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INFORMATION MODEL FOR SUSTAINABILITY ANALYSIS OF FISH RESOURCES IN GREECE

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Abstract. Fishery activities in Greece have a strong impact on the structure of the ecosystems and the patterns of sustainability of fish resources. The presented information model consists of a multi-dimensional database on sea fishery in Greece and data mining software for sustainability analysis of fish resources. The 2241 time series data for the period 1990–2007 are stored in database and concerns quantity of fish catch by areas, species, months, kind of fishery and fishing tools as well as value and employment. The developed system of data mining rules applies the computing of descriptive statistics and trend models. The database analysis shows sustainability for total fish catch in the time period 2000–2007, but some significant changes of the fish catch by areas and by species. The attained information has 2 aspects: (1) ecological, regarding needed measures to control water quality and minimise pollutions of coastal areas; (2) economical, related to effective management of sea fish resources in Greece. An analysis of the mined information, for the present and the future, can support experts and researchers in the fields of biology and ecology to study changes in sea fish communities, in biodiversity and in marine ecosystems as a whole.

Keywords: time series database, data mining software, sustainability of fish resources, fishery ecosystem.

AIMS AND BACKGROUND

A key characteristic of most sustainable development analysis and policy is the attempt to provide framework in terms of which ecological, social and economic dimensions are integrated[1]. Each dimension is dynamic, complex and evolving in its own right[2].

Greece supports marine fishery in order to enhance domestic sea food consumption and export to other countries as well. On the other hand, fisheries activities have a strong impact on the structure of the fishery ecosystems and the patterns of sustainability of fish resources. Many scientists consider that the lack of sustainability and over-fishing cause strong exhausting of the fish resources and other

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negative effects[3,4]. National Statistical Service of Greece (NSSG) collects spatial and temporal statistical datasets on fish catch by areas, species, months, kind of fishery and fishing tools as wells as value and employment[5]. This is a precondition for the development of modern software approaches for studying important characteristics of the sustainable development of fish resources. Sustainability analysis of fish resources by the use of integrated multidimensional data will help scientists and managers to take adequate decisions regarding the balance between economical activities and protection of the fish resources[6–8].

This work aims:

- Development of information model for sustainability analysis consisting of multidimensional PC database and embedded software;
- Software implementation for real data analysis on sustainability of fish resources and discussion of the obtained results.

EXPERIMENTAL

The developed information model consists of a multidimensional time series database on fishery in Greece and software for sustainability analysis of fish resources.

Primary data source of the information model is the mainframe database of the National Statistical Service of Greece (NSSG) (Fig. 1). The extracted datasets from NSSG database are used for building fishery time series (FTS) database of Greece[9,10]. FTS stores 2241 time series concerning quantity of fish catch by areas, species, months, kind of fishery and fishing tools as well as value and employment for the time period 1990–2007. The time series datasets of FTS are managed through DBMS 'Access©' and software for annual updating.

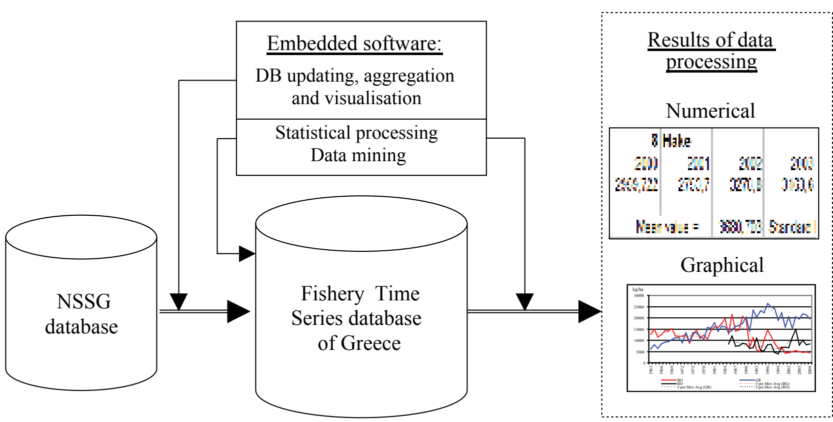

Fig. 1. Basic conception of the information model building

The geographical (spatial), organisational and accounting criteria determine the collection of multidimensional data on fishery in Greece. Figure 2 represents the used in the information model 3 basic dimensions (time, quantity of fish catch and employment) and the indicators regarding fishery data. The number of corresponding indicators/items is shown in parentheses. For example 'Quantity of catch' is accounted by 18 areas and each area by 71 fish species for the period of time 1990–2007. The whole data set has a temporal character and part of data is spatially oriented. An advantage of FTS database is the given opportunity for realisation of spatial and temporal sustainability analysis. Data aggregation provides processing of total time series data.

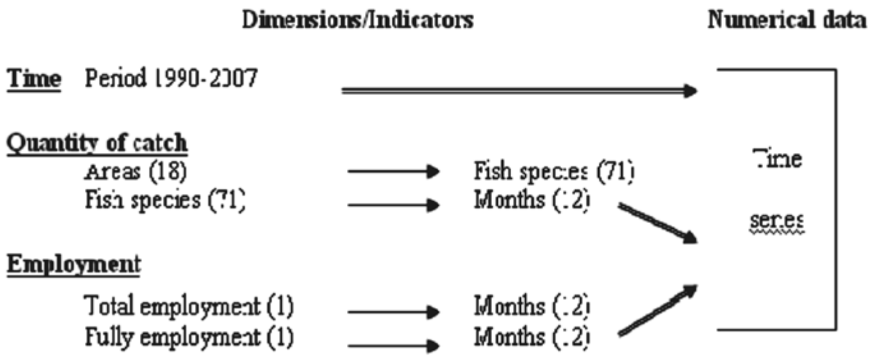

Fig. 2. Multidimensional data of FTS database

The statistical data software of the information model includes computation of descriptive statistics – mean, standard deviation, coefficient of variation as well as sum and percentage. It takes in also studying linear, polynomial and exponential trend.

Data mining algorithm is an important part of the information model for sustainability analysis of fish resources of Greece. This algorithm aims to find out the time period of total fish catch sustainability and then fish species and areas following or not this tendency. Data mining algorithm is built by using statistical methods and classification rules.

Data mining rules classify fish species and areas, based on catch of the sustainable time period into three classes A, B and C:

• Class A – small variations of studied time series on fish catch, i.e. process is sustainable in time;

• Class B – big variations and increasing trend;

• Class C – big variations and decreasing trend.

Generally, data mining algorithm can be presented as follows:

1. Dataset extraction from FTS. It can be a table containing time series on fish catch by areas or by species.

2. Data aggregation for the extracted dataset. Estimation of the sustainable time period regarding total fish catch based on computing of the coefficient of variation c_v:

$$c_v = \sigma/|\bar{y}|$$

c_v is presented in % and should not exceed 5% for the sustainable time period.

3. Computing of descriptive statistics – mean, standard deviation, coefficient of variation for each time series (object), presenting fish catch by areas and by species.

4. Application of rules:

4.1 Rule 1:

IF ($c_v < Q$) THEN Object $\in$ Class A
ELSE apply Rule 2

The value of the parameters Q is defined by the user. Q = 20% is considered proper for the case of time series on fish catch.

4.2 Rule 2:

Apply trend analysis

IF	increasing adequate trend	THEN	Object $\in$ Class B
	decreasing adequate trend		Object $\in$ Class C
	no adequate trend		End of the procedure

5. Numerical and graphical presentation of results.

The used statistical methods provide building of reusable software components of the model. They can be used as much for statistical estimations only as for a part of the classification procedure. This flexibility of the model is shown in the application of the algorithm on real data from FTS. The developed software is embedded into FTS database.

RESULTS AND DISCUSSION

The data aggregation software is used for finding the total fish catch for the time period 1990–2007. Figure 3 shows the attained results. The computing of descriptive statistics proves that total fish catch are sustainable for the period 2000–2007. It is useful to mention that c_v = 1.75 % for the period 2000–2007 while for the period 1999–2007 c_v = 7.19.

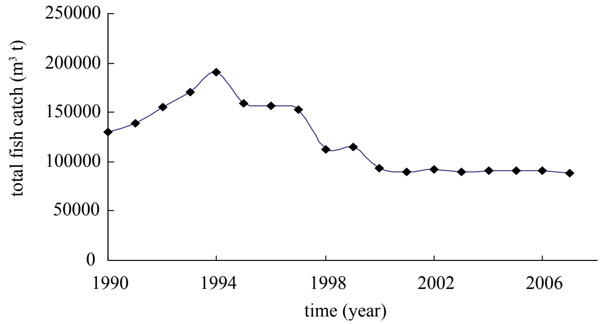

Fig. 3. Quantity of total fish catch

Sustainability analysis of fish catch by areas. Table 1 presents the results of classification of fish areas based on quantity of catch for the period 2000–2007. Class A includes only 5 fish areas. In the same time the sum of their catch for year 2007 is 65.5% of the total quantity of catch. The two biggest Greek fish areas Thermaikos gulf – gulf of Chalkidiki and Kavala–Thassos are in class A (Fig. 4).

Table 1. Classification of fish areas based on data mining algorithm

Class	Name of the fish areas
A	coasts of Kefalonia, Zakynhos and gulf of Patra; gulf of Korinthia; Thermaikos gulf and gulf of Chalkidiki; Str. G., G. of Kavala–Thassos and sea of Thraki, Kyklades
B	Amvrakikos gulf and coasts of Lefkada island; gulf of S and N. Evia–gulf of Lamia
C	Atlantic ocean; gulf of Argolida and Saronikos gulf; Dodekanissos

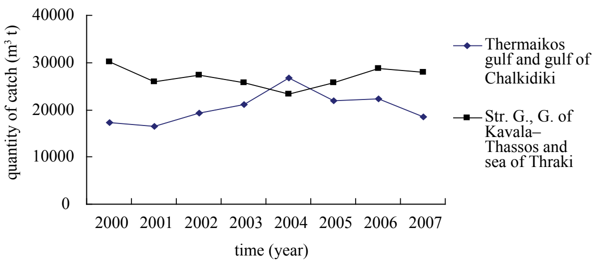

Fig. 4. Fish areas with sustainable catch and big quantity of catch

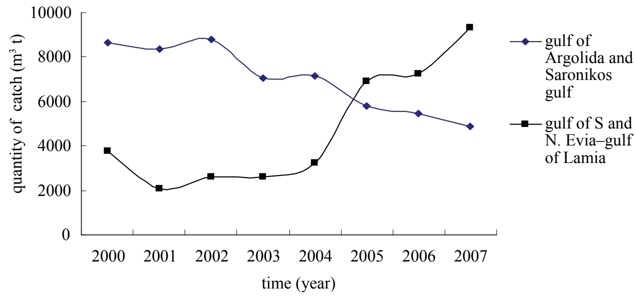

Fig. 5. Fish areas with increasing and decreasing trend of fish catch

Trend analysis shows a balance between fish regions with big variations of fish catch – classes B and C. Figure 5 presents examples of fish areas with increasing and decreasing catch trend.

It is needed to point out that quantity of fish catch for the left 8 fish areas has not adequate trend for the studying time period.

Sustainability analysis of fish catch by species. The first significant results of applying data mining algorithm concern variations of time series on catch of fish species by biological groups (Table 2). Coefficient of variation for all 'Pelecypoda' species, 80% of 'Crustaceans' and 72% of 'Fishes' exceeds 20%. Variations of catch of fish species from the group 'Cephalopods' are significantly less.

Table 2. Coefficient of variation of fish species catch by biological groups

Coefficient of variation c_v	Biological groups of fish species				Total
	Fishes	Cephalopods	Crustaceans	Pelecypoda	
0–20%	16	3	1	–	20
> 20	40	2	4	5	51

More detailed information is extracted by applying the classification rules. The quantity of catch for 20 fish species from class A is sustainable for the studied time period 2000–2007 (Table 3). The number of these fish species is only 28.2% of the total number. At the same time the sum of their catch for year 2007 is 59.11% of the total quantity of catch. Most of fish species from class A have relatively big quantity of catch exceeding 1000 t per year (bonito, bogue, pickerel, anchovy, etc.). An example is presented in Fig. 6. Fish catch of these fish species has significant impact to the sustainability of total fish catch in Greece.

Table 3. Classification of fish species through data mining algorithm

Class	Fish species number	Name of the fish species
A	20	gurnard, anchovy, bogue, club mackerel, pickerel, bonito, goat fish, red mullet, flying squid, pulp, octopus, large-eyed dog's teeth, etc.
B	11	hake, bass, sole, anglerfish, couch's whiting, large-eyed dog teeth, common prawn, etc.
C	25	stone bass, bluefish, brill, sprat, shepper, white bream, tune fish, tub fish, black-mouthed godfish, etc.

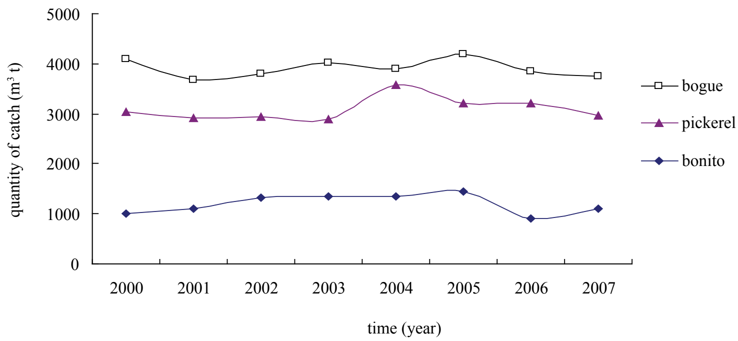

Fig. 6. Fish species with sustainable catch (class A)

Class B includes several fish species with catch quantity more than 1000 t (hake, anglerfish and common prawn) and also fish species with small amount of catch (the couch whiting and bass). The number of fish species of class C is relatively high – 25. At the same time their quantities of catch usually do not exceed 500 t. Figure 7 presents examples of fish species from class A and B. It is useful to point out the fact that quantity of catch of several economically significant fish species decreases 2–3 times for the studied period of time. For example the quantity of catch of 'tune fish' is 1752.4 for year 2000 while only 657 t for year 2007.

The characteristics of time series on catch quantity of fish species out of classes A, B and C are: big variance and no adequate trend. The number of these fish species is 24. Most of them such as John dory, red sea bream, skipjack, etc. have small quantity of catch, less than 300 t.

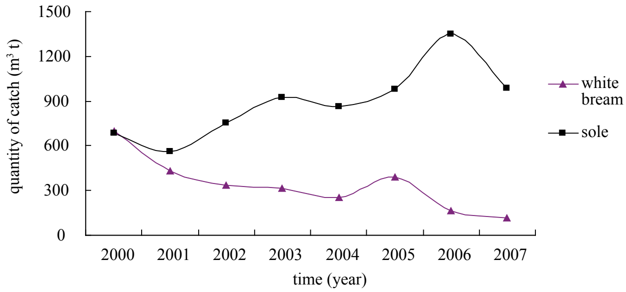

Fig. 7. Fish species with unsustainable quantity of catch (classes A and B)

Sustainability of the employment in fishery sector of Greece. The developed software components are used for trend analysis of time series on total and full employment in Greek fishery (Fig. 8). Slight decreasing tendency is proved for the studied period of time 2000–2007. The number of employees diminishes each year by 390. From one side, this fact indicates the increasing productivity of labour in the fishery sector, because practically the quantities do not change. From the other side, the decreasing of employees in fishery is very sensitive social problem especially in the islands and other remote geographical areas of the country.

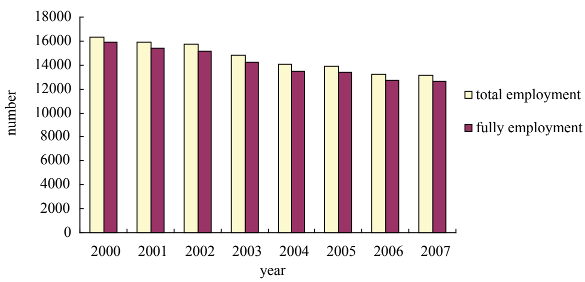

Fig. 8. Employment in fishery sector of Greece

CONCLUSIONS

The developed information model is an effective solution for sustainability analysis of relatively big amount of multidimensional fishery data. The implemented data analysis shows the sustainable total fish catch for the time period 2000–2007. The application of data mining rules makes available the extraction of fish species and areas which do not follow this general tendency. In the same time period, trend analysis shows slightly decreasing employment.

The extracted information from the database about the sustainability of fish resources can support the process of making decisions on Greek fishery with:

(a) Ecological and environmental importance regarding needed measures to control water quality and minimise pollutions in coastal areas in order to protect fish resources in Greece;

(b) Economical and social aspects toward effective management of economical activities and employed in fishery sector.

The information model can be advanced in the future through updating of Fishery Time Series database and data mining rules development for more effective studies of fish resources sustainability.

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