Chapter

Forecasting Shrimp and Fish Catch in Chilika Lake over Time Series Analysis

Rohan Kumar Raman and Basanta Kumar Das

Abstract

Chilika lagoon (a Ramsar site) is a large source of fish production and biodiversity situated in the east coast of India, Odisha. Shrimp landings contribute an average of 4185 MT (Metric Ton) around 35% of total fish production. In this study, SARIMA (Seasonal Auto Regressive Integrated Moving Average) model has been developed on quarterly time series shrimp catch data during the year 2001–2015 and forecasted up to 2018. The best model was selected on Akaike Information Criteria (AIC) and Bayesian Information Criterion (SBC). Results showed that maximum average shrimp landings were observed in the first quarter period (summer season), whereas maximum variation in catch was observed during second quarter Q2 (monsoon season) and lowest variation in the fourth quarter Q4 (winter season) catch during the year 2001–2015. The developed time series SARIMA $(0,1,1)(0,1,1)_4$ model was found to be the best fitted model for the shrimp landings in the lagoon. This article also delineates the application of SARIMAX model (SARIMA with regressors) using monthly catch prediction of fisheries in the Chilika Lake. The developed model is validated with less than 10% errors showing increasing fish catch in the upcoming years by maintaining the present lake condition.

Keywords: Chilika, shrimp, fisheries, time series, forecasting

1. Introduction

Coastal lagoon is a junction of fresh, brackish, and marine water system and known for its large fish species production and diversity among aquatic ecosystem [1, 2]. The fresh and saline water combination makes it more liable for attracting different finfish and shellfish species in the aquatic ecosystem. The Chilika lake (lagoon) (a Ramsar site of International importance) is the largest brackish water lagoon in the eastern coast of India situated between latitude 19°20′13.06″–19° 54′47.02″ N to longitude 85°06′49.15″–85°35′32.87″ E in the humid tropical climatic zone in the state of Odisha, India (**Figure 1**). The lagoon is composed of fresh, brackish and marine water ecosystems and divided into outer channel, central sector, northern sector and southern sector. The lagoon is a rich source of fisheries production and biodiversity, which harbours more than 29 species of shrimp from 8 families [3], providing livelihood around 0.2 million people around it. Fisheries resources in Chilika lake account more than 71% total valuation of the lake ecosystem [4]. The lake has been supporting around 200 million rupees to the state economy and contributing to the earning of valuable foreign exchange. However, continued natural changes and unabated anthropogenic pressure fisheries suffered the most in terms of both yield and biodiversity in the last two decades [5]. Before restoration (opening of the new lake mouth, year 2000–2001) of the lagoon, the *Penaeid prawns'* population decreases due to the failure in breeding as the lake mouth was shifted far (about 30 Km) from the lake proper, and the confluence point of outer channel (recruitment route) at Magarmukh was silt-choked [5]. Average fisheries catch increased around 520% after four years of new lake mouth opening in 2000. Northern sector was found to have maximum catch percentage of total catch followed by central sector, southern sector and outer channel. The commercial fish catch of the lagoon is composed of 12 fish groups namely mullets, clupeoides, perches, threadfins, crockers, beloniformes, catfishes, tripod fishes, cichlids, murrels, featherbacks and others. After the opening of new lake mouth and desiltation of outer channel, the salinity of the lake increases due to high intake of sea water, resulting favourable for effective recruitment of all economic fishes except cichlids. Shrimp production individually contributed 35% of total fish production in the Chilika lagoon. Some dominating shrimps are *Fenneropenaeus indicus, Penaeus monodon*, *Metapenaeus dobsoni*, *Metapenaeus monoceros,* etc. in the lagoon. The annual landings of shrimp species fluctuated between 2347.78 Metric Ton (MT) and 6413.78 (MT) during last 15 years (2001–2015) in this lagoon after the opening of new lake mouth. Quarter wise shrimp landings fluctuated between 82.55 (MT) and 745.55 (MT) during the period 2001–2015 in the lagoon. To support the prediction of shrimp catch landing in the lagoon, domain specialists need to develop the forecasting models over time series analysis. Time series data are a sequence of data which are collected at successive equally spaced time interval, and it depends on its past value. Time series analysis built stochastic models based on time correlations of collected data. The main objective of time series analysis in respect to the fishery fields is to describe the underlying structure using input data to provide short-term

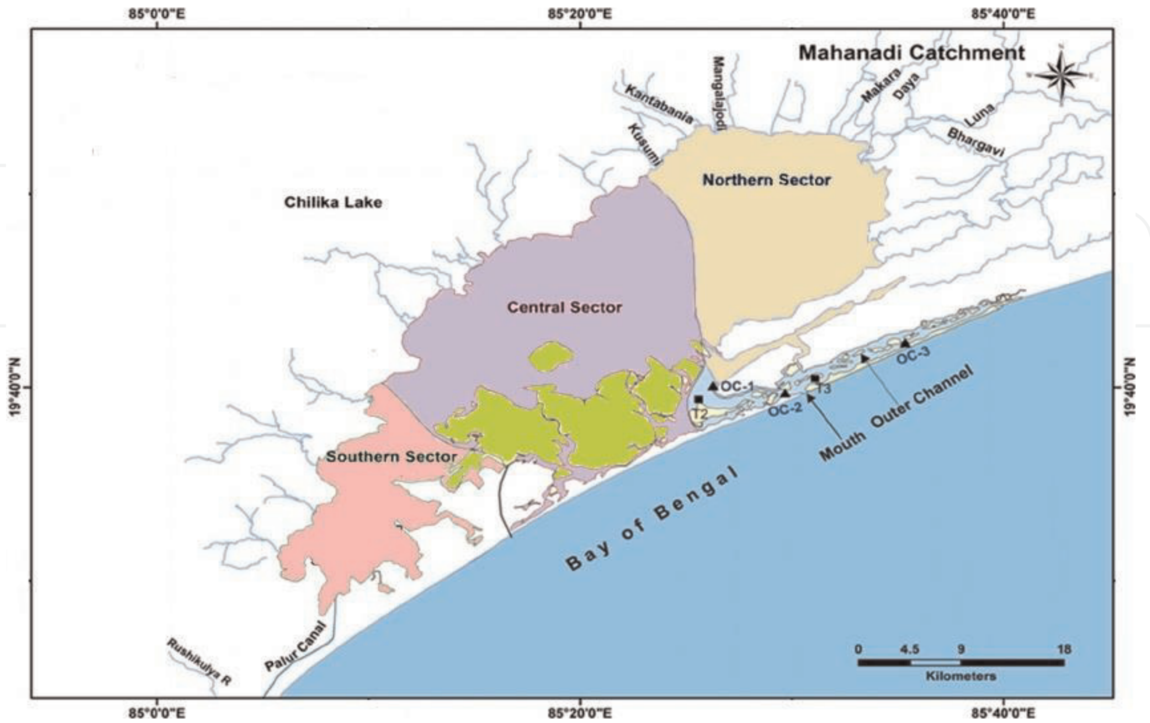

Figure 1.
Map of Chilika lagoon (lake) consisting four ecological sectors (outer channel, central sector, northern sector and southern sector) (Source: [14]).

forecasts of the output variables of a dynamic system [6]. Very well-known Box Jenkin's [7] Auto Regressive Integrated Moving Average (ARIMA) model is used to analyse and forecast the univariate time series data. SARIMA model is composed of ARIMA model including seasonal component of the time series data and very frequently used for time series modelling. Applications of ARIMA and SARIMA models were used to analyse and forecast fisheries data [12–14]; illustration on catch and effort data for the skipjack tuna fleet at Hawaii [8], Saila [9] modelled on monthly average catch per day of rock lobster, Sathianandan and Srinath [10] modelled of all India marine fish landings using ARIMA model, while NunoPrista et al. [11] described the application of SARIMA models for data-poor fisheries with a case study on sciaenid fishery of Portugal. Modelling and forecasting of marine fish production in Odisha, India, using the SARIMA Model [12].

When exogenous variable is included in the ARIMA model, it is known as ARIMAX model. Similarly, SARIMAX model is developed using well-known seasonal ARIMA model with external regressors associated with the time series data. SARIMAX model performs with better accuracy in fish catch prediction than the SARIMA model with minimum error variance [14]. However, the environmental factors' influence as a regressor in the time series ARIMA (SARIMA) model could be quantified by identifying the underlying patterns in periodic time series data using ARIMAX (SARIMAX) model. The influence of water quality parameters of Chilika lake on monthly catch of commercial fisheries (Beloniformes: order) and total fisheries of the lake was modelled using SARIMAX modelling approach [13, 14]. In this case study, SARIMA model for modelling and forecasting the 15 years quarterly time series shrimp catch data of Chilika lagoon of post restoration period since 2001 was developed as case study and further using this model to forecast shrimp catch landings up to 2018. Very few studies have been conducted based on time series model based forecasting of fish species in general and shrimp in particular of Chilika lagoon. The aim of this study is to develop the best fitted time series forecasting model for shrimp landing in Chilika lagoon and further model based catch forecast up to the period 2018. Since catch prediction in advance would be necessary for appropriate planning and designing of the national fishery development plan for sustainable exploitation of fisheries of the said water bodies, this shrimp forecasting study in the Chilika lagoon will be immensely useful in decision making for the policy makers and lagoon managers for sustainable fisheries production and management. In this chapter, a case study of shrimp prediction model using quarterly time series data of the Chilika lagoon was developed, and further prediction model of fisheries and commercial fish (Beloniformes: order) in the Chilika lagoon was also discussed.

2. Materials and methods

2.1 Study area

Chilika Lagoon (**Figure 1**) water spread area fluctuates between monsoon and dry season at maximum of 1165 km^2 to minimum of 906 km^2, respectively [15, 16]. The water quality of lagoon is influenced by the influx of sea water from West Bengal, Mahanadi distributaries and from the western catchment rivers. The lagoon is an assemblage of shallow to very shallow marine, brackish and freshwater ecosystems [15] characterised by the lagoon with marine, brackish and freshwater fisheries. Shrimp landing plays a significant contributor in commercial landings after the opening of new lagoon mouth as a part of hydrological intervention for eco-restoration of the lake in September 2000.

2.2 Sample data collection

The quarter wise estimated total shrimp catch (MT) data and monthly total fish catch (MT) data along with physicochemical parameters of water quality [14] of the Chilika lagoon for the period April 2001 to March 2015 were collected from Chilika Development Authority (CDA). The systematic random sampling methods with landing centre approach [17–19] modified with site-specific conditions followed on monthly basis were used to catch estimation in Chilika lagoon. In this study, quarter wise (seasons) catch of the shrimp was taken; such as first quarter (Q1) consists of March, April and May months together (summer season); second quarter (Q2) consists of June, July and August months (monsoon season); third quarter (Q3) consists of September, October and November months (post monsoon season) and fourth quarter (Q4) consists of December, January and February months (winter season). This quarter wise shrimp catch and total fish catch data for the period 2001 to 2015 of the Chilika lagoon were used for the development of SARIMA time series prediction modelling, and SARIMAX model has been described using monthly total fish catch data with the physicochemical parameters of water quality of the lagoon [14].

2.3 Resource distribution mapping

Annual shrimp catch distribution mapping at 5-year interval is presented using ArcGIS version 9 software.

2.3.1 SARIMA and SARIMAX model development

ARIMA model is developed on stationary data, but very few data sets in the fisheries field are found to be stationary in nature. It becomes mandatory to test the time series data sets for stationarity before using for modelling. Augmented Dickey-Fuller [20, 21] (ADF) test used to test stationary of the original time series data. If data were found to be nonstationary, then it is made stationary by transformation procedure. Stationary time series data were further used for SARIMA model development. SARIMA model was developed by Box-Jenkins [7] Seasonal Auto Regressive Integrated Moving Average (SARIMA) model for seasonal quarterly time series data following four steps as model identification, parameter estimation and model validation (diagnostic checking) and finally forecasting by the following methodology:

SARIMA model defined as ARIMA with seasonal parameters denoted as ARIMA (p,d,q) (P,D,Q) s,

where p = auto regression (AR) order, d = differencing order, q = moving average order, P = seasonal AR order, D = seasonal differencing order, Q = seasonal MA order and s is seasonality using the back shift operator B (the operator B is such that $Bz_t = z_{t-1}$) is expressed as,

$$\varphi(B^s)\phi(B)\nabla^d\nabla_s^D z_t = \Theta(B^s)\theta(B)\varepsilon_t \quad (1)$$

where,

$$\begin{aligned}
&\nabla = 1 - B \\
&\nabla^s = 1 - B^s \\
&\phi(B) = 1 - \phi_1 B - \cdots - \phi_p B^p \\
&\theta(B) = 1 - \theta_1 B - \cdots - \theta_q B^q \\
&\varphi(B^s) = 1 - \varphi_1 B^s - \cdots - \varphi_P (B^s)^P \\
&\Theta(B^s) = 1 - \Theta_1 B^s - \cdots - \Theta_Q (B^s)^Q
\end{aligned}$$

Parameters of the model are
$\phi_1, \cdots, \phi_p, \theta_1, \cdots, \theta_q, \varphi_1, \cdots, \varphi_P, \Theta_1, \cdots, \Theta_Q$ and σ^2.
Now, SARIMA model for time series data y_t using Eq. (1) can be defined as;

$$y_t = \varphi(B^s)\phi(B)\nabla^d\nabla_s^D y_t + \Theta(B^s)\theta(B)\varepsilon_t \tag{2}$$

Moreover, the SARIMAX model (seasonal ARIMA with explanatory variable) can be represented as a time-series forecasting model using the multiple regressions with seasonal ARIMA model that takes care of the residual's serial correlations.

Further, SARIMAX model can be defined using Eq. (2) and regressors as follows;

$$y_t = \varphi(B^s)\phi(B)\nabla^d\nabla_s^D y_t + \Theta(B^s)\theta(B)\varepsilon_t + \beta x_t \tag{3}$$

Where, x_t is the input series at time t and β is the regression coefficients of the input series considering the assumptions of ARIMA and regression model together [22].

Here, the sequence $\varepsilon_t^{'}S$ is independently and identically distributed ($i.i.d$) random variable with zero mean and constant variance σ^2, which represents the error term in the model.

Model parameters estimation and its significance were performed using statistical software such as SAS, R, MATLAB, SPSS, etc. Generally 70% data sets were taken for model development and 30% data for model validation for long time series data, but one can change the percentage based on the data availability. Model development approach (a) model identification: model parameters are identified by investigating autocorrelation function (ACF) and partial auto correlation function (PACF) of the time series data (see [23] for more details); (b) parameter estimation: identified model parameters are estimated using various recursive statistical algorithms computation [23]; (c) model validation: inspection of residuals for no significant lags using ACF. The best model was selected based on model selection criteria and finally forecast is done data using best model for the given period of time. The known model selection criteria (minimum is better), such as Akaike [24], known as Akaike Information criterion (AIC), Bayesian Information Criterion proposed by Schwartz [25], known as SBC and R square fit statistics, RMSE (root mean square error), are used for identification of the best fitted model. The minimum is preferable criteria except R square (maximum) for identifying best selection model. Finally, the Ljung and Box [26] statistics Q based on the autocorrelations of the residuals were used for testing adequacy of estimated models. Finally, forecasting or prediction for the short term period is done based on best fitted model. For shrimp catch forecasting modelling, Quarter wise shrimp catch data for the period April, 2001 to March, 2013 was used for best model selection and estimation and the data April, 2014 and March, 2015 were used for validation of the model for Chilika lagoon. Further based on developed model, quarterly shrimp catch was forecasted up to 2018. Further SARIMAX model is described using monthly total fish catch data with the physicochemical parameters of water quality as a factor of regressor of the lagoon as regressors [14]. The total fish data sets for the period April 2001–-March 2011 were used for training data sets, and the period April 2011–March 2014 was used as testing and validation data sets for the model.

3. Results

The quarter wise shrimp catch landings (total, mean and standard deviation) of Chilika lagoon are shown in **Table 1**. The total catch in first quarter Q1 (7427.36)

Time (quarter)	Total catch (MT)	Mean catch (MT)	Std. (MT)
Q1	7427.36	495.15	126.61
Q2	7033.78	468.91	164.69
Q3	3216.19	214.41	84.03
Q4	3226.56	215.10	55.60

Table 1.
Quarter wise total, mean and standard deviation of shrimps landing in Chilika lagoon for the period 2001–2015.

was found to be maximum followed by second quarter Q2 landings (7033.78). The catch of third quarter Q3 (3216.19) and fourth quarter Q4 (3226.56) are nearly equal for the period 2001–2015. The quarterly average landings Q1 (495.15) are found to be more than Q2 (468.91), but the variation in catch in Q2 (164.69) is higher than Q1 (126.61). The mean catch of Q3 (214.41) is similar to that of Q4 (215.10), but the variation in catch in Q3 (84.03) is higher than Q4 (55.60). The variation in quarter wise shrimp catch data in Chilika lagoon was shown in **Figure 2**. Temporal variation using image mapping of the lagoon in **Figure 3** showed that catch increases in the first decade but decreases thereafter, and in 2015, catch was found comparatively low with respect to 2010–2012. The highest peak in catch was observed during 2011 and then starts decreasing till 2015 (**Figure 3**).

The best fitted SARIMA model was selected based on model selection criteria (AIC and SBC), and SARIMA $(0,1,1)(0,1,1)_4$ model with lowest AIC (509.23) and SBC (517.26) found the best fitted model **Table 2**. The parameter's estimate of best-fitted SARIMA $(0,1,1)(0,1,1)_4$ model in **Table 3** showed nonseasonal moving average (component) parameter Q at lag 1 (0.71, $p < 0.001$) and seasonal moving average parameter (0.78, $p < 0.001$) at lag 4 as significant effect in the developed model. Two catches of second quarter for the year 2005 and 2011 showed the significant outliers, and catch showed significantly increase during this period. The R^2 value 0.70 showed the good fit of the SARIMA $(0,1,1)(0,1,1)_4$ model. The residual of the developed SARIMA model was tested by Ljung, and Box test ($p > 0.05$) showed the adequacy of the fitting of the estimated models. The developed SARIMA model was validated with the actual shrimp catch data (**Table 4**). The annual catch prediction error for the developed model was found below 10%,

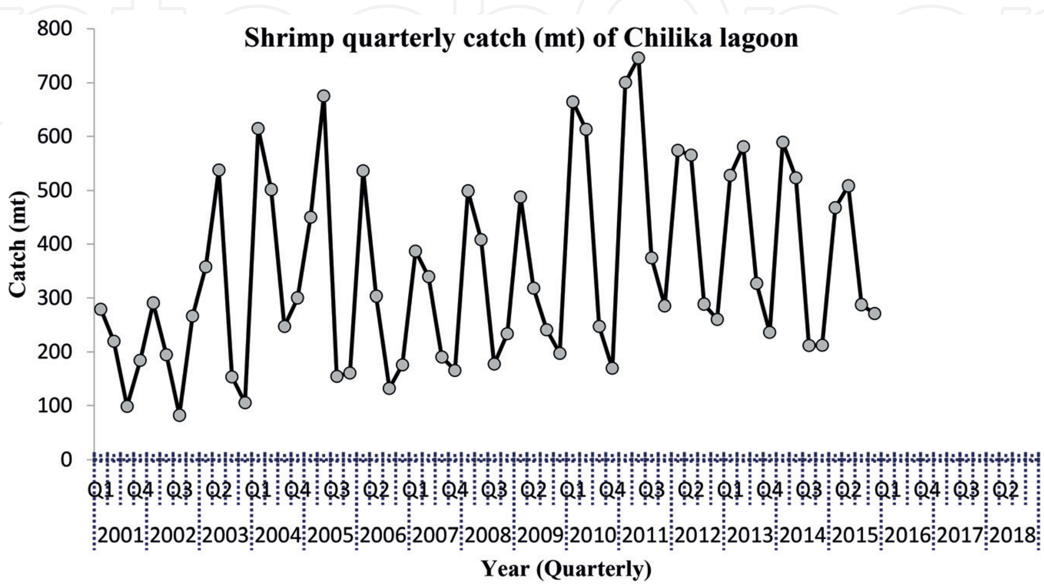

Figure 2.
Quarter wise shrimp catch (MT) in Chilika lagoon for the period 2001 to 2015.

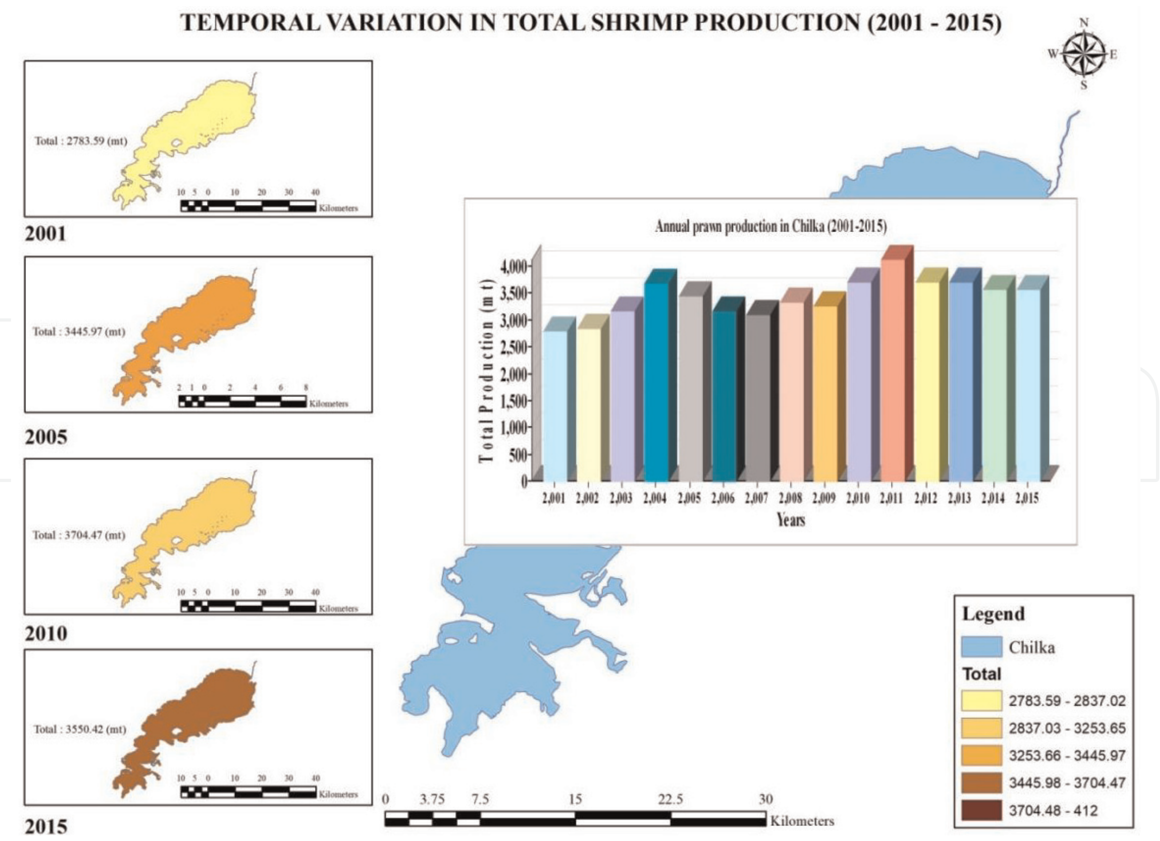

Figure 3.
Temporal variation of shrimp production of Chilika lagoon ecosystem from 2001 to 2015.

Sl. No.	SARIMA model	AIC	SBC
1	SARIMA(0,1,1)(0,1,1)$_4$	509.23	517.26
2	SARIMA(0,0,1)(1,1,1)$_4$	519.19	529.32
3	SARIMA(1,0,1)(1,1,1)$_4$	520.88	533.03
4	SARIMA(1,0,1)(1,0,1)$_4$	558.60	573.26
5	SARIMA(1,0,0)(1,1,1)$_4$	518.55	528.10
6	SARIMA(1,1,1)(1,0,0)$_4$	585.03	595.85
7	SARIMA(0,0,1)(0,1,1)$_4$	517.35	525.46
8	SARIMA(2,0,0)(1,1,1)$_4$	519.94	532.10

Table 2.
Comparisons of best fitted SARIMA model with fit statistics (AIC, SBC) for quarter wise shrimp landings in Chilika lagoon for the period 2001–2015.

Model parameter	Estimate	Std. Error	Prob>|T	Fit Statistics
Q (Lag 1)	0.71	0.11	<.0001	AIC = 509.23
q (Lag 4)	0.78	0.14	<.0001	SBC = 517.26
2011:Q2 (catch)	205.16	82.48	0.01	R^2 = 0.70
2005:Q2 (catch)	266.90	82.31	0.002	

Table 3.
Best fitted SARIMA (0,1,1)(0,1,1)$_4$ model parameter's estimate and their significance for quarter wise shrimp landings in Chilika lagoon for the period 2001–2015.

Year	Actual shrimp catch (MT)	Predicted shrimp catch (MT)	% error in catch prediction
2014	1536.418	1676.94	9.14
2015	1535.96	1520.201	1.02
2016		1605.134	4.5
2017		1627.088	5.9
2018		1649.041	7.36

Table 4.
Yearly actual versus predicted shrimp catch forecast with % prediction error using SARIMA $(0,1,1)(0,1,1)_4$ *model in Chilika lagoon for the year 2014–2018.*

e.g., for year 2014 (9.14%) and 2015 (1.02%). The percentage forecast error in shrimp catch for the year 2016, 2017, and 2018 was found to be 4.5, 5.9, and 7.36%, respectively (**Table 4**). The quarter wise forecast of shrimp catch for the period 2016–2018 with 95% upper and lower catch was shown in **Table 5**. The quarter wise actual catch versus predicted catch with 95% confidence limit of shrimp catch for the period of 2001 to 2018, showing an increase in catch with respect to 2015, is shown in **Figure 4**.

An application of SARIMAX model for total fish production forecasting is analysed for Chilika lagoon [14]. Mullets, clupeids, engraulids, perches, catfishes, sciaenids, threadfins, cichlids, tripod fishes, featherbacks, murrels, carps and

Year (quarterly)	Actual catch (MT)	Forecasted catch (MT)	Upper 95% catch (MT)	Lower 95% catch (MT)
2014(Q1)	589.113	604.435	795.914	412.956
2014(Q2)	522.827	546.637	738.091	355.183
2014(Q3)	211.991	310.37	501.812	118.929
2014(Q4)	212.487	215.502	436.937	94.0664
2015(Q1)	468.227	567.049	758.48	375.618
2015(Q2)	508.377	482.476	673.891	291.06
2015(Q3)	287.953	243.258	434.666	51.8502
2015(Q4)	271.403	227.418	418.822	36.0139
2016(Q1)		555.174	746.527	363.821
2016(Q2)		519.439	718.554	320.324
2016(Q3)		278.325	484.91	71.7396
2016(Q4)		252.196	465.991	38.4016
2017(Q1)		560.662	794.815	326.509
2017(Q2)		524.927	768.392	281.463
2017(Q3)		283.813	536.246	31.3805
2017(Q4)		257.685	518.778	93.4083
2018(Q1)		566.151	848.368	283.933
2018(Q2)		530.416	823.301	237.531
2018(Q3)		289.302	592.479	183.875
2018(Q4)		263.173	576.304	149.957

Table 5.
Quarter wise actual versus forecasted shrimps catch with upper 95% catch (MT) and lower 95% catch (MT) prediction error using SARIMA modelling approach for the period 2014 (Q1) to March 2018 (Q4) of Chilika lagoon.

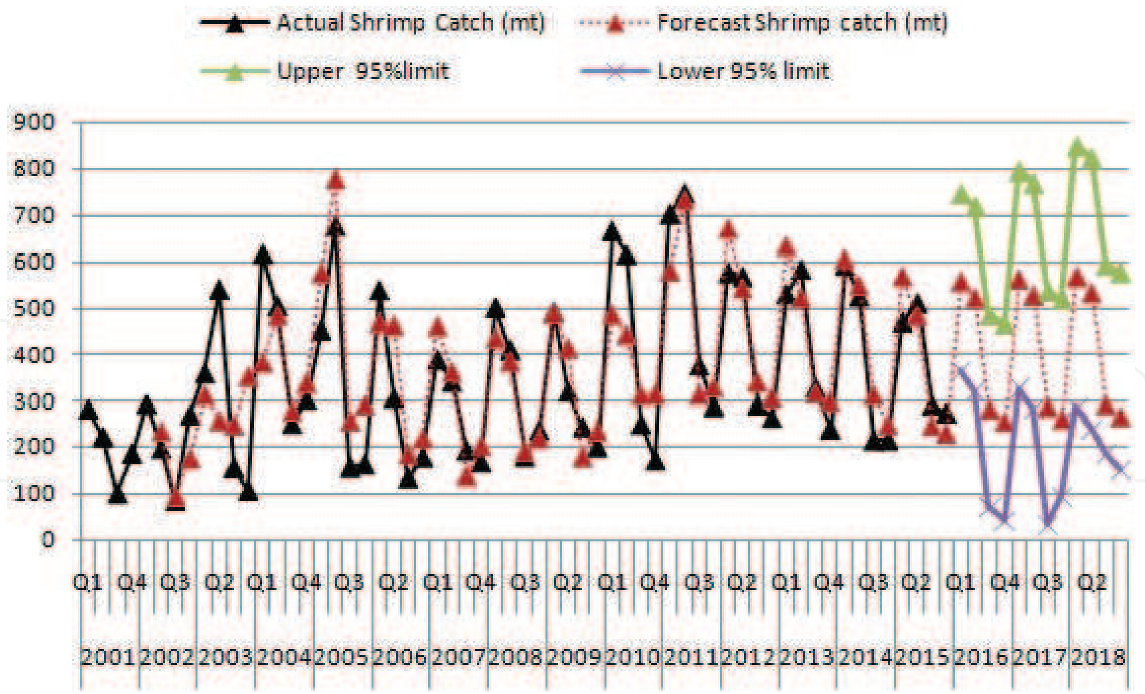

Figure 4.
Quarter wise actual versus predicted shrimp catch (MT) with 95% confidence limit of Chilika lagoon for the period 2001 to 2018.

minnows with some miscellaneous catch are the major fish catch of the lagoon with an average annual estimate of fish landing 12,000 tons per annum from 2000–2001 to 2014–2015. The fish landing was fluctuated between 10,286.34 tone (2003–2004) and 6463.92 tone (2006–2007) with average at 7725.42 tone contributing 63.65% of total fish landing of the whole lagoon. Around 64.88% of commercial catch was contributed by the yield of fish since last 15 years of post-restoration period. More than 90% fish species which contributed to the commercial landing of Chilika are of brackish or marine habitats. SARIMAX model was developed using monthly time series fish catch data, and regressor is used as a factor (combination of lagoon

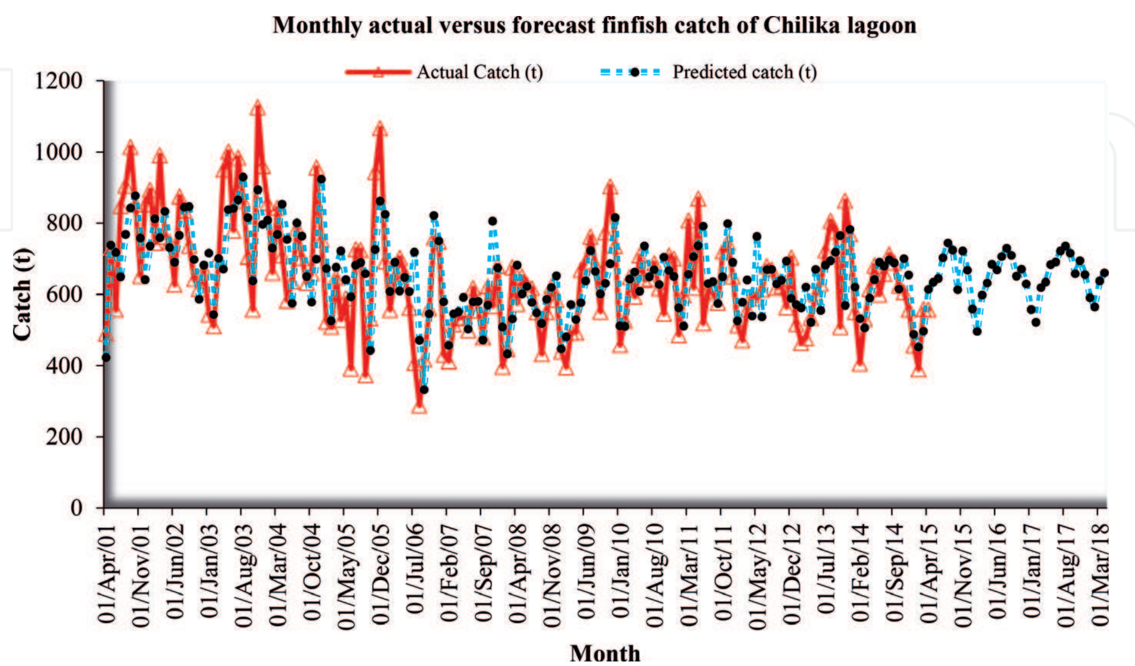

Figure 5.
Monthly actual fish catch versus predicted (forecasted) catch by SARIMAX model for the period April 2001 to March, 2018 of Chilika lagoon (Source: [14]).

temperature and salinity for the same period of April 2000–2001 to March 2014–2015 of the Chilika lagoon). The data sets for the period April 2001–March 2011 were used for training sets and April 2011 to March 2015 were taken as validation of the model. SARIMAX (1,0,0)(2,0,0)12 was found to be the best fitted model. Here, SARIMA (1,0,0)(2,0,0)12 model is also compared with the SARIMAX (1,0,0)(2,0,0)12 (SARIMA (1,0,0)(2,0,0)12 with regressors as factor) and found that the R square value is greater for SARIMAX than SARIMA and root mean square error is less for SARIMAX than the SARIMA model, which reveals that SARIMAX model is better performer than the SARIMA model for the forecasting of the total fish catch of the lagoon. The regressor, i.e., temperature and salinity used for SARIMAX development, showed significantly positive influence ($p < 0.05$) on the fish catch in the lagoon. Using SARIMAX model, forecasting is done for the fish production within the error catch less than 10% (for details please see [14]; **Figure 5**). Total fish catch forecasting also showed an increasing catch in the upcoming year till 2018 with respect to the base year 2015.

4. Discussion

In Chilika lagoon, fisheries in general and shrimp catch in particular play an important role in support of livelihoods of fishermen around it. The quarterly catch variation in shrimp landings in lagoon could be due to direct or indirect influence by hydrology and environmental condition of the lagoon system [27–29]. Average shrimp landings during first quarter Q1 were maximum, which reflects the summer season (March, April and May) catch and the lowest in third quarter Q3 representing the post-monsoon season (September, October and November). The maximum variation in shrimp catch was observed during second quarter Q2 representing monsoon season and lowest variation in fourth quarter Q4 winter season (December, January and February). Seasonal and environmental variation influences the special trends of fisheries in the estuaries system [30]. Physicochemical parameters such as salinity and water temperature influence the distribution of various Penaeid shrimp [31]. The physicochemical parameters of the Chilika lagoon are very much influenced by the seasonal variation as it is connected with the fresh water river by one side and the Bay of Bengal on the other side. The fresh water flow showed positive, negative and inconsistent influence on fish production in the coastal lagoon system for different fish species across different countries [32]. The major commercial fishes in the lake are mostly migrant species (between sea and lake) and account more than 86% of the total fish diversity [33]. For feeding and breeding purpose, the migrant species enter the lake from the sea. The lagoon environment becomes favourable in post winter through summer due to the more availability of food. The higher temperature and salinity phase triggers spawning activity of many clupeid species which contribute more than 26% of total annual catch. Hence, in general, more number of fish species abundance is influenced by the temperature and salinity of the lagoon. As reported, the total fish production showed an increase trend in catch with the increase in temperature and salinity [14]. Similar observation was made as marine-dependent species increased from February month to onset of monsoon (June) [19] in Chilika lagoon. Moreover, during monsoon season, the nutrient inflow in the lake comes through catchment runoff and fresh water, which induces plankton production during post winter and summer (high salinity and temperature) period.

The information on fisheries catch prediction in advance plays a crucial role for managing fisheries resources in the lagoon ecosystem. In fisheries, several time series models were developed and forecasted for fisheries catch data such as ARIMA model, multiple linear regression, non-linear regression and dynamic models, Gaussian autoregressive model, etc. [34–36], but in general, ARIMA models have been widely used for better forecasting. SARIMA model is found good fit for short time series catch data and used as common forecasting model by several researchers [34, 37, 38]. This study also analysed and forecast the quarterly shrimp landing of Chilika lagoon using SARIMA time series modelling approach using data for the period 2001–2015. The best fitted SARIMA $(0,1,1)(0,1,1)_4$ model developed for the shrimp catch in Chilika lagoon was validated with actual quarterly catch data for the period 2014–2015 and further quarter wise forecast of the shrimp catch up to the year 2018. The forecast of shrimp catch for the years 2016, 2017, and 2018 shows an increase in catch by 4.5, 5.9, and 7.36% with respect to the base year 2015 if the environmental condition of the lagoon remains the same. SARIMAX (1,0,0)(2,0,0) 12 also showed the total fish increasing catch up to year 2018 with respect to the base year 2015. These model-based fish catch forecasting for Chilika lagoon results will be useful for understanding fish catch forecast with acceptable accuracy that will enable lagoon fish managers to facilitate fisheries management by predicting the lagoon fisheries progress toward fish production. Reliable fish catch production forecasting methods are important for managers for confident decision making in fishery management. Hence, the study suggests the regular monitoring and maintenance of fish catch and water quality data to be continued for assessing fisheries trends to enable corrective steps for short- and long-term management interventions in the lagoon.

5. Conclusions and future work

Time series SARIMA $(0,1,1)(0,1,1)_4$ model and SARIMAX (1,0,0)(2,0,0)12 model are statistical forecasting models for predicting time series quarterly catch of shrimp production and monthly total fish production in Chilika lagoon. Seasons play a significant influence in shrimp and total fish production in the lagoon. Model prediction showed shrimp and total fish catch of the lagoon will increase in the upcoming years by maintaining the present environmental and ecological conditions of the lagoon. Summer and monsoon seasons have explicit influence on shrimp production in the lagoon. Salinity and temperature of the lagoon positively influence on the total fish catch in the lagoon. Model predicts that shrimp and total fish catch will increase in the upcoming years till 2018 with respect to the base year 2015 in the lagoon. Therefore, continuous monitoring in the lagoon is essential to manage its rich and productive fishery resources, as well as its ecological integrity. This information would provide kind support to the managers of Chilika Development Authority to continue the present efforts for getting a good rich production for the livelihood of the fishermen dependent upon and sustainable management of fisheries. This time series model based study will be useful for forecasting fish production in different lagoon or aquatic system. Besides the catch and water quality monitoring, some related information regarding average monthly influx of tides in respect of amplitude and duration may be recorded for correlation with the catch variability of important species and consideration in trend analysis.

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References

[1] Elliot M, Hemingway KL. Fishes in Estuaries. 2nd ed. Oxford: Blackwell Science; 2002. p. 636

[2] George B, Kumar JIN, Rita NK. Study on the influence of hydro-chemical parameters on phytoplankton distribution along Tapi estuarine area of Gulf of Khambhat, India. Egyptian Journal of Aquatic Research. 2012;**38**: 157-170

[3] Mohapatra A, Mohanty SK, Mishra SS. Fish and Shellfish Fauna of Chilika Lagoon: An updated checklist. In: Venkataraman K, Sivaperuman C, editors. Marine Faunal Diversity in India. Elsevier Inc. Publications; 2015. pp. 195-224. DOI: 10.1016/B978-0-12-801948-1.00013-6

[4] Ritesh K. Economic valuation of Chilika lagoon. Chilika Newsletter. 2003;**4**:24-26

[5] Mohanty SK, Bhatta KS, Mohanty RK, Mishra S, Mohapatra A, Pattnaik AK. Eco-Restoration Impact on Fishery Biodiversity and Population Structure in Chilika Lake. Lakes and Coastal Wetlands Conservation, Restoration and Management. New Delhi: Capital Publishing Company; 2007. ISBN-81-85589-51-0

[6] Rothschild BJ, Smith SG, Li H. The application of time series analysis to fisheries populations assessment and modelling Stock Assessment: Quantitative Methods and Applications for Small-Scale Fisheries, Florida: CRC Press; 1996. pp. 354-402

[7] Box GEP, Jenkins GM. Time Series Analysis: Forecasting and Control. San Francisco: Holden-Day; 1976

[8] Roy M. Using Box-Jenkins models to forecast fishery dynamics: Identification, estimation and checking. Fishery Bulletin. 1981;**78**(4):887-896

[9] Saila SB, Wighbout M, Lermit RJ. Comparison of some time series models for the analysis of fisheries data. Journal du Conseil. 1980;**39**:44-52

[10] Sathianandan TV, Srinath M. Time series analysis of marine fish landings in India. Journal of the Marine Biological Association of India. 1995;**37**:171-178

[11] Prista N, Diawara N, Costa MJ, Jones C. Use of SARIMA models to assess data-poor fisheries: A case study with a sciaenid fishery of Portugal. Fishery Bulletin. 2011;**109**:170-185

[12] Raman RK, Sathianandan TV, Sharma AP, Mohanty BP. Modelling and forecasting marine fish production in Odisha using seasonal ARIMA model. National Academy Science Letters. 2017;**40**(6):393-397

[13] Raman RK, Sahoo AK, Mohanty SK, Das BK. Forecasting of commercial fish (Beloniformes: Order) catch in Chilika lagoon, Odisha, India. Journal of the Inland Fisheries Society of India. 2017; **49**(1):55-63

[14] Raman RK, Mohanty SK, Bhatta KS, Karna SK, Sahoo AK, Mohanty BP, et al. Time series forecasting model for fisheries in Chilika lagoon (a Ramsar site, 1981), Odisha, India: A case study. Wetlands Ecology and Management. 2018;**26**(4):677-687

[15] World Bank. Scenario assessment of provision of environmental flows to Lake Chilika from Naraj Barrage, Orissa, India. Reports from the environmental flows window of the bank Netherlands water partnership programme (World Bank) to the Government of Orissa, India; 2005. p. 40

[16] Mohapatra ARK, Mohanty SK, Mohanty, Bhatta KS, Das NR. Fisheries enhancement and biodiversity

assessment of fish, prawn and mudcrab in Chilika lagoon through hydrological intervention. Wetlands Ecology and Management. 2007;**15**(3):229-251

[17] Biradar RS. Fisheries Statistics Course Manual No-14. Bombay: Central Institute of Fisheries Education (ICAR); 1988. p. 229

[18] Gupta RA, Mandal SK, Paul S. Methodology for collection and estimation of inland fisheries statistics in India. Central Inland Capture Fisheries Research Institute (ICAR), Barrackpore, West Bengal Bull. No. 58 (Revised); 1991. p. 64

[19] Jhingran VG, Natarajan AV. Study of the fishery and fish populations of the Chilika lake during the period 1957–65. Journal of Inland Fisheries Society of India. 1969;**1**:47-126

[20] Dickey DA, Fuller WA. Distribution of the estimators for autoregressive time series with a unit root. Journal of the American Statistical Association. 1979; **74**:427-431

[21] Dickey DA, Fuller WA. Likelihood ratio statistics for autoregressive time series with a unit root. Econometrica. 1981;**49**:1057-1072

[22] Andrews B, Dean M, Swain R, Cole C. Building ARIMA and Arimax Models for Predicting Long-Term Disability Benefit Application Rates in the Public/Private Sectors. Society of Actuaries; 2013

[23] Cryer JD. Tome Series Analysis. Boston: Duxbury Press; 1986

[24] Akaike H. Use of an information theoretic quantity for statistical model identification. In: Proceedings of the 5th Hawaii International Conference on System Sciences; 1972. pp. 249-250

[25] Schwartz G. Estimating the dimension of a model. The Annals of Statistics. 1978;**6**:461-464

[26] L-Jung GM, Box GEP. On a measure of lack of fit in time series models. Biometrika. 1978;**65**:297-303

[27] Blaber SJM, Blaber TG. Factors affecting the distribution of juvenile estuarine and inshore fish. Journal of Fish Biology. 1980;**17**:143-162

[28] Elliott M, O'Reilly MG, Taylor CJL. The forth estuary: A nursery and overwintering area for North Sea fishes. Hydrobiologia. 1990;**195**:89-103

[29] Morin B, Hudon C, Whoriskey FG. Environmental influences on seasonal distribution of coastal and estuarine fish assemblages at Wemindji, eastern James Bay. Environmental Biology of Fishes. 1992;**35**:219-229

[30] Pomfret JR, Elliot M, Reilly MGO, Philips S. Special and temporal patterns in the fish communities in the U. K. North Sea estuaries. In: Elliot M, Ducrotoy JP, editors. Estuaries and Coast: Special and Temporal Intercomparisons, 2077–284. Fredenborg: Olsen and olsen; 1991

[31] Walsh CJ, Mitchell BD. Factors associated with variations in the abundance of epifaunal caridian shrimps between and within seagrass meadows. Marine and Freshwater Research. 1998;**49**:769-777

[32] Gillson J. Freshwater flow and fisheries production in estuarine and coastal systems: Where a drop of rain is not lost. Reviews in Fisheries Science. 2011;**19**(3):168-186. DOI: 10.1080/10641262.2011.560690

[33] Mohanty SK, Mishra SS, Khan M, Mohanty RK, Mohapatra A, Pattnaik AK. Ichthyofaunal diversity of Chilika Lake, Odisha, India: An inventory, assessment of biodiversity status and comprehensive systematic checklist (1916–2014). Check List. 2015;**11**(6): 1-19

[34] Stergiou KI. Describing and forecasting the sardine-anchovy complex in the eastern Mediterranean using vector autoregressions. Fisheries Research. 1991;**11**:127-141

[35] Stergiou KI, Chritou ED, Petrakis G. Modelling and forecasting monthly fisheries catches: Comparison of regression, univariate and multivariate time series methods. Fisheries Research. 1997;**29**:55-95

[36] Romilly P. Time series modelling of global mean temperature for managerial decision-making. Journal of Environmental Management. 2005;**76**: 61-70

[37] Pajuelo JG, Lorenzo JM. Analysis and forecasting of the demersal fishery of the Canary Islands using an ARIMA model. Scientia Marina. 1995;**59**:155-164

[38] Hae-Hoon P. Analysis and prediction of walleye Pollock (*Theragra chalcogramma*) landings in Korea by time series analysis. Fisheries Research. 1998;**38**(1):1-7