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ESTIMATING FISHERY PRODUCTION MODELS OF LAKES KORONIA AND VOLVI (MACEDONIA – GREECE) AIMING TO THEIR SUSTAINABLE DEVELOPMENT

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Abstract. The lakes Koronia and Volvi in the region of Central Macedonia (Greece) are very important lakes due to their natural environment and they are protected by specific environmental laws. Recently, both of these protected wetlands are under intense exploitation of their biological resources while a lot of developmental human activities are in conflict functions and uses of their waters. This paper describes the fishing efforts of these two environmental sensitive wetlands and attempts to generate models for forecasting their fishery production. Annual fishery production data originated directly from the relative 'Fisheries Public Authorities' of each lake ecosystem as well as from relative scientific papers, studies and programs. Annual fishery production models were defined through 'Trend Analysis', 'Moving Average' and 'ARIMA' modelling and can support short-term forecasts. The degradation of the fishery production of the lakes Koronia and Volvi, which are identified as traditionally inland water fishery areas, is mainly related with the general reduction of their biological resources, the overfishing and also from the recent environmental changes. The existing fishery management is insufficient and not so well adapted with the environmental features of these lakes, following mainly general fishery regulations and ignoring their specific characteristics. The results of this paper can support the local authorities to apply a sustainable and environmental-friendly fishery management plan.

Keywords: lakes, fisheries, fishery models, sustainable development, fishery management.

AIMS AND BACKGROUND

The lakes Koronia and Volvi in the region of Central Macedonia (Greece) are very important wetlands due to their natural environment and they are protected by special environmental laws[1]. Recently, both of these protected ecosystems are under intense exploitation of their biological resources while a lot of developmen-

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tal human activities are in conflict functions and uses of their waters. Additionally, the degradation of the fishery production in these lakes, which are identified as traditionally inland water fishery areas, is mainly related with the general reduction of their biological resources, their environmental changes as well as their overfishing[2–4]. The existing fishery management is insufficient and not so well adapted to the environmental features of these lakes, following mainly general fishery regulations and ignoring their specific characteristics[1–6].

THE LAKE KORONIA

This lake is located in the northeast of the city of Thessaloniki, 75 a.s.l. The lake's surface during the decade of 70's came up to 4600 ha and the mean depth was 5 m. During the last decade the area of the lake reduced significantly. The lake is subjected to intense human pressures and became hypertrophic[7,8], because of the concentration of urban, industrial and agricultural wastes. In our days, the maximum depth of the lake is only 1m and the surface of the lake is limited under 3000 ha. Water inflow into the lake is not sufficient to cover the shortage and the aquatic balance is negative because of the overirrigation of waters from drillings[8,9]. In the summer of 2002 the waters of the lake totally disappeared, however, lately they have started to reappear.

The fish-fauna of the lake till 1995 consisted of 16 species, three of them *Rhodeus amarus, Barbus cyclolepis* and *Cobitis strumicae* are under protection by the EU Regulation for Ecotopes (92/43/EEC), the above-mentioned and the fish species *Salaria fluviatilis* by the Bern's Convention (Council of Europe, 1979; Convention on the Conservation of European Wildlife and Natural Habitats). The species *Leuciscus cephalus, Alburnus alburnus, Barbus cyclolepis* and *Cobitis strumicae* are included in the Red List as 'vulnerable' and 'locally threatened'[1]. After the collapse of the lake Koronia environment in August 1995, the fish fauna was totally extinguished[2]. However, some of the species, especially the small ones, have survived in streams that discharge into the lake[2].

THE LAKE VOLVI

This lake is located in the east of the Koronia lake and communicates with a connecting channel. It is the greatest lake in Macedonia region (Greece) and the second in Greece covering a total area of 76 km^2. The lake has a mean depth of 14 m and maximum of 22 m (Refs 7-9). The altitude of the lake's surface from the level of the sea is 37 m. It is supported with waters from the streams of the mountains Holomontas, Kerdyllia and Volvi and joins the Strymonic gulf through the river Rehios. It exhibits a satisfactory aquatic balance and the volume of the waters is high enough, hence it can survive easily in difficult times of drought. The lake is classified as an eutrophy lake[7,8].

The fish fauna of the lake consists of 24 species, from which seven (*Alosa macedonica, Barbus cyclolepis, Rhodeus amarus, Aspius aspius, Chalcarlburnus chalcoides, Cobitis strumicae* and *Silurus aristotelis*) are protected by the EU Regulation for Ecotopes (92/43/EEC), 9 by the Bern's Convention (Council of Europe, 1979; Convention on the Conservation of European Wildlife and Natural Habitats), as in the above-mentioned the EU regulation are added the fish species *Silurus glanis* and *Salaria fluviatilis.* Finally, 6 fish species are included in the Red List, 4 as 'vulnerable' and 'locally threatened' (*Leuciscus cephalus, Barbus cyclolepis, Alburnus alburnus* and *Cobitis strumicae*), 1 as 'vulnerable' (*Chalcarlburnus chalcoides*) and 1 as 'endangered' (*Vimba melanops*)[1,2].

FORECASTING IN FISHERIES

Forecast in fisheries is used to predict and describe what will happen at a given set of circumstances and planning involves the use of the forecasts to support decisions on the most attractive alternatives, e.g. if the forecast shows that the fishery production will fall next year, the proper management plans should be enhanced in order to prepare a plan of action. The forecasting in fisheries has an important role within environmental management process, however, it is very difficult to acquire accuracy because of the many uncertain situations the forecasters have to face. Hence, a key aspect of decision-making is being able to predict the circumstances surrounding individual decision situations[10]. The procedure of decision-making has to be based on the proper information on the given situation[11]. Aiming to produce forecasts of future outcomes using quantitative methods through statistical procedures engage the assessment of present and past data, either in annual or seasonal basis, assuming that the process remains stable over the forecast time horizon, although this assumption may just be valid for short-term forecasts[12].

Modelling process is a key ingredient to decision making, as it supports managers in non-routine decision tasks since models are mathematical representations of real-life system that can be computerised[13]. Modelling and forecasting fishery procedures and production have successfully adapted univariate time series techniques, where forecasting is based on projecting past values of a variable and/or past errors into the future[14,15]. The basic approach used was to fit various time series methods that produce models to the data and to forecast production onwards, more specifically. World-wide, time series data have been applied successfully in recent studies within analysing and forecasting procedures concerning fisheries data in the Pacific area[16,17], in the Atlantic Ocean[18–20], in the Mediterranean Sea[14,21–24], and lake ecosystems[25–30].

This paper describes the fishing effort of two environmental sensitive ecosystems (the lakes Koronia and Volvi), and attempts to generate models for forecasting their fishery production. The analytical description of fisheries production represents an important indicator for the evaluation of the fisheries ability of the lakes, while it is suggestive of the designing of a rational model for their fisheries management. Furthermore, fishery data analysis could considerably enhance the capability of environmental managers to consider the impact of alternative tactics for local strategic environmentally friendly fishery management and sustainable development.

EXPERIMENTAL

In this study fishery data were collected and analysed in order to sufficiently develop a clear picture of the fishery evolution of the ecosystems over time. In the paper are described the fishery efforts in the lakes Koronia and Volvi (the Northern Greece), and attempts to generate models for short-term forecasting of their fishery production for their rational and sustainable management.

Time series data concerning fishery production are often used in order to assess the present situation and consequently to forecast and enhance planning and consequently decision-making. These kind of data are useful because they are easily retrieved from formal sources, e.g. Fishery Departments, and it is easily assumed that the aspects of the past pattern will continue to exist and appear in future conditions within the same ecosystem, also known as the assumption of continuity[10,14,24].

The detailed data on total fishery production of the lake Koronia are available from 1950 till 1995 onwards and for the lake Volvi from 1960 till 2003. Data on fishery production have been recorded on yearly basis by the Department of Fisheries in Langadas city, in the Prefecture Local Authority of Thessaloniki, responsible for the lake ecosystem. Concerning the lake Koronia, the forecast is totally theoretical since after the year 1995 the fish population of this system collapsed as well as the greater part of the fish fauna[2].

The available collected historical data were initially registered with the aid of Ms-Excel 2000 software to be appropriately organised and easily retrieved. Then, the Minitab Statistical software, Release 13.20 was used in order to analyse the time series data and produce forecast models.

Annual fishery production models were defined through 'Trend Analysis', 'Moving Average' and 'ARIMA modelling' methods and can support short-term production forecasts with 95% confidence.

'Trend Analysis' fits a general trend model to time series data and provides forecasts as extrapolations of the trend model. Data prior to the forecast origin year have been used as input to fit the trend. Then, mean square deviation (MSD), which is a commonly used measure of accuracy of fitted time series values, was estimated between actual and forecast values. Because MSD is always computed using the same denominator, n, regardless of the model, the MSD values are directly compatible across models.

'Moving Average' method smoothes the data by creating consecutive average observations in a series and provides short-term forecasts.

'ARIMA' models were also fitted for annual production data for each lake and were used to calculate forecasts with 95% prediction intervals for the coming year. The coefficients for all parameters that participated in the model were recalculated using all data preceding the forecast period, therefore, the 1-year forecast that was generated for the year 2003 (e.g. for the lake Volvi) used the original annual models but parameters were updated previous to forecasting for the year 2002. Difference (d) is specified as the number of differences used to discount trends over time. Given ρ is the term of the order of the autoregressive term in the model and q is the order of the moving average term, the model is represented as ARIMA (ρ, d, q) and the value x at time t can be described by the following equations[31]:

$$(1 - \varphi_1 B^{\rho})(1 - B^{d})X_t = (1-\theta_1 B^{q}))e_t \tag{1}$$

where φ and θ are coefficients, e_t – the error term in time t, and B^{ρ} is called the backward shift operator where

$$B^{\rho}X_t = X_{t-\rho} \tag{2}$$

The identification of the models was based on the plots for autocorrelation function (ACF) and partial autocorrelation function (PACF) in the transformed time series. Their graphical presentations in combination with testing Student's t-values in order to indicate significant correlation[21], aided to estimate the coefficients of the model p, q. Within the procedure, alternative models were checked, adding autoregressive (AR) and/or moving average (MA) terms.

Diagnostic checking of the model involved residual analysis to ensure that the estimated model has independent and identically distributed errors. The randomness of the residuals, which represent the difference between actual and fitted values, were assessed from the autocorrelation and partial autocorrelation functions, after examining the values of t-statistics and the spikes in the dotted area that stands for 95% interval of confidence in ACF and PACF plots[31,32]. When an 'ARIMA model' has been fitted to a time series for each case, short-term ahead forecasts were generated[10]. Finally, time series plots were computed where back forecasts are also presented in addition to next terms forecast.

RESULTS AND DISCUSSION

The fluctuations of the fishery production of the lakes Koronia and Volvi are related mainly to the fishery effort, the environmental changes and the conflicted usage of their waters during the near past. It is related also to the general reduction of the biological resources and the applied incorrect fishery management, which follows mainly a traditional and not so well adapted character[1-5].

The results of this paper include 'Trend Analysis', 'Moving Average' and 'ARIMA models' for the total fishery production between the years 1950-1995 for the lake Koronia and 1960-2003 for the lake Volvi.

Table 1. Estimated 'Trend' and 'ARIMA' models for the time series of the total fishery production of lakes Koronia and Volvi

Trend model	Arima model	Arima coefficients			SE	P
		Lake Koronia				
$Y_t = 1243.9\ (0.940076^t)$	(2,1,1)	AR	1	−0.772	0.1476	0.000
		AR	2	−0.322	0.1475	0.035
		MA	1	0.9837	0.0454	0.000
		Lake Volvi				
$Y_t = 978079\ (0.921765^t)$	(2,1,1)	AR	1	−0.716	0.1398	0.000
		AR	2	−0.463	0.1398	0.002
		MA	1	0.991	0.0463	0.000

Table 2. Actual and estimated total fishery productions of lakes Koronia and Volvi using 'Moving Average', 'Trend' and 'ARIMA' models

	Lake Koronia			Lake Volvi		
Actual value	1995:	47.2		2002:	23418	
Actual difference	1995:	−46.9		2002:	11925	
FORECASTS						
Moving average	Lake Koronia			Lake Volvi		
		fitted value	confidence interval (95%)		fitted value	confidence interval (95%)
	1995-1996:	70.65	(−382.401, 523.701)	2002-2003:	17455.5	(−112415, 147326)
Trend model	Lake Koronia			Lake Volvi		
	1995:	75.3863		2002:	32966	
	1996:	70.9610		2003:	30421.4	
Arima model	Lake Koronia			Lake Volvi		
		fitted differences	differences C.I.		fitted differences	differences C.I.
	1995:	−52.561	(−492.178, 387.057)	2002:	−9923	(−125262, 105415)
	1996:	−0.342	(−551.359, 550.674)	2003:	−13742	(−155002, 127518)

In Table 1 are presented the fitted 'Trend' and 'ARIMA' models for the total fishery production for both of the lakes, for the years mentioned above. Regarding 'ARIMA' models, it was computed the fitted 'ARIMA' model and its coefficients, SE of coefficients (Table 1) and the forecast for one year ahead (Table 2). In Table 2 are also presented the forecasts, back forecasts and confidence of interval for the forecasts estimated with 'Trend Analyses' and 'Moving Average' method.

The fishery production of the lake Koronia has a continuous degrading trend since the decade of the 1950, and became null in 1995 (Fig. 1*a*). The decrease in fishery production in decades became very significant after 1951-1960 and 1961-1970. Respectively, an important decrease was observed between the values of the last decade 1991-1995 (Refs 2 and 5). An important decrease was also observed between the values of the last decade 1991-2000. The decrease in total production is observed also for the most commercially important fish species as the common carp (*Cyprinus carpio*) and the common roach (*Rutilus rutilus*)[2].

In Fig. 1 time series plots of the total fishery production of the lake Koronia are presented with three different analysis methods, i.e. 'Trend Analysis' (Fig. 1*b*), 'Moving Average' (Fig. 1*c*) and 'ARIMA' models (Fig. 1*d*), yet the 95% confidence of intervals appear for 'Trend Analysis' and 'ARIMA' models forecasts.

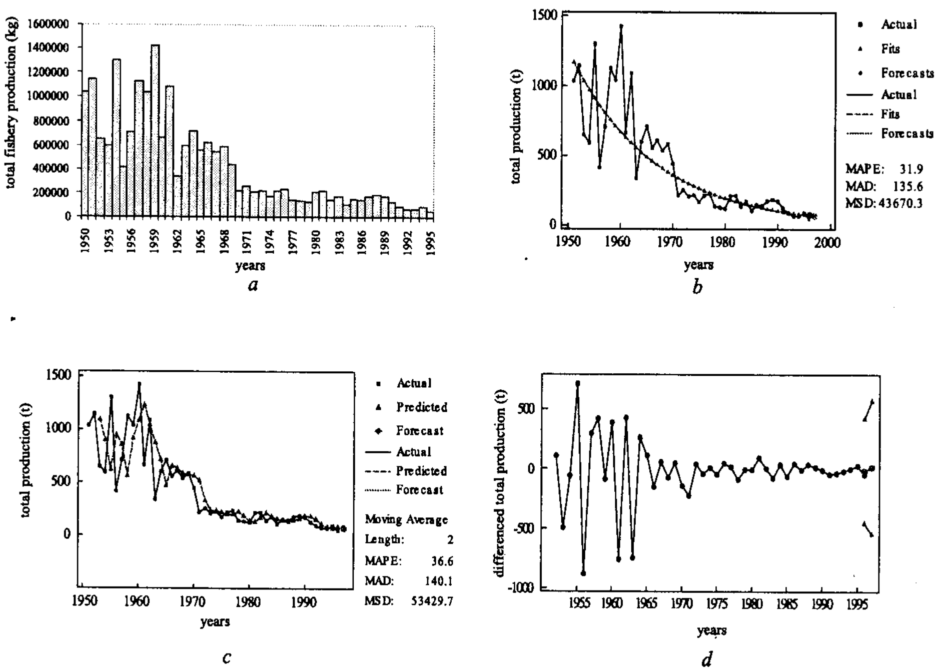

Fig. 1. Time series plots of the total fishery production of the lake Koronia (*a*), the fitted curves using 'Trend Analysis' (*b*), 'Moving Average' (*c*) and 'ARIMA' (*d*) models, with the 95% confidence of intervals for 'Trend' and 'ARIMA' models forecasts

This figure summarises the time series plots for the total fishery production actual values, the fitted values with 1-year forecast onwards (1995). However, the forecast is totally theoretical since after that year the fish population in the system and the greater part of the fish fauna collapsed.

The total fishery production of the lake Volvi till the end of the decade of the 70's was kept at a level over 300 000 kg (Fig. 2*a*). In the decade of the 80's it decreased to 200 000 kg and since 1990 it remains under 100 000 kg. Since the middle of the decade of 70's, almost disappeared the fish species *Leuciscus cephalus* and *Silurus glanis* from the fish catch[2]. The indigenous species *Silurus glanis* disappeared from the lake's caches since the beginning of the decade of 1990, after the import of the species *Silurus aristotelis*, which was initially introduced in 1986 (Ref. 1).

Figure 2 summarises the time series plots of the total fishery production of the lake Volvi (actual and fitted values) with 1-year forecast onwards, and one back forecast, with three different analysis methods as 'Trend Analysis' (Fig. 1*b*), 'Moving Average' (Fig. 1*c*) and 'ARIMA' models (Fig. 1*d*). The 95% confidences of intervals appear also for 'Trend' and 'ARIMA' models forecasts.

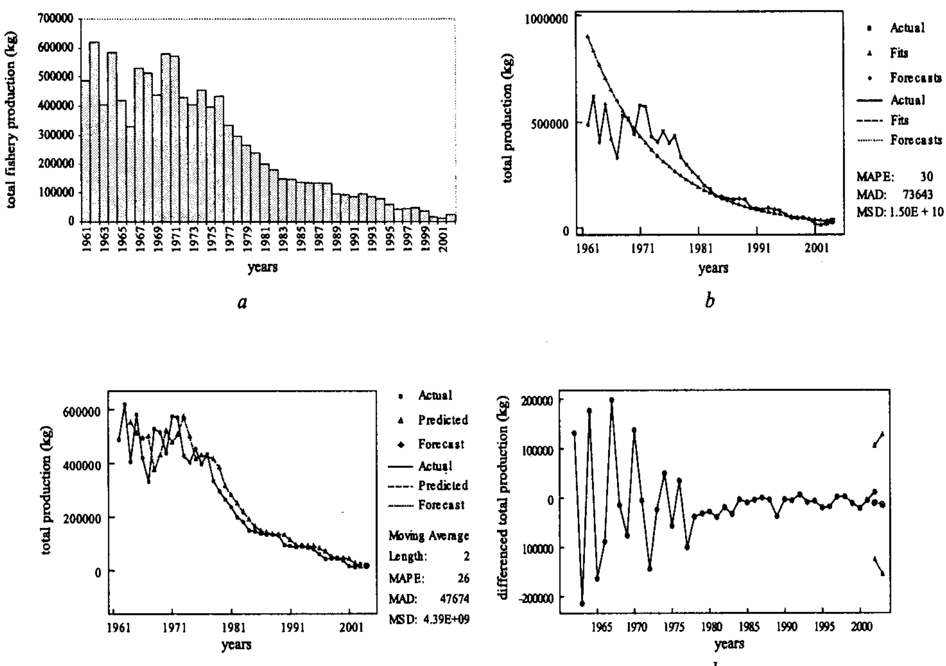

Fig. 2. Time series plots of the total fishery production of the lake Volvi (*a*), the fitted curves using 'Trend Analysis' (*b*), 'Moving Average' (*c*) and 'ARIMA' (*d*) models, with the 95% confidence of intervals for 'Trend' and 'ARIMA' models forecasts

CONCLUSIONS

Lake ecosystems, as also other types of environmental sensitive systems such as forests, are areas where the application of management projects usually stands in conflict with the economic profit of local users, such as fishermen. Hence, it is difficult for the local authorities to organise successfully their management.

The changes of the fishery production, which are analysed in the present paper for the lakes Koronia and Volvi, describe not only the fisheries ability of the total wetland ecosystem but also its ecological disorder. Data analysis and modelling of the fluctuations in the total annual fishery production indicate the impact of environmental changes along with the improvement of the fishery efforts. A combination of factors contributed to the decrease of the fish production in the both lakes in the recent past. One of them is the inadequate fishery management, especially of the species with important commercial value, such as *Cyprinus carpio*, *Perca fluviatilis* and *Anguilla anguilla*[1,2]. The strong demands of the fish market, especially after 1980, have made the fishermen to catch fish more specifically and intensely, thus destroying the natural resources. Meanwhile, other causes for this decrease are the illegal fishing methods, the improvement of the fishery infrastructure of the fishermen (changes of the fishing gears), the excessive drilling for water close to the lake for agricultural reasons (irrigation) that has reduced lakes water, the reveal of the suitable areas for fish reproduction and the disconnection of the two lakes[1,2]. Unfortunately, nowadays the existing fishery management in the neighbouring lakes is not environmentally friendly and is directed selectively to the species with important commercial value and ignores the others[1,2].

The success of a fisheries management plan depends on both external factors that can not be controlled, such as the weather changes that affect fishery production, and factors that can be controlled and directly affect the variables in question, as fishing effort[24]. Monitoring programs for the factors affecting inland waters are essential to comprehend how fish populations and community dynamics affect the sustainability and management of the fisheries to moderate the social and economic impacts of different management plans. Future suggestions for fisheries management planning and development in lake ecosystems should consider thorough social and environmental impact assessment before accomplishment. During the last decade, a constructive effort has been initiated from the government within the framework of the EU, to establish a modern legislative framework for wetland ecosystems that defines their boundaries, adjusts the uses of their natural resources and initiates their integrated management and development plans with the active contribution of local communities[33].

In this paper, univariate time series forecasting methods were performed to estimate the forthcoming total fishery production, taking into consideration the available time series data, between 1950-1995 for the lake Koronia and 1960-2003 for the lake Volvi. However, the model that fits best in each case is not necessarily the one that forecasts best[34]. The generation of these models consists of an initial effort in the assessment of the production fluctuation through time in a lake ecosystem and it can act as an useful aid within management efforts for other lakes, too. Guidance from fishery production based on time series models has been practically useful to fisheries biologists in order to employ quantitative management recommendations[35].

The results of the total fishery production data analysis from the lakes Koronia and Volvi can support the local authorities to apply a sustainable and environmental-friendly fishery management plan which will be well adapted to the natural environmental conditions. Decisions for local interventions must take into account the upgrade of fisheries production, the safeguarding of the special protection character of these two lakes and must be planned within sustainable development principles. In addition, the new types of fishery data analysis would considerably enhance the ability of fishery managers and environmental decision-makers to assess the impact of alternative plans for the strategic fishery management. As a result, an environmental friendly, rational model, well adapted to the environmental features of the ecosystem, would aim in the upgrade of fisheries production for local profit and in the protection of the environment through sustainability.

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