small-scale fisheries play a crucial role on a worldwide basis, especially in developing nations. They have a crucial function in guaranteeing food security, generating employment, and serving as fundamental economic support for numerous coastal communities, particularly in developing nations. Nevertheless, these fisheries have consistently faced difficulties concerning discrepancies in income, sustainability, and poverty. Small-scale fisheries make a substantial contribution to the overall fish production worldwide, playing a crucial role in providing food security for millions of people. Hence, the intricate layers of complexity that surround discrepancies in income, sustainability, and poverty must be studied in depth (Ellis and Bahiigwa, 2003; Bene, 2006; Bene *et al.,* 2007; Islam and Chuenpagdee, 2013; Oladimeji *et al.,* 2013, 2014; Kalikoski *et al.,* 2019; Kruijssen *et al.,* 2020). Research conducted by Appadoo *et al.* (2022) in Mauritius highlights the extensive knowledge that artisanal fishers possess on their maritime environment. The knowledge acquired from everyday contact with the sea offers essential insights regarding environmental fluctuations, fish response to gear, and the overall health of the ecosystem (Yuerlita *et al.*, 2013; Wijayanto *et al.*, 2022). The socio-economic consequences of small-scale fisheries are significant (Inoni and Oyaide, 2007; Teh *et al.*, 2011; Rahman *et al.*, 2020). These fisheries, which frequently operate in areas with few other job options, have a vital impact on employment, local commerce, and community growth. If difficulties are not resolved, they might result in economic weaknesses, causing communities to fall into poverty and debt trap (Carter and Julian, 1999; Twigg, 2001; Rew and Martin, 2003). The studies conducted by Muallil *et al.* (2013), James and Philip (2014), Valdes and Arturo (2014) and Bravo *et al.*

(2015) elicit that the extent of artisanal fisheries, primarily in developing countries is extensive and often unregulated, requiring urgent implementation of scientifically-supported management strategies to ensure sustainability (Gilmar *et al.*, 2016). Silvia *et al.* (2017) focused specifically on small-scale fisheries systems, providing insight into their essential features, variables, linkages, and factors influencing their management. The study provided a thorough overview of various fisheries, incorporating an analysis of community performance and the shared difficulties in managing them (Ngonga *et al.*, 2019; Rachman *et al.*, 2019).

The primary objective of this study was to analyze the livelihood challenges of traditional fishing vessels operating large modified ring seine along the coastal waters of central Kerala. The secondary objective was to analyze the seasonal variations in the operation of traditional large modified ring seiners due to climate variability. The vulnerability context analysis of the fishery under study is expected to bring out seasonal variations in the operation of modified artisanal fishing vessels equipped with huge ring seine fisheries concerning extreme weather conditions. The discussion is focused on the consequences of climate variability on the livelihoods and recommendations are framed to address the livelihood challenges of the modified traditional fishing sector of coastal Kerala.

Material and methods

The term livelihood is defined as the combination of capabilities, assets (including both material and social resources), and activities necessary for sustaining one's means of living. A sustainable livelihood can withstand and recover from external pressures and unexpected events, while also preserving or improving its resources and abilities, without depleting the natural environment (Chambers and Conway, 1992). This study adhered to the DFID livelihood framework, which provides a conceptual and theoretical foundation (Fig. 1).

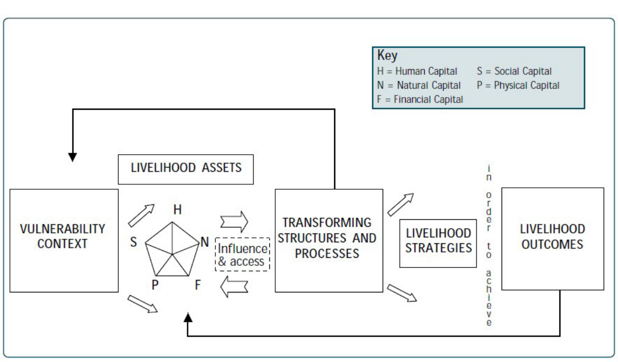

Fig. 1. Conceptual framework of the study (Source: DFID2000)

The study commenced by examining the vulnerability background of the sector, which has been influenced by both natural forces and the demands of modernization. An analysis is conducted to examine the periodic weather patterns that influence the lives of individuals who depend on the fishing industry, focusing on trends, seasonality, catch quantity and economic returns. In time series analysis, our initial approach involved data aggregation and the management of missing values. We then focused on addressing the original, trend, and seasonality components using the seasonal decomposition method. The stationarity check and transformation test involved conducting the Augmented Dickey-Fuller (ADF) test, applying the Box-Cox Transformation, and performing differencing. Two processes were carried out in the Autocorrelation study. The Autocorrelation Function (ACF) Plot and Partial Autocorrelation Function (PACF) Plot will be provided in detail in the appendix and the number of samples selected cruise explained in Table 1.

Using descriptive statistics, the mean revenue and operational expenditures, as well as the intricate components of indirect expenses (auction fees, trip and gasoline outlay, and ration expenditures) were examined. The seasonal Autoregressive Integrated Moving Average (SARIMA) model was used for analyzing time series data, on trends in fish harvest, pricing, and other critical variables across time due to its ability to handle seasonal swings and non-stationarity in time series data. The study area is shown in Fig. 2.

Table 1. Number of fishing cruises undertaken by modified artisanal mechanized fishing units operating large ring seines along central Kerala

Year	Monsoon	Post Monsoon	Pre-Monsoon	Year wise Total
2010	3	–	–	3
2011	83	15	6	104
2012	155	116	34	305
2013	139	69	133	341
2014	62	45	9	116
2015	57	9	24	90
2016	27	32	17	76
2017	65	49	61	175
2018	81	64	15	160
2019	74	82	25	181
2020	69	51	19	139
2021	71	43	13	127
2022	93	68	22	183
Season wise Total	979	643	378	2000

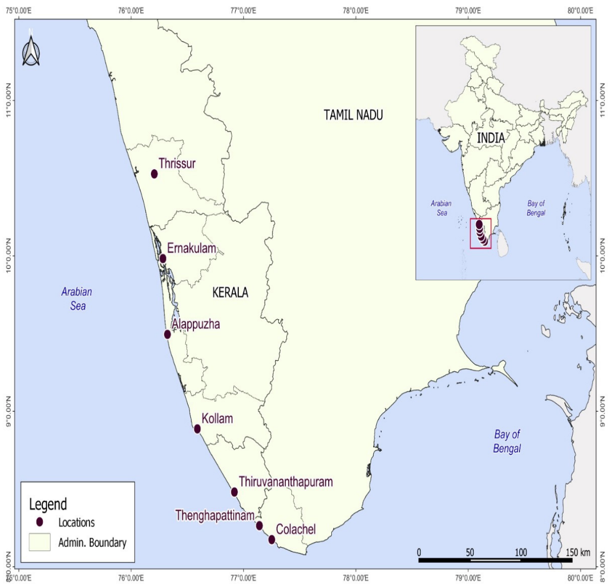

Fig. 2. Study area

Results and discussion

Vulnerability Context

An overview of marine fisheries in Kerala reveals that before the early 1960s, artisanal fisher in the region relied on non-mechanized techniques to fish within its territorial waters. This limited their ability to capture and supply sufficient quantities of fish to satisfy the increasing demand in international markets. The mechanization of Indian fisheries began in 1954 with the implementation of the Indo-Norwegian project in the state of Kerala (Kurien, 1985; Pillai and Katiha, 2004). Initially, the first-generation mechanized boats were primarily used for gill net fishing, although trawling and purse-seine fishing gained popularity at a later stage. The traditional fishing crafts were upgraded by installing outboard engines over the years enabling the expansion and endurance of their operations. During the later part of the 1980s, artisanal fisher significantly increased their fishing activities by employing enormous ring seines, a type of net similar to purse seines, to exploit pelagic resources. The motorized industry by 1988, emerged as the dominant sector. Consequently, a motorized sector was introduced alongside the existing mechanized sector, while the remaining sector remained non-mechanized and indigenous. In the 1990s, mechanized marine fisheries experienced increased technological advancements. Artisanal fishers transitioned from using outboard motors to installing internal engines. Mechanized trawlers redefined their fishing areas and enhanced fishing vessel endurance to 11-14 days by increasing vessel size, engine horsepower, fuel, freshwater storage, and fish hold capacity. Advanced navigation and communication devices, such as eco-sounders, wireless technology, and GPS were also utilized to improve the efficiency of fishing vessels.

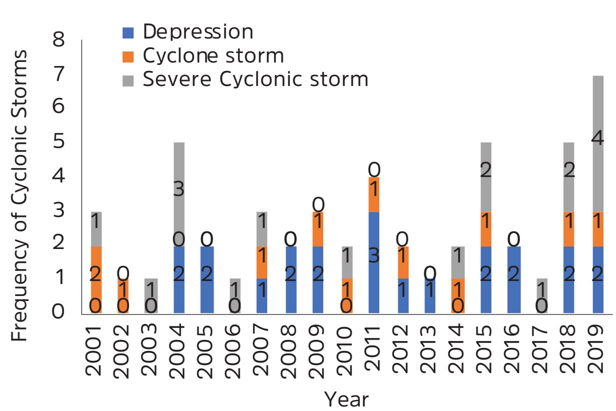

Fig. 3. Depression, Cyclonic storm and Severe Cyclonic storm in Arabian Sea

The vulnerability context focused on natural hazards and the increasing frequency of cyclogenesis in the eastern Arabian Sea, which poses several issues in the fishing sector. The cyclones provide a substantial hazard to the densely inhabited fishing communities of the Indian peninsula due to the combination of powerful winds, intense rainfall, and storm surges. Tropical cyclones generally form over tropical ocean basins where the sea surface temperatures (SST) are higher than 26 degrees Celsius (Gray, 1979). Cyclogenesis in the North Indian Ocean (NIO) commonly occurs during the pre-monsoon (March to May) and post-monsoon (October to December) seasons. The presence of substantial vertical wind shear prevents the low-pressure systems that form during the southwest monsoon season (June-September) from strengthening and transforming into cyclonic storms (Xavier and Joseph, 2000). According to a recent study by Sahoo and Bhaskaran (2016), it has been found that the Bay of Bengal (BOB) usually experiences an average of 4 cyclones per year, but the Arabian Sea (AS) typically creates 1-2 cyclones annually (Fig. 3). Over the past few years, there has been a notable surge in the frequency of tropical cyclones (TCs) in the Arabian Sea (ARB) due to faster-than-average warming. The changes in the vertical thermal structure of the atmosphere and water above the Arabian Sea, as seen in recent decades (Abhiram *et al*., 2023), are responsible for this phenomenon. A new study has found that changes in the warming patterns of the ocean and atmosphere are causing a rise in the intensity of cyclones in the Eastern Arabian Sea, which is situated adjacent to India's densely populated west coast. Tropical cyclones in the Arabian Sea are prevalent during the pre-monsoon period, spanning from March to June, and the post-monsoon period, from October to December. Recent data shows a significant increase in the average number of cyclones, which has risen to 2-3 during the past two decades.

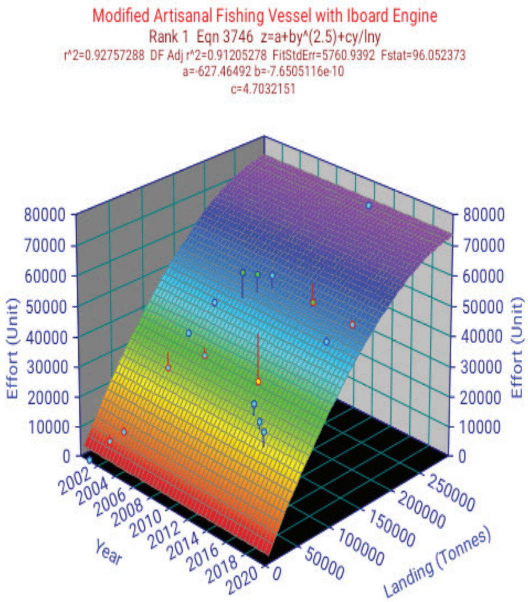

Fig. 4. Catch per unit effort and landings of modified artisanal mechanized fishing units operating large ring seines along the central Kerala

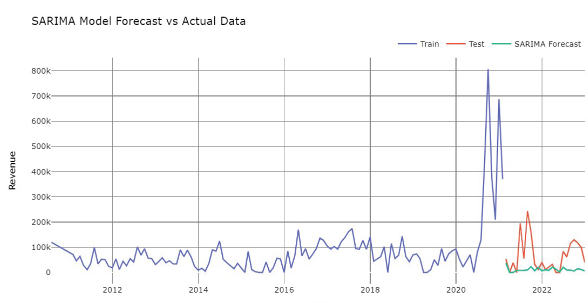

Fig. 5. SARIMA model forecast plot of modified artisanal fishing vessel with large ring seine

Abhiram *et al.* (2023) have provided evidence that there has been a noticeable rise in both the occurrence and strength of cyclonic systems in the past several decades. Hence, the recent surge in cyclone occurrences along India's western coastline calls for the adoption of development strategies that take into account the hazards linked to a changing climate and weather patterns.

The prevalence of modified artisanal fisheries and ring seine, which primarily target sardines and mackerel as well as prawns in Kerala. The depiction of the Catch Per Unit Effort (CPUE) (Fig. 4) exhibits variations in the year, reaching its highest point in 2011 and subsequently seeing a gradual decline. CPUE The positive trajectory shown until 2011 may imply enhanced efficacy or ample fish populations, whereas the subsequent decline might reflect overexploitation, diminished fish stocks, or alterations in fishing methodologies. The trend line serves to emphasize the temporal fluctuations. The null hypothesis suggested that there is no significant correlation between landing and effort, while the alternative hypothesis implied that either b or c is not equal to zero, implying a substantial association between landing and effort. The statistical measurements are as follows: r^2, which indicates a high level of model fit; adjusted r^2, which confirms the strong fit after accounting for the number of predictors; Fit Standard Error, which is relatively high; and F-statistic, which indicates that the model is statistically significant (Fig. 5). Based on the substantial r^2 value and the significant F-statistic, we reject the null hypothesis and support the alternative hypothesis. The analysis determined that the nonlinear regression model exhibits a robust fit to the data, effectively accounting for a significant amount of the variability in the dependent variable. Nevertheless, the elevated fit standard error indicates significant fluctuation in the predictions, implying the possible impact of additional unconsidered elements. The seasonal variation in landings of artisanal modified fishing vessels in Kerala is being affected by the scarcity of sardines.

Analysis of capital

An upgraded artisanal fishing vessel equipped with a large ring seine was inaugurated at Cochin fisheries harbor in Kerala in the year 1998. The average total length of a fishing vessel at that period was approximately 13-14 m, specifically referring to the technologically enhanced "*thanghuvallam*". After a decade of expertise, the physical structure of the vessel transformed from a canoe to a transom canoe design, measuring over 20 m in length and featuring a substantial "*aniyam*". A significant transformation in the hull material involves transitioning from wood to steel, requiring an average cost of 40 lakh rupees. The average gross tonnage of the vessel has increased from 20 to 45 due to the replacement of the 150 HP Ashok Leyland engine with a 450 HP Chinese engine. These engines, which cost 20 lakh rupees, are now frequently used in pelagic fisheries. Medium-sized ring seines are employed during the initial phase of technical intensification, resulting in a 10-ton increase in tonnage and requiring a 25-ton investment, equivalent to 30 lakh rupees. The human capital of the modified artisanal fishing vessel consists of key individuals such as the Leader, Treasurer, Aryakkaran, Srank, Chattakkar, Vallakkallikar, Career canoe cooperator, Auctioneer, Tharakan, Local money lender, Cook, Vellakkaran, and the core team of the group, along with other fisher. A leader is a crucial team member who organizes and guides a fishing group, coordinating and mobilizing all resources in a unified manner. The appointed leader in the meeting is primarily responsible for the allocation of finances, facilitating communication

Table 2. Average Financial Capital of Modified Artisanal Marine Ring Seine Fisheries in Kerala period 2010-2022

Economic Indicators	Monsoon	Post Monsoon	Pre-Monsoon	Average
Fuel Charge	13071.42	11211.14	10125.80	11916.62
Travel Charge	2037.66	2075.73	1782.56	2001.68
Auction commission	5089.42	4009.72	2535.70	4259.64
Ration food charge	1256.40	1346.13	1532.12	1337.36
Average share of fisher	46060.06	37312.08	24364.49	39147.12
Average share per fisher	1068.43	900.88	559.66	918.40
Average share of craft and gear	46340.86	35833.68	9630.62	36024.57
Average total operating cost	73907.63	61796.24	48202.82	65155.61
Average revenue	101788.32	80194.34	50713.97	85192.80
Average gross profit	73940.75	55710.18	26875.63	59184.31

Source: Analysis of account book of ring seine fishing unit

between intermediaries (*tharakan*), officials from the fisheries department, and primary producers' group, and ensuring the upkeep of fishing equipment. Another significant individual is the Treasurer, responsible for maintaining financial records and presenting the income and spending summary during the Sunday meeting. The core team is an accountable executive body responsible for collecting required contributions (ranging from 1 to 2 lakh) from members of the fishing group, which typically consists of 10 to 20 individuals.

The social capital of fisheries is characterized as KFDWCS, which stands for community sharing, artisanal fisher union, trust, information and network, livelihood sharing mechanism, the notion of shared property, social opportunity fishing, and *kadamkuri* informal money saving scheme. One of the most observable processes is the local practice of livelihood sharing, commonly referred to as "*Ponthipidutham*". The mechanism of income spreading in fisheries was previously discussed by Kurien and Vijayan (1995) and Kurien (2000). *Ponthipidutham* refers to a system of community livelihood sharing that is commonly practised among ring seine fishers, particularly in the Ernakulam region. This section focuses on the livelihood-sharing system of ring seine fisheries. During the operation of ring seine, another fishing unit of a lower or similar kind will assist in arranging the floats (ponthi) for fishing. This fishing unit will also receive a portion of the catch. This is referred to as *ponthipidutham*. This is also a form of livelihood stability for other fisher as well. John Kurien's 1995 study provides a scientific explanation of the income-spreading mechanism in fisheries. This is an alternative approach to sharing livelihoods in the fisheries industry. The concept of property is ubiquitous and belongs to everyone. Community regulations, particularly self-organizing regulations, are implemented to safeguard fishery resources (Baiju *et al.*, 2022). Table 2 shows the average financial capital of modified artisanal marine ring seine fisheries in Kerala from 2010 to 2022.

Climate variability

The coastal communities are more vulnerable, especially those whose incomes are low, food resources are limited and people have no alternative options for occupation and food. Large-scale changes in the climate can pose a serious threat to both the marine ecosystem and coastal livelihood which depends on marine resources. Linking the climate-induced stress factors and their response to the marine ecosystems is challenging mainly due to the complex infractions between the physical and bio-geo-chemical processes involved. We attempted to investigate the seasonal variability of environmental parameters like Sea Surface Temperature (SST), salinity, wind, and currents using multi-satellite derived merged Chlorophyll for 1998-2013 as a proxy to marine productivity and evaluated its seasonal evolution and analyzed its link to other physical parameters. The spatial trend analysis of SST, wind and Chlorophyll showed large spatial variability. Though it exhibits a general decreasing trend over most of the NIO region, there exist small pockets where the chlorophyll trend is positive, which is an indication of increased productivity and may be linked to the shifting pattern of marine primary productivity in response to the changing pattern of climate parameters like wind and SST. A decreasing trend was persistent near the coast, which may indicate an expansion of eutrophication from the coast to the deep sea. The decreasing trend in Chlorophyll off the southwest coast is primarily driven by decreasing wind speed along with a decreasing trend in the upwelling favourable wind and surface currents. The increasing trend in SST along the coast might have also contributed to the decreasing trend in Chlorophyll near the coastal region mainly by increasing the stability in the upper layers of ocean water, which limits the vertical mixing in the ocean and blocks the supply of nutrients to top layers of ocean water. Further to explore the linkage of climate change forcing to Oxygen minimum zone (OMZ) and stability, marine pollution and

Table 3. Estimated loss in number of fishing days and revenue due to adverse weather induced fishing ban among modified traditional (inboard engine) large ring seine fishing units in Kerala *(*464 inboard vessels registered in Kerala 2014, Department of Fisheries, Government of Kerala.)*

Year	Adverse weather warning days	Loss of cruise	Loss of average Fishing man-days	Loss of average per fisher share (In Lakh)	Loss of average share of craft and gear (In crore)	Loss of average gross profit share (Crore)
2018	123	57072	2282880	19838.2	238.858	334.676
2019	60	27376	1095040	9494	97.5681	126.806
2020	94	43616	1744640	43755.6	680.833	997.69
2021	84	39440	1577600	13551.6	188.156	269.513

Source: Estimated primary survey

availability of photosynthetically active visible light source in the ocean, changing pattern of upwelling favourable wind and wind stress in more detail. Table 3 shows the estimated loss in the number of fishing days and revenue due to adverse weather-induced fishing bans among modified traditional large ring seine fishing units in Kerala. It indicates that there were 123 ban days in 2018, while the minimum number of ban days recorded was 59 in 2019. The fishing cruise loss in the year 2018 reached its peak at 57,072, according to the official records of the Fisheries Department, Government of Kerala. In contrast, the least cruise loss occurred in 2019, with a recorded loss of 27,376, as per the registered vessel data of 2014. The number of fishing man-days lost in ring seine fisheries for the typical fisherman was 40 in total, amounting to 2,282,880 in the year 2018. In 2019, the lowest number of fishing man-days lost was 1,095,040. It also represented the proportion of fisher's share in other economic variables, such as the share of boats and gear, as well as the share of profits. Ring Seine fishing is a single-day fishing method that takes place from early morning to dusk, without the use of ice storage. The movement of ring seine fishing within the boundaries of a state's jurisdiction. The decision regarding the cruise will be based on factors such as weather conditions, roughness of the sea, and wind speed. The *Aryakkaran* of ring seine fishing boats in Kerala possesses indigenous wisdom that allows them to foresee fishing weather conditions. The micro-level weather factors have an impact on ring seine fisheries. Therefore, it is recommended that the Kerala State Disaster Management Authority (KSDMA) and the Government of Kerala address the issue of weather-related fishing bans seriously, especially if the main concern is the livelihood of those involved in marine fisheries in Kerala.

Time series analysis

The process of identifying model parameters commenced by utilizing the auto ARIMA function from the pmdarima package. This tool automated the process of selecting ARIMA models by iteratively exploring various combinations of parameters. The function was configured to investigate an extensive array of parameters, including start p, start q, max p, max q, m, start P, start Q, max P, and max Q, to determine the optimal combination for the SARIMA model. The variables p and q denote the magnitude of the autoregressive and moving average components in the non-seasonal section of the model, respectively. Similarly, the variables P and Q reflect the magnitude of the seasonal component. To account for the seasonal patterns in the fisheries revenue data, the model was configured to include seasonal components (seasonal=True). The number m=12 signifies a yearlong seasonal cycle, which is appropriate for capturing annual patterns in fisheries earnings. The auto ARIMA function determined that the SARIMA (4, 1, 4) (3, 0, 2) [12] model had the lowest Akaike Information Criterion (AIC) value during the process of model fitting. A lower AIC value suggests a model that achieves a better trade-off between goodness of fit and simplicity. The SARIMA model was defined using the identified parameters. The non-seasonal component of the model (4,1,4) indicates that the revenue data needed to be differenced once (d=1) to achieve stationarity. Additionally, it consisted of four autoregressive terms and four moving average terms. The model's seasonal component (3,0, 2) [12] suggests that no seasonal differencing was required because the model includes three seasonal autoregressive terms and two seasonal moving average terms. The SARIMA model was applied to the dataset that has been both converted and differenced. While conducting the fitting process, a convergence alert was observed, suggesting possible complications in the optimization procedure. This may be attributed to the intricacy of the model or idiosyncrasies in the data. The SARIMA model forecast plot of a modified artisanal fishing vessel with a large ring seine is given in Fig. 6.

In the SARIMA forecast Fig. 5, the training data (shown by the blue line) corresponds to the historical data used to train the SARIMA model. It displays the current recorded revenues until a specific moment in time. The Test Data (Red Line) corresponds to the factual revenues that were not part of the training data and were employed to evaluate the forecasting ability of the model. The SARIMA Forecast (Green Line) displays the projected revenue numbers derived from the SARIMA model. Fig. 5 provides the following observations: The training data exhibits periodic variations and potentially some seasonal patterns, which the SARIMA model aims to capture. The test data exhibits a notable surge in early 2020, which was not anticipated by the model. This occurrence may be classified as an outlier or an unforeseen event that the model failed to predict using historical data. If the sudden increase is attributed to a singular occurrence or an irregularity (such as an unaccounted external influence), it could elucidate why the SARIMA model failed to capture it. The SARIMA forecast aligns with the overall trend of the historical data but fails to capture the significant fluctuations observed in the test data. These findings indicate that the model might not accurately represent all of the fluctuations in the time series, including unexpected disruptions or significant changes in structure. The model suggests a stable future trend, implying that significant fluctuations in revenue are not anticipated based on the past data.

The interpretation of the outcomes of the model summary and specification explanation is provided. The notation SARIMAX (4, 1, 4)x(3, 0, 2, 12) represents a model known as Seasonal Autoregressive Integrated Moving Average with exogenous components. The non-seasonal component of the model has an autoregressive order of 4, a differencing order of 1, and a moving average order of 4. The seasonal component has an autoregressive order of 3, no differencing, and moving average orders at lags 1 and 2, with a seasonal period of 12. Regression coefficients and statistical significance The AR and MA coefficients denote the autoregressive and moving average parameters, respectively. The values and standard errors of these metrics serve as indicators of their strength and reliability. For example, the variable L1 has a coefficient of -0.5549 and a p-value of 0.033, indicating that it is a statistically significant predictor. The column labelled P>|z| displays the p-values corresponding to each coefficient. A p-value below the threshold of 0.05 implies that the coefficient

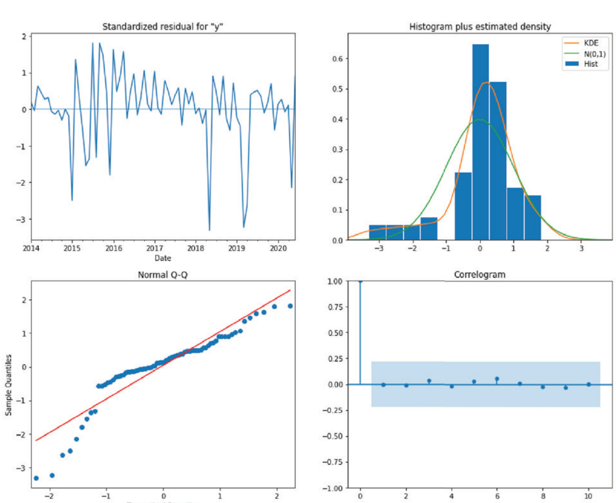

Fig. 6. Model Diagnostic Plot of modified artisanal fishing vessel with large ring seine

is statistically significant and makes a meaningful contribution to the model. Model fit statistics encompass Log Likelihood, AIC (Akaike Information Criterion), BIC (Bayesian Information Criterion), and HQIC (Hannan- Quinn Information Criterion), which serve as measurements of model fit. Smaller values typically suggest a more optimal match. Nevertheless, these indicators should be employed comparably. Comparing several models provides more informative insights than analyzing them individually.

Model diagnostics employ four methods, with the first being the Ljung-Box Test (Q), which assesses the presence of a lack of fit. A p-value that is near to 1 indicates that the residuals are independent, which is a positive indication. The Jarque-Bera Test (JB) is used as a second step to assess the normalcy of the residuals. A low p-value suggests that the residuals do not follow a normal distribution, which could be problematic. The Heteroskedasticity Test (H) examines whether the residuals' variance remains consistent throughout time. A high p-value indicates the absence of heteroskedasticity. Skewness and kurtosis offer insights into the distribution of residuals. Skewness measures the degree of asymmetry in a distribution, while kurtosis measures the degree of peakedness. Skewness values deviating from 0 and kurtosis values deviating from 3 (in the case of a normal distribution) indicate deviations from normalcy. Regarding the model's prediction performance in Performance Metrics, the accuracy metrics portrayed a pretty discouraging scenario. The elevated Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) values indicate that the model's predictions deviated significantly from the actual data. The Mean Percentage Error (MPE) and Mean Absolute Percentage Error (MAPE) had remarkably high values, suggesting substantial mistakes in terms of percentages. Moreover, the model's weak predictive performance was highlighted by the low correlation coefficient between observed and anticipated values. The model's deficiencies were evident from the extremely high Min Max Error and the negative MAPA (Accuracy %) score, which served as additional clues.

The standardized residuals plot is used in diagnostic plots. Fig. 6 displayed the standardized residuals over the observed timeframe. Optimally, a random dispersion of residuals centred around the zero line is preferred, suggesting that the model has accurately captured the intrinsic structure of the data, leaving only random variations. The Histogram and Estimated Density Plot diagnostic tool compares the histogram of standardized residuals with a kernel density estimate and a normal distribution curve for study and comparison. A Normal Q-Q Plot is used to determine whether the residuals adhere to a normal distribution. This plot compares the distribution of residuals with a theoretical normal distribution. A correlogram, also known as an ACF plot, is used to analyze the autocorrelation present in the residuals. An ideal model would display negligible autocorrelations, which would be contained within the confidence intervals.

The coefficients of the model, especially those with low p-values, indicate the presence of significant temporal patterns that are represented by the model. The diagnostic tests reveal that although the model well represents the time series pattern, there are doubts regarding the normality of the residuals. The performance indicators indicate a moderate degree of predictive inaccuracy. The diagnostic graphs indicate that the SARIMA model fits the data rather well. Nevertheless, the presence of non-normality in the residuals, which could be attributed to outliers or extreme values, necessitates additional scrutiny. In general, the SARIMAX model seems to accurately represent the fundamental patterns of the time series data, although there are indicators that the model may not be entirely adequate. These data indicate that although the model is satisfactory as a starting point, additional improvement or investigation of alternative models could be advantageous Fig. 6 shows the Model Diagnostic Plot of the modified artisanal fishing vessel with large ring seine.

Conclusion

The artisanal fishing sector in Kerala is highly vulnerable to climate unpredictability and economic problems, which significantly impact its resilience. The seasonal variability highlighted the crucial influence of seasonal elements on the operational dynamics of the industry. Seasonal patterns have a substantial impact on both revenue generation and cost structures, with noticeable variations found between the Monsoon, Post-Monsoon, and Pre-Monsoon seasons. The comprehensive financial study unveiled an intricate relationship between costs and income, characterized by significant swings across the years. The sector's economic vitality is demonstrated by its profitability, as evidenced by the average profit shares and net profit shares, despite the hurdles it faces. The lack of diversity in artisanal pelagic fisheries and the absence of new species in fishing are significant issues in the fishery sector. The creation of a marine fisheries disaster policy can be vital in Kerala.

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