SCI. MAR., 60 (2-3): 427-430 SCIENTIA MARINA 1996

NOTE

"Heures" a bio-economic model for Mediterranean fisheries, towards an approach for the evaluation of management strategies*

JORDI LLEONART[1], RAMON FRANQUESA[2], JORDI SALAT[1] and PERE OLIVER[3]

[1]Institut de Ciències del Mar (CSIC), P. del Mar s/n. Barcelona 08039, Spain.
[2]Gabinete de Economía del Mar, Universidad de Barcelona, Fac. Económicas, Avda. Diagonal 690. Barcelona 08034, Spain.
[3]Instituo Español de Oceanografía, Centro Oceanográfico de Baleares, Moll de Ponent s/n. Apdo. 291, Palma de Mallorca 07080, Spain

SUMMARY: The bio-economic model "Heures" is a first attempt to develop a simulation procedure to understand the Northwestern Mediterranean fisheries, to evaluate management strategies and to analyze the feasibility of implementing an adaptative management. The model is built on the interaction among three boxes simulating the dynamics of each of the basic actors of a fishery: the stock, the market and the fishermen. A fourth actor, the manager, imposes or modifies the rules, or, in terms of the model, modifies some particular parameters. Thus, the model allows us to simulate and evaluate the mid-term biologic and economic effects of particular management measures.The bio-economic nature of the model is given by the interaction among the three boxes, by the market simulation and, particularly, by the fishermen behaviour. This last element confers to the model its Mediterranean "selfregulated" character. The fishermen allocate their investments to maximize fishing mortality but, having a legal effort limit, they invest in maintenance and technology in order to increase the catchability, which, as a consequence, will be function of the invested capital.

Key words: Bio-economic models, North Western Mediterranean Fisheries, Fisheries Management.

RESUMEN: "HEURES" UN MODELO BIOECONOMICO PARA LAS PESQUERÍAS MEDITERRÁNEAS, HACIA UN ENFOQUE PARA EVALUAR ESTRATEGIAS DE GESTIÓN. – El modelo bioeconómico "Heures" constituye un primer intento de mecanismo de simulación capaz de servir de base para comprender el funcionamiento del sistema pesquero del Mediterráneo occidental, evaluar medidas de gestión, y analizar las posibilidades de la puesta en marcha de una gestión adaptativa. Esencialmente el modelo consiste en la interacción de tres compartimentos, o cajas, que simulan el comportamiento de cada uno de los agentes que intervienen en la pesquería: el recurso explotado, el mercado y el pescador. Hay un cuarto agente, el gestor, que interviene estableciendo y modificando regulaciones, lo que equivale, en términos del modelo, a modificar ciertos parámetros. De esta forma, el modelo permite simular y evaluar los efectos biológicos y económicos, a medio plazo, de determinadas acciones de gestión. El enfoque bioeconómico del modelo reside en la interacción entre los tres compartimentos, en la simulación del mercado y, muy especialmente, en el comportamiento del pescador. Este último elemento es el que confiere al modelo su carácter "autorregulado" mediterráneo. El pescador encamina sus inversiones a maximizar la mortalidad ejercida sobre el recurso. Así, ante un esfuerzo limitado por la legislación, invertirá en mantenimiento y equipos para aumentar la capturabilidad, de modo que ésta resultará ser función del capital invertido.

Palabras clave: modelos bioeconómicos, Pesquerías del Mediterrráneo Noroccidental, Gestión Pesquera.

*Received June 28, 1996. Accepted August 2, 1996.

INTRODUCTION

Many of the main fisheries around the world are being managed using adaptative strategies. This means monitoring the fishery, assessing it by quantitative modelling once a year, and recommending management actions to be implemented (usually TACs) based on both, the assessment results and an empirical process of trial and error (Hilborn and Walters, 1992).

Mediterranean fisheries are not regulated, at large scale, by any adaptive management procedure, but rather by more or less static rules which include effort, power and gross tonnage limits, closed areas, and other technical measures (Farrugio *et al.*, 1993). TACs have not been implemented in the Mediterranean fisheries. Many of such regulations are not based on scientific advice, and in some cases are contradictory (e.g. legal minimum length versus mesh size) (Caddy, 1990, 1993). Furthermore some of such measures are far from being properly enforced and the use of illegal cod-end mesh sizes or the commercialization of undersized fish are common.

Nevertheless in the Mediterranean, at small scale and at the local community levels, some management measures (so called "bottom-up management" in OECD terms, OECD, 1996) are adopted as feedback response to the direct fishermen experiences and behaviour (Hilborn, 1985) without scientific advice. These measures are based mainly in socioeconomic parameters.

Current methodology to test assessment and management methods can be described under the general title of "Modeling management strategies" (Punt, 1992, 1993; Butterworth and Bergh, 1993; Horwood,1994) or "risk analysis" (Francis, 1991, 1992), and consist in simulating the complete process of fishing, assessing and managing a stock. The dynamics of the exploited stock is simulated by a model, the so-called "operating model" (Linhart and Zuccini, 1986) which is also used to generate historical data. An assessment is carried out on this simulated data. Since the true situation of any real stock is usually not well known, the assessment model can be different (and usually is) from the operating model. Different management methods can then be simulated: determination of TACs by different criteria, limiting effort, modifying mesh size, etc. Note that this procedure does not include any economical consideration.

The process of "fishing, assessment and management" is simulated and projected several years (e.g. 15) into the future. Uncertainty is simulated by Monte-Carlo procedures, introducing stochasticity by random variables affecting some parameters and running a number of simulations (at least 100). The results of the simulations are summarized by the statistics of several variables (i.e. spawning stock biomass, catches, etc.). Uncertainty is also simulated by using a number of alternative operating models. The aim of this procedure is to test different management procedures (including assessment methods) under different uncertainty conditions and assess the risk of different management decisions. The goodness of a management procedure could be defined by several criteria (maximizing long term catches, minimizing fluctuations, minimizing risk of collapse etc.), but in any case it must be robust to the changes of operating models.

Any attempt to applying this methodology to Mediterranean fisheries presents a first problem: no adaptive management procedure has been implemented (in spite of local management measures). Therefore, a fundamental part of the above procedure is not readily applicable, although it could be very useful to simulate such an adaptive management (Caddy, 1993). Since the "selfregulation" of Mediterranean fisheries is driven by economics, the appropriate way to model those fisheries must include the economics as control mechansims (Franquesa, 1993).

THE MODEL

During the last three years, the authors have developed a bio-economic model within the frame of the project "Heures" (Franquesa, 1994). This model is intended to be a starting point for an adaptive management strategy for Mediterranean fisheries. The model introduces economic factors such as market simulation and the response of fishermen according to the economic results.

The model, named "Heures", takes account of the above considerations and is composed of three dynamic boxes named: Stock, Market and Fishermen, and one Management Control box.

a) Stock

Converts fishing mortality at age into catch at age. Any exploited stock simulator can be used as operating model. The only conditions are to have an input vector of fishing mortalities at age (F_t) and an ouput catch at age vector (C_t). The usual equations of the age-structured stock dynamics have been chosen as default model. Different gears (fleets) competing for the same resource are also included (the analysis of competing gears is in fact an important objective of the modelling of Mediterranean fisheries). A stock-recruitment model must also be implemented in order to provide future recruitments.

b) Market

Converts the catch at age vector (C_t) into money. Total revenues are calculated according to:

$$R = \sum_t P_t C_t$$

where P_t is the price of a unit of weight of an individual at age t. Prices are calculated as a function of the size and abundance of the species in the market (allowing the inclusion of external catches going to the market) according to the formula.

$$P_t = \gamma_1 W_t^{\gamma_2} C^{\gamma_3}$$

Where γ_1 γ_2 γ_3 are constants, W_t is the weight if an individual of age t and C is the catch (including the external one). γ_1 is positive. Usually γ_2 will be positive (the greater is the fish, the higher is its price), but it also can be negative (as it occurs with red mullet). γ_3 must be negative since the higher supply reduces market prices.

c) Fishermen

Converts money into fishing mortatlity at age. The Fishermen box attempts to simulate the behaviour of the fishermen and how they convert money into fishing mortality. It is assumed that the goal of fishermen is to get as much catch as possible, given the limitations on effort according to the current regulations in the Mediterranean, where the effort has an upper limit (its legal concept in the Mediterranean context includes fishing time, number of boats, and some of their characteristics -CV, GRT, dimension, etc.- Farrugio, 1994). In principle, fishermen are unable to act on the effort, although they try to by-pass some of these rules; in particular, it is easy to bypass the power limits). Then we should expect the fishermen will fish during maximum time allowed with the maximum efficiency. Since the effort (E) is limited, they should try to increase the fishing mortality (F) by increasing the catchability (q), according the classic formula:

$$F = qE.$$

For a particular gear we assume that catchabilty depends on the state of conservation of the gears and of the capacity to modernise the fleet. Then catchability depends on the total capital (K) invested in the fleet. In the model we assume catchability as proportional to $\ln(K)$.

The concept of capital of a fleet is the current value of the fleet. In brief, this includes the initial cost of the fleet, minus the amortisation and plus the mantenaince cost and the reinvestment.

The model assumes that the goal of fishermen is to increase the catchability as much as possible, and this is a function of their financial capacity. Then, the benefits will be invested following a hierarchy of preferences. In a simplified way, these are:

1. If the profits are positive, the fishermen reinvest part of them in order to increase the catchability (investment in new technology, mantenaince of the boat and gears, etc.). This produces an increment of the fishing mortality.
2. If profits are negative, but fishermen are able to obtain a loan (this ability is function of their credit account, interest rate and capital as guarantee of the loan). In this case they take a loan to maintain their catchability.
3. If profits are negative and fishermen are not able to obtain a loan, they must reduce their catchability by reducing capital (the fleet begins to be obsolete), but the effort is maintained. In this case however the fishing mortality is reduced.
4. If profits are negative and fishermen do not have enough cash to operate (no money for oil or other basic investments), then the effort is reduced and, eventually they go out of the fishery.

Economical parameters are taken from fishermen accounting books. The costs structure includes: costs as salaries, interest rates, oil costs, maintenance, taxes, and also revenues, including subsides.

This is the key box of the model and contains the current selfregulation mechanisms. The external management mechanisms, such as the administrative rules can be included in an external box that we call Management box.

d) Management

This box contains the administrative management tools.

Management measures can be classified as technical ones: setting of effort limits, maximum number of boats, power limits, mesh sizes, etc. (Oliver, 1991), and economic tools such as oil price, interest rate, taxes, subsides, import authorizations, etc. Probably the economic measures could be more efficient than the technical ones in order to manage such fisheries.

Management measures mainly act on the fishermen box, although some can affect the market box (regulating external catches, for instance).

FURTHER ISSUES

Although, as said before, in the Mediterranean no administrative adaptive management system is in place, simulated assessments using methods applicable in Mediterranean fisheries (such as LCA, Lleonart and Salat, 1992; Lleonart, 1993), can be a good exercise for illustrating how such an adaptive mechanism would run.

In its current status the "Heures" model is able to simulate the consequences of management strategies in a fishery. Then, it could be used to extract information to perform an assessment. In order to get an adaptative management the following steps will be implemented.

i) The model has to be fully tested with real data and realistic parameters.

ii) Once the behavior of the model has been tested in a local area it will be exported to other Mediterranean fisheries.

iii) Since the time scale for economic decisions is smaller than those usually employed for stock dynamics, the year appears to be too large a unit of time to properly simulate realistic bio-economic dynamics. Furthermore this implementation is necessary in order to simulate seasonal closures, which are real management tools.

iv) A main problem of the Mediterranean model is related with the multispecificity and multi-target characteristics of almost all fisheries. When a target species produces economic losses fishermen can shift to another objective.

ACKNOWLEDGMENTS

This work is being developed within the project "Heures: Quantitative analysis of the relationships which condition the north-occidental Mediterranean fishing system", founded by the U.E. D.G. XIV MED/93/022, and the project "Un modelo bioeconómico para las pesquerías mediterráneas" founded by CICYT (Spanish government) under contract MARS95-1767. Authors are grateful to D. Bailly for its scientific advice and, to R.Goñi and F. Maynou for their comments to the manuscript.

REFERENCES

Butterworth, D.S. and M.O. Bergh. – 1993. The development of a management procedure for the South African anchovy resource. pp. 83-99. In: S.J. Smith, J.J Hunt and D. Rivard (Eds.) *Can. Spec. Publ. Fish. Aquat. Sci.*, 120.

Caddy, J.F. – 1990. Options for the regulation of Mediterranean demersal fisheries. *Natural Resource Modeling*, 4: 427-475.

Caddy, J.F. – 1993. Some future perspectives for assessment and management of Mediterranean fisheries. *Sci. Mar.*, 57: 121-130.

Farrugio, H., Alvarez, F., Lleonart, J. De Ranieri, S. and Relini, G. – 1994. Study for the assessment and management of fisheries in western Mediterranean. *Final report*. EC.FAR.MA-3-621.

Farrugio, H., P.Oliver and F. Biagi. – 1993. An overview of the history, knowledge, recent and future trends in Mediterranean fisheries. *Sci. Mar.*, 57: 105-119.

Francis, R.I.C.C. – 1991. Risk analysis in fisheries management. *NAFO Sci. Coun. Studies*, 16: 143-148.

Francis, R.I.C.C. – 1992. Use of risk analysis to assess fishery management strategies: a case study using orange roughly (*Hoplostethus atlanticus*) on the Chatham Rise, New Zealand. *Can. J. Fish. Aquat. Sci.*, 49: 922-930.

Franquesa, R. – 1993. Fishery models and management systems. *In The use of the Individual Quotas in fisheries management*, OECD, Documents, Paris.

Franquesa, R. (Coord.). – 1994. *Quantitative analysis of the relations which condition the north occidental Mediterranean fishing system*. Partial Report. Contract no DGXIV-MED/93/022. 211 p (mimeo).

Hilborn, R. – 1985. Fleet dynamics and individual variation: why some people catch more fish than others. *Can. J. Fish. Aquat. Sci.*, 42: 2-13.

Hilborn, R. and C. Walters. – 1992. *Quantitative Fisheries Stock Assessment. Choice, Dynamics and Uncertainty*. Chapman and Hall, New York. London.

Horwood, J.W. – 1994. Modelling of fisheries management strategies. Privately published.

Linhart, H. and W. Zuccini. – 1986. *Model Selection*. Wiley. New York.

Lleonart, J. – 1993. Methods to analyse the dynamics of exploited marine populations: use and development of models. *Sci. Mar.*, 57: 261-267.

Lleonart, J. and Salat, J. – 1992. VIT un programa para análisis de pesquerias. *Inf. Tec. Sci. Mar.*, 168-169: 116 pp.

OECD. – 1996. *Synthesis Report on Management Study (draft version)*. Fisheries Committee.

Oliver, P. – 1991. Bases Técnicas para la regulación de la pesca de arrastre en el Mediterráneo. *Inf. Tec. Inst. Esp. Oceanogra.*, 100.

Punt, A.E. – 1992. Selecting management methodologies for marine ressources with an illustration for Southern African hake. *S. Afr. J. Mar. Sci.*, 12: 943-958.

Punt A.E. – 1993. The comparative performance of production model and *ad hoc* tuned VPA based feed back control management procedures for the stock of Cape hake off the West Coast of South Africa. p. 283-299. In: S.J. Smith, J.J Hunt and D. Rivard (Eds.). *Can. Spec. Publ. Fish. Aquat. Sci.*, 120.

Scient. ed.: J.M. Gili.

ERRATUM

Fluctuations in abundance of small and mid-size pelagics (Erratum)*

J. CSIRKE

FAO, Fisheries Department, Via delle Terme di Caracalla, 00100 Rome, Italy.

In page 491, column 1, paragraph 4, line 1, says:

This is shown in figure 11, where the landing ...

Should say:

This is shown in figure 12, where the landing ...

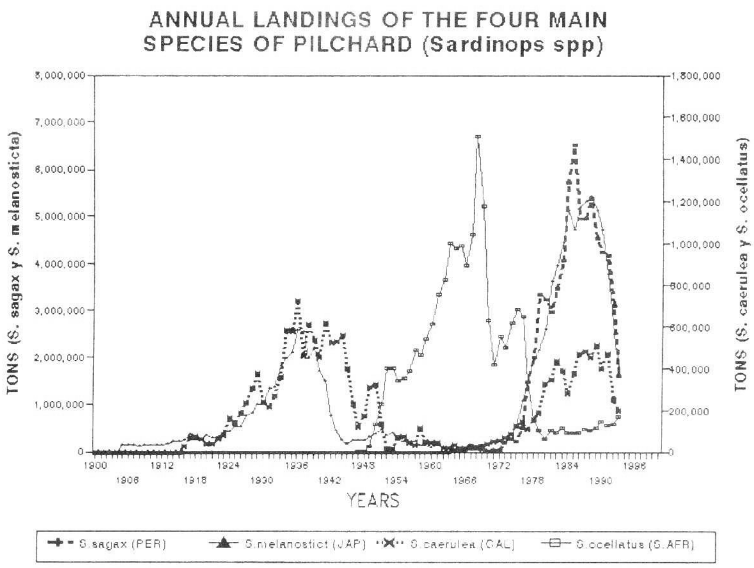

FIG. 12. – Total annual landings of the four main species of pilchars (Genus *Sardinops*) from the Pacific and the Atlantic Ocean.

*Paper published in full in the volume 59(3-4): 481-490 (1995)

INTERNATIONAL SYMPOSIUM ON MIDDLE-SIZED PELAGIC FISH. *C. BAS, J.J. CASTRO and J.Mª. LORENZO (eds.).*