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OVERVIEW OF STOCK ASSESSMENT METHODS AND THEIR SUITABILITY TO MEDITERRANEAN FISHERIES

JORDI LLEONART*

INTRODUCTION

The purpose of this paper is to contribute to the discussion of the 1st point of the terms of reference addressed to SAC by the GFCM. Particularly it refers to the 1st sentence of the 1st paragraph of the appendix G of the Report of the 26th session of the GFCM:

> "To review existing stock/fisheries assessment methods highlighting data needs, outputs expected, pros and cons, and their suitability to Mediterranean stocks and fisheries."

Stock assessment is, according to the SAC glossary (which is taken from ICCAT glossary):

> "The application of statistical and mathematical tools to relevant data in order to obtain a quantitative understanding of the status of the stock as needed to make quantitative predictions of the stocks reactions to alternative future regimes."

I would like to add some remarks to this definition. The output of the stock assessment should provide some parameters that can be related to reference points. Estimations of fishing mortality and stock biomass are particularly useful in this context.

On the other hand, a fishery is a complex system and it cannot be completely described in a simple form. A stock assessment method is a way to see a piece of this system from a very particular point of view, hence a perfect image cannot be obtained from only one method. Different methods are complementary and it is recommended to use several of them if possible.

In this paper do not pretend to be exhaustive in the enumeration of methods neither in the bibliographic references. For that it a complete assessment manual would be required.

However some further definitions and classifications are needed

Indirect methods. According to the GFCM glossary the indirect methods are

> "Methods for stock assessment based on fishery-dependent data, such as catch and effort statistics and age structure of the catch".

Usually the methods based on mathematical models of population dynamics are included under this heading. There are several manuals of population dynamics: Ricker (1975), Csirke (1980), Laurec & Le Guen (1981), Rothschild (1986), Sparre et al.

* ICM-CSIC. Passeig Marítim, 37-49. 08003 Barcelona. lleonart@icm.csic.es

(1989), Hilborn & Walters (1992), King (1995), Gallucci et *al*. (Eds.) (1996), Guerra & Sánchez Lizaso (1998), Cadima (2000), Lassen & Medley (2001) among others.

Direct methods. According to the GFCM glossary the direct methods are

> "Fishery independent methods used in order to avoid the biases of commercial catch data by using research surveys. They are traditionally used for estimating abundance, demographic structure at sea, as well as for the collection of other biological information".

Evaluations based on surveys give biomass, or densities, of fish present in a particular area, during the survey period. The availability of several years of surveys carried out with the same methodology allows the computation of biomass trends. Gunderson (1993) and Foote (1996) present exhaustive study of surveys of fishery resources.

Statistical methods. I include under this heading the procedures of analysis based on the use of more or less descriptive statistical methods such as GLM or time series analysis. They share with the direct methods the absence of any underlying biological conceptual model or mathematical model of the demographic structure. However according to the definitions above, they neither can be included as direct because the input data can arise from commercial as well as survey sources.

Analytic versus **global**. The indirect methods are analytic if the structure by ages or lengths is modelled. An indirect method is global when a model to simulate the whole stock without any internal structure is used. However for some models this distinction is not so clear-cut.

The expansion of the classical assessment methods: single-species and purely biological, are done in several directions:

Ecological approach. The multi-species, ecological, simulation, analysis of environmental effects, and other methods that go further than the classical single-species (which can be classified as indirect) are currently being developed and have start to be applied to fisheries.

Bio-economic approach. The development of models including both, the biology of the stocks and the economics of the fisheries, is a field in development and several approaches have been implemented, also for the Mediterranean fisheries.

Modelling techniques and computing science. The classical assessment methods and parameter estimation are based on quite simple mathematical procedures (differential equations, regression, approximate solutions, etc.). Since much more computing power is available, numerical simulations, non-lineal modelling, bayesian statistics, and other methods requiring medium-high computing performances have been implemented.

A CLASSIFICATION OF ASSESSMENT METHODS AND RELATED TOPICS

1 Indirect
- 1.1 Analytical
  - 1.1.1 VPA
  - 1.1.2 LCA
  - 1.1.3 Y/R
  - 1.1.4 Stock-recrutiment relationship
- 1.2 Global or production model

2 Surveys
- 2.1 Bottom trawl survey
- 2.2 Echo survey
- 2.3 DEPM
- 2.4 Direct counts (not analysed in this paper)
  - 2.4.1 Aerial
  - 2.4.2 Underwater

3 Marking (not analysed in this paper)

4 Statistical methods
- 4.1 Time series analysis
- 4.2 GLM

5 Ecological approaches

6 Bio-economic approaches

7 Modelling techniques and computing science
- 7.1 Simulation
- 7.2 Estimation (not analysed in this paper)
- 7.3 Optimisation
- 7.4 Game theory and risk analysis (no analysed in this paper)

Method	VPA (Virtual Population Analysis). Also called Cohort Analysis (particularly when Pope's approach is used)
Description	From catch-at-age data and some parameters, VPA reconstructs the past history of stock in terms of number of individuals and fishing mortalities. The VPA, and its variants, is the most standard and reliable method of stock assessment.
Variants	The basis of the VPA is the catch equation: $C=F\cdot\overline{B}$ This equation does not have analytical solution for F, and algorithms of approximate solution (like Newton-Raphson) are used. Pope (1972) developed an approach that, with a small bias, allows the catch equation to be solved analytically; this approach is usually known as Cohort analysis. Since VPA is the fundamental method for stock assessment many variants have been developed. The most important that should be mentioned are: Separable VPA (Pope & Shepherd, 1982) which allows to split up F into two factors: a year component (related to the effort) and an age component (related to the selectivity pattern) XSA or extended survivors analysis (Darby & Flatman, 1994; Shepherd, 1999) and ADAPT (Gavaris, 1988; Lassen & Medley, 2001) that incorporate external information (biomass indices, CPUE from commercial catches or from trawl surveys) in order to tune the VPA. LCA and MSVPA are treated in other boxes.
Data needs	Catch-at-age of several years by operational unit (this implies previous age estimations and length composition of catches) M vector Terminal Fs (this imply tuning, through surveys or CPUEs) Length-weight relationship (if biomasses are wanted in the output) Total catch in biomass by operational unit and year
Outputs expected	Numbers of individuals and biomass at sea by year and age (thus series of recruitment, total biomass at sea etc.) Fishing mortality by year, age and operational unit
Pros	The most efficient standard assessment method.
Cons	Many parameters are needed, some of them assumed (M). Tuning is required. It is difficult to get a general view of the resource.
Suitability to Mediterranean stocks and fisheries	Few Mediterranean fisheries dispose of data series and parameter estimations to run a reliable VPA (i.e. Oliver, 1993; Aldebert & Recasens, 1996) but steps in this direction are being taken and the applicability of VPA can be foreseen in the near future. Software: Mesnil (1989), Darby & Flatman (1994), Lassen & Medley (2001)

Method	LCA (length cohort analysis)
Description	A modification of VPA (Jones, 1984). Essentially is a VPA on a pseudocohort that can be run also on the length frequency distribution of the catch. Steady state is assumed
Data needs	A length or age frequency distribution of the catch representing the pseudocohort. *M* vector Terminal *F*s (this imply tuning, through surveys or CPUEs) Length-weight relationship (if biomasses are wanted in the output) Total catch in biomass by operational unit
Outputs expected	Numbers of individuals and biomass at sea by age (recruitment, total biomass at sea etc.) Fishing mortality by age or length and operational unit
Pros	With short data series (even one year) something can be said about the state of the stock
Cons	Since the steady state is assumed (pseudocohort), important biases can be obtained if this hypothesis is far from reality. Hilborn & Walters (1992) express a sharp criticism on this method.
Suitability to Mediterranean stocks and fisheries	It has been extensively used in the Mediterranean fisheries because the problems in applying the VPA due to the generalised lack of long historical series. Mesnil (1989), Gayanilo et *al.*, (1996) Lleonart & Salat (1997) among others have provided software for this analysis.

Method	Yield per recruit (Y/R)
Description	Computes the yield that produces one recruit given particular exploitation pattern (*F* vector) at different intensities of effort.
Data needs	Fishing mortality vector (*F*) Natural mortality vector (*M*) Age-length key or parameters of the growth model
Outputs expected	Equilibrium surface of yield as function of overall *F* (or effort) and exploitation pattern (selectivity). Y_{MAX}, F_{MAX}, virgin biomass. All these results are relative (it means "by recruit")
Pros	The output is very synthetic and gives a general overview of the state of the fishery. Easy to relate to reference points (maxima, current stock vs. virgin stock, etc.). With this method it is easy to detect growth overfishing and get the clues of management alternatives.
Cons	Assumes steady state
Suitability to Mediterranean stocks and fisheries	Very useful and applicable to the Mediterranean when combined with other analytical method providing the required data. It has been extensively applied to the Mediterranean fisheries using as input the output of LCA. The method developed by Thompson & Bell (1934) is an instance of this approach (Sanders, 1995).

Method	Stock-recruitment relationship
Description	It is not properly an assessment method, but an approach to understand the factors driven the recruitment process, which is of fundamental importance in stock assessment.
Data needs	Time series of spawning stocks and recruitments
Outputs expected	There are several proposed models to fit (Beverton & Holt, Ricker, and other more general), but just a glance at the scatter plot “recruitment vs. stock” could be enlightening to understand what is happening with the current and the past situation of the spawning stock and recruitment.
Pros	The only way to detect the recruitment overfishing.
Cons	Inputs are difficult to obtain, can present important biases and is difficult to split off the environmental factors from noise.
Suitability to Mediterranean stocks and fisheries	Good estimators during many years are required, which is difficult to obtain in the Mediterranean.

Method	Production model (also known as global model, surplus production model or catch-effort model)
Description	Method of estimation of the past and current level of biomass and the state of the stock, from the analysis of the relationships between effort and catch. It is based on a growth equation, the relationship $F=q\cdot E$ and the catch equation $C=F\cdot \bar{B}$
Variants	The fundamental approach is the Schaeffer model, which is based on the Verhulst population growth equation. The Fox's approach uses a logarithmic populaton growth equation and the Pella & Tomlinson's approach uses a generalized population growth equation. There are several dynamic (non-equilibrium) models. The composite production model is a modification by substitution of time in the series with different areas, supposed to be in different levels of the steady state. Assumes equilibrium. Abella et *al.* (1999) have applied the composite production model.
Data needs	Historical series of catch-effort data (usually on an annual basis) of one species.
Fitting	It is based on a regression procedure. Warning: it is very easy to fit the model in equilibrium, but this procedure is incorrect. The dynamic approach, more difficult to fit is better. There are some dynamic software to be applied (Fréon et al., 1993, Punt & Hilborn, 1996)
Outputs expected	The three parameters of the production model are obtained: Carrying capacity (equivalent to Virgin Biomass), catchability and growth rate. These three parameters allow drawing the equilibrium curve in the catch-effort plane. If the observed path of the fishery is also drawn on the same graphic, a very general and useful view of the fishery's history is obtained. MSY and E_{MSY}
Pros	Gives a very general view of the current state of the fishery and its history. Easy to relate to sound reference points.
Cons	Inapplicable to multi-species fisheries, mainly due to the difficulties of effort allocation. Not suitable when clear changes of catchability (although this parameter can also be modelled) or changes in selectivity. The only control parameter is the effort.
Suitability to Mediterranean stocks and fisheries	Unfortunately it is not very much adequate to Mediterranean fisheries because of the multi-species, the lack of long historical series, the modifications of the catchability, etc.

Method	Generalised Linear Model (GLM)
Description	An expansion of the multiple regression. It attempts to explain a dependent variable (not necessarily normal distributed) from a set of independent variables, quantitative as well as categorical (factors). It can include interactions among independent variables.
Data needs	Any kind of multivariate data set in which one variable can be considered dependent on the others. Series of data, usually catch, CPUE, effort, data on vessel characteristics, environmental etc.
Outputs expected	It is possible to relate the dependent variable to the independent variables, as effects of environment or fishing power as function of the vessel characteristics. Used for vessel standardisation.
Pros	Absence of underlying biological hypotheses has both pros and cons. It has no constraints from limiting hypothesis. Useful to understand the relationships between fisheries variables (mainly catch and CPUE) and environmental or technical variables.
Cons	It is difficult to accept predictions or any other extrapolation.
Suitability to Mediterranean stocks and fisheries	There are several good examples of application of this procedure to the Mediterranean fisheries (Daskalov, 1998, 1999; Goñi et *al.* 1999)

Method	Time series analysis
Description	The standard ARIMA method is the analysis of a time series (usually monthly structured) which is split off into trend (including cycles), seasonality and noise. Some further developments, as transfer functions, allow to associate these outputs with environmental or other external variables, or intervention analysis to detect anomalous events. (Rotschild et *al.*, 1996)
Data needs	Series of data, usually catch, CPUE, effort, data on vessel characteristics, environmental etc.
Outputs expected	Most frequently the trend and seasonality of the variable analysed are obtained. When additional information (i.e. environmental) is added, it is possible to relate the behaviour of the dependent variable to other variables, such as effects of environment. Short term forecasting.
Pros	Absence of underlying biological hypotheses has both pros and cons. It is a powerful method to reveal hidden structures in the data. Useful for short term forecasting, with due caution in its interpretation.
Cons	Mainly descriptive.
Suitability to Mediterranean stocks and fisheries	Any good temporal series is suitable to be studied by this procedure. Applications to the Mediterranean by Stergiou & Christou, (1996), Stergiou et *al.* (1997), Lloret et *al.* (2000, 2001)

Method	Bottom trawl survey
Description	Abundance (CPUE, biomass and density) estimation of demersal species using scientific non-commercial cruises (regardless of the commercial nature of the vessel or the gear). The so-called swept area method is the procedure to compute biomass and densities (Sparre et *al.*, 1989).
Data needs	Detailed knowledge of the nature (topography, kind of bottom) of the area under study. Well calibrated sampler (bottom trawl). Efficiency of the gear must be estimated. Trawl width and door spread should be also known. Sensors (i.e. SCANMAR) are very useful tools in this task. (Foote, 1996) A very detailed sampling strategy is required. The objective is to estimate actual densities in different areas, not to fish as much as possible.
Outputs expected	Relative measure of abundance (index). Absolute if trawl performance can be quantified. Biomass, density or CPUE estimations by species and area. Detailed species composition of the catch. Spatial distribution of species and communities. Biological data.
Pros	The sampling procedure is under control. The data obtained are reliable and independent of that of commercial catch.
Cons	Representativity of sampling (Foote, 1996). The sampler (trawl) is selective so their product does not necessarily represent the exploited stocks (i.e. the longline exploited stocks). Sampling only possible on soft grounds.
Suitability to Mediterranean stocks and fisheries	Bottom trawl surveys has been used in the Mediterranean for long time, specially in Italy (Levi et *al.*, 1993; Ardizzone & Corsi (Eds.), 1997) From 1994 the UE funded project MEDITS has shown its suitability to the Mediterranean grounds and fisheries (Bertrand & Relini, 1998; Bertrand et *al.*, 1998; Abella et *al.*, 1999)

Method	Echo survey
Description	Biomass and density evaluation using acoustic systems. Particularly suitable for small pelagics (Hedgepeth et *al*., 1996; Foote, 1996)
Data needs	Research cruises Echo sounders and the technology involved (calibration, echo counting, target strength, etc.) Survey design, sampling and sampler (pelagic trawl) Like any other survey, the temporal series including some years gives an added value to them and allows to estimate trends.
Outputs expected	Estimations of fish abundance, as biomass and densities by area. Like any other survey, the temporal series including some years gives an added value to them and allows to estimate trends.
Pros	Fast and efficient
Cons	Fish too close to bottom or surface may be impossible to detect. Species identification Estimating size and age composition Technologic biases
Suitability to Mediterranean stocks and fisheries	Systematic cruises are being carried out in some areas of the Mediterranean for many years (Abad et *al*. 1996; Guennegan et *al*. 2000; Patti et *al*., 2000) Some comparisons with other assessment methods (i.e. indirect, DEPM) have shown a good coherence (Pertierra & Lleonart, 1996).

Method	Daily Egg Production Method (DEPM)
Description	Spawning stock biomass evaluation from the quantity of eggs present in the sea. Particularly applicable to small pelagics
Data needs	Sex ratio Mature female weight Fecundity (and batch fecundity) of females Area of distribution and area of spawning Egg production at sea (through ichthyoplankton cruises in the appropriate areas and periods)
Outputs expected	Biomass of the spawning stock Egg mortality
Pros	Very efficient for small pelagics.
Cons	Delimiting the spawning area Ageing the eggs Estimating egg mortality Expensive
Suitability to Mediterranean stocks and fisheries	Some assessments based on this procedure have been carried out in several zones of the Mediterranean. They have showed to be applicable. Some comparisons with other assessment methods have shown a good coherence. (Chavance, 1980; Regner, 1990; Palomera & Pertierra, 1993; Garcia & Palomera, 1996; Somarakis & Tsimenides, 1997; Casavola *et al*., 1998; Casavola, 1999; Quintanilla *et al*., 2000)

Method	Ecological approaches
Description	Several approaches can be included under this heading. Multispecies modelling (Rose et al., 1996). Some approaches are straight expansions of the indirect (population dynamics) assessment methods taking into account the biological interaction between species (technical, or technological interaction* can be studied by the classical methods). Multispecies VPA or MSVPA (Sparre, 1991; Magnusson, 1995) belong to this group. Other recent development is the individual-based approach (De Angelis and Gross (Eds.) 1992) Ecological modelling based on mass balance and food webs approach (Pauly et *al.*, 2000).
Data needs	In addition to the single species analysis data needs, it requires the interaction factors, particularly the quantification of the predator-prey relationships.
Outputs expected	Quantified pathways of matter and energy between the different species (in steady state).
Pros	It approaches much better the real ecological system than the single species does.
Cons	Huge amount of biological information is required. The number of interaction parameters to be estimated grows with the square of species considered (hence the unknowns become more numerous than the equations)
Suitability to Mediterranean stocks and fisheries	For the moment is difficult to obtain the input data suitable for these models. However there are some scientific teams trying to develop projects in this direction.

* According to the GFCM glossary a technological interaction is "An interaction between fisheries resulting from the impact of one fishery using a particular technology on another fishery, usually using a different technology but exploiting the same resources as target or bycatch. Because of their importance the cross-impact of various fleets targeting overlapping species groups must be assessed. Major source of failure in TACs and quotas management strategies for multispecies and multigear fisheries"

Method	Bio-economic approach
Description	Approach including the population dynamics and the economic structure of fisheries. There are two main kinds of approach: simulation and optimisation techniques.
Data needs	All population dynamics parameters Economic parameters concerning all aspects of extractive activities and commercialisation (costs, profits, prices, etc.)
Outputs expected	Depends on the type of methodology used. Conditions giving optima according different criteria (optimisation approach) or results
Pros	Since the economics is, an important aspect driving the fishing activities, bio-economic modelling is much more realistic than purely biological (or purely economic) approaches.
Cons	Many parameters are needed, hence the complexity of the model increases its uncertainties.
Suitability to Mediterranean stocks and fisheries	Fisheries management is, in the Mediterranean, based on economics rather than in biological or technical measures (unlike the Atlantic, where the TACs are computed without economic considerations). Bio-economic fishery modelling is particularly suitable to Mediterranean fisheries. There are some models (and software) available: Sparre & Willmann (1993), Seijo et *al.* (1994, 1997), King (1995), Pascoe (1997), Ulrich et *al.* (2001), even some bio-economic models are being developed for Mediterranean fisheries: Lleonart et *al.* (1996), Placenti & Rizzo (1998), Franquesa & Lleonart (Eds.) (2001), Lleonart et *al.* (2002).

Method	Optimisation
Description	To find optimal solutions, that is locating the maximum of an objective function subject to constraints (biological, technical, economic)
Data needs	The data required by the chosen objective function and constraints. Since it is usually employed to optimise effort allocation, data on CPUE, and cost-benefit of the fleets are necessary.
Outputs expected	Effort and exploitation patterns giving the optima for given constraints.
Pros	According to the economists, optimisation models are more comprehensive than simulation. They include everything in simulation models plus an objective function to be maximised.
Cons	It has more theoretical interest rather than practical. Seeking optima seldom drives management actions.
Suitability to Mediterranean stocks and fisheries	It is the most beloved method of fisheries economists, and they prefer them to simulation procedures (Pascoe, 1997). Placenti & Rizzo (1998) have developed one approach for the Mediterranean.

Method	Simulation
Description	Indirect (population dynamics) method that reproduce in the computer the dynamics of a stock. Often with the aim to test the effects of different environmental situations or alternative management actions.
Data needs	All population dynamics parameters A recruitment-stock relationship
Outputs expected	Projection to the future of different variables (biomass, catch) and trends at short and medium term. In the case of stochastic models confidence intervals are provided.
Pros	Very useful to analyse and compare the possible results of alternative management measures at short and medium term. To understand complex natural systems.
Cons	Uncertainties in the projection, particularly because of the stock-recruitment relationship.
Suitability to Mediterranean stocks and fisheries	Useful in the stock assessment and suitable to the Mediterranean fisheries. Biologists prefer this approach to optimisation techniques. Le Pape (1991), Verdelhan (1993), Sparre & Willmann (1993), King (1995), Lleonart & Salat (1997), Pauly et *al.* (2000) among others provided software for simulations.

REFERENCES

Abad R., J. Miquel and M. Iglesias. – 1996. Campañas de evaluación por métodos acústicos de sardina, boquerón y ochavo en el Mediterráneo Occidental. *FAO Fish. Rep.* 537: 191-193.

Abella A., A. Belluscio, J. Bertrand, P.L. Carbonara, D. Giordano, M. Sbrana and A. Zamboni. – 1999. Use of MEDITS trawl survey data and commercial fleet information for the assessment of some Mediterranean demersal resources. *Aquat. Living Resour*. 12 (3): 155-166.

Aldebert, Y. and L. Recasens**.** - 1996. Comparison of methods for stock assesssment of European hake *Merluccius merluccius* in the Gulf of Lions (Northwestern Mediterranean). *Aquat. Living Resour.* , 9 (1):13-22.

Ardizzone, G.D. and F. Corsi (Eds.) - 1997. Atlas of Italian demersal fishery resources. Trawl surveys 1985-1987. *Biol. Marin. Medit*., 4(2):568 pp.

Bertrand, J., L. Gil de Sola, C. Papaconstantinou, G. Relini and A. Souplet.- 1998. An international bottom trawl survey in the Mediterranean: the MEDITS programme. In: J.A. Bertrand and G. Relini (co-ordinators). *Demersal Resources in the Mediterranean. Actes de Colloques IFREMER* nº 26: 76-93.

Bertrand, J.L. and G. Relini (Coord).- 1998. *Demersal Resources in the Mediterranean. Actes de Colloques IFREMER* nº 26

Cadima, E.L.- 2000. Manual de avaliação de recursos pesqueiros. *FAO Doc. Técn. sobre as Pescas*, 393. 162 pp.

Casavola N., P. De Ruggieri, E. Rizzi and S. Lo Caputo. - 1998. Daily egg production method for spawning biomass estimates of Sardine in the South-Western Adriatic Sea. *Rapp. Comm. int. Mer Médit*., 35 (2): 396.

Casavola N. - 1999. Valutazione della biomassa di alici mediante la stima della produzione giornaliera di uova lungo le coste adriatiche pugliesi nel 1995. *Biol. Mar. Medit*., 6 (1): 553-555.

Chavance, P.- 1980. Production des aires de ponte, survie larvaire et biomasse adulte de la sardine et de l'anchois dans l'est du golfe du Lion (Méditerranée occidentale). *Tethys*, 9(4):399-413.

Csirke, J.- 1980. Introducción a la dinámica de poblaciones de peces. *FAO, Doc, Téc. Pesca*, 102: 82 pp.

Darby, C.D. & S. Flatman.- 1994. Virtual Population Analysis: version 3.1 (Windows/DOS) user guide. Text modified 29/5/98 for version 3.2 VPA95. Information Te

Daskalov, G. - 1998. Pêcheries et changement environnemental à long terme en Mer Noire. Thèse de doctorat, Université de la Méditerranée (Aix-Marseille II).

Daskalov, G. - 1999. Relating fish recruitment to stock biomass and physical environment in the Black Sea using generalized additive models. *Fisheries Research.* 41, pp.1-23.

De Angelis D.L. & L.J. Gross (Eds.)- 1992. *Individual-based models and approaches in ecology*. Chapman & Hall.

Foote, K.G.- 1996. Quantitative fisheries research surveys, with special reference to computers. In: B.A. Megrey & E. Moksness. *Computers in fisheries research*. Chapman & Hall. 254 pp. 80-112.

Franquesa, R. & J. Lleonart (Eds.)- 2001. Bioeconomic Management Tools for Mediterranean Fisheries. CIHEAM-COPEMED. CD-ROM

Fréon, P., C. Mullon & G. Pichon.- 1993. CLIMPROD. Experimental interactive software for choosing and fitting surplus production models including environmental variables. *FAO Computerized Information Series (Fisheries).* Nº 5, Rome, FAO. 76 pp.

Gallucci, V.F., S.B. Saila, J. Gustafson and B.J. Rothschild. (Eds,)- 1996. *Stock Assessment: auntitative methods and applications for small-scale fisheries.* CRC Press. Lewis Publishers. 527 pp.

Garcia, A. and I. Palomera.- 1996. Anchovy early life history an its relation to its surrounding environment in the Western Mediterranean basin. In: I. Palomera and P. Rubiés, Eds., *The European Anchovy and its Environment. Scient. Mar.,* 60 (supl.2): 155-166.

Gavaris, S.- 1988. An adaptive framework for the estimation of population size. *CSFSAC Res. Doc.,* 88/129 (mimeo).

Gayanilo Jr., F.C., P. Sparre & P. Pauly.- 1996. FAO-ICLARM Stock assessment tools. User's manual. *FAO Computerized Information Series (Fisheries).* Nº 8, Rome, FAO. 126 pp.

Goñi, R., F. Álvarez and S. Adlerstein.- 1999. application of generalized linear modeling to catch rate analysis of Western Mediterranean fisheries: the Castellón trawl fleet as a case study. *Fish. Res.* 42:291-302

Guennegan Y., B. Liorzou and J.L. Bigot.- 2000. Exploitation des petits pelagiques dans le Golf du Lion et suivi de l'evolution des stocks par echo-integration de 1999 a 2000. Paper presented at WG on small Pelagics. Fuengirola (Spain) 1-3 March 2000: 27 p.

Guerra, A. & J.-L. Sánchez Lizaso.- 1998. Fundamentos de explotación de recursos vivos marinos. Ed. Acribia S.A. Zaragoza. 249 pp

Gunderson, D.R.- 1993. *Surveys of Fisheries Resources*. John Wiley & Sons, Inc., 248 pp.

Hedgepeth, J.B., V.F. Gallucci, R.E. Thorne & J. Campos.- 1996. The application of some acoustic methods for stock assessment for small-scale fisheries. In: Gallucci, V.F., S.B. Saila, J. Gustafson and B.J. Rothschild. (Eds.)- 1996. *Stock Assessment: auntitative methods and applications for small-scale fisheries.* CRC Press. Lewis Publishers. 527 pp. 271-353.

Hilborn, R. & C.J. Walters.- 1992. *Quantitative Fisheries Stock Assessment. Choice, Dynamics and Uncertainty.* Chapman & Hall. 570 pp.

Jones, R.- 1984. Assessing the effects of changes in exploitation pattern using length composition data (with notes in VPA and cohort analysis). *FAO Fish. Tech. Pap.*, 256: 118 pp.

King, M.- 1995. *Fisheries biology. Assessment and management*. Fishing News Books. 341 pp.

Lassen, H. & P. Medley.- 2001. Virtual Population Analysis. A practical manual for stock assessment. *FAO Fish. Techn. Pap.* 400. 129 pp

Laurec, A. & J.-C. Le Guen.- 1981. Dynamique des populations marines expliotées. *Publications du Centre National pour l'Exploitation des Océans. Rapports. Scientifiques et Techniques* Nº 45. 117 pp.

Le Pape, 1991. *Gérez vos pêcheries. Logiciel pédagogique de gestion des pêcheries*. Mémoire de fin d'études DAA halieutique ENSAR, 60 P; D; 2684.

Lleonart, J., R. Franquesa, J. Salat & P. Oliver.- 1996. "Heures" a bio-economic model for Mediterranean fisheries, towards an approach for the evaluation of management strategies. *Sci. Mar.*, 60:427-430.

Lleonart, J. & J. Salat.- 1997. VIT: Software for fishery analysis. User's manual. *FAO Computerized Information Series (Fisheries).* Nº 11, Rome, FAO. 105 pp.

Lleonart, J., F. Maynou, L. Recasens, and R. Franquesa.- 2002. A bioeconomic model for mediterranean fisheries, the hake off catalonia (western mediterranean) as a case study. *Sci Mar.* (in press).

Lloret, J., J. Lleonart and I. Solé.- 2000. Time series modelling of landings in Northwest Mediterranean Sea. *ICES J. Mar. Sci*., 57:171-184.

Lloret, J., J. Lleonart, I. Solé and J.M. Fromentin.- 2001. Fluctuations of landings and environmental conditions in Northwest Mediterranean Sea. *Fisheries Oceanography* , 10(1):33-50.

Magnusson, K.- 1995. An overview of multispecies VPA – theory and applications. *Rev. Fish Biol. Fish*., 5:195-212

Mesnil, B.- 1989. ANACO software for the analysis of catch data by age group on IBM PC and compatibles. *FAO Fish. Techn. Pap.* (101) Suppl. 3:73 pp.

Oliver, P.- 1993. Analysis of the fluctuations observed in the trawl fleet landings of the Balearic Islands. *Sci. Mar.* 57(2-3): 219-227

Palomera, I. and. J.P. Pertierra.- 1993. Anchovy biomass estimate by the daily egg production method in 1990 in the Western Mediterranean. In: J. Lleonart (Ed.) *Northwestern Mediterranean Fisheries. Sci. Mar.*, 57(2-3):243-251.

Pascoe, S.- 1997. A preliminary Bioeconomic Model of the UK Component of the Fisheries of the English Channel. Centre fro Economics and Management of Aquatic Resources (CEMARE), University of Portsmouth, Portsmouth, Research Paper No 112.

Patti B., S. Mazzola, L. Calise, A. Bonanno, G. Buscaino and G. Cosimi.- 2000. Echosurveys estimates and distribution of small pelagics Fish concentrations in the Strait of Sicily during June 1998. Paper presented at WG on small Pelagics. Fuengirola (Spain) 1-3 March 2000: 11 p.

Pauly, D., V. Christensen & C. Walters.- 2000. Ecopath, Ecosim and Ecospace as tools for evaluating ecosystem impact of fisheries. *ICES J. Mar. Sci*., 57:697-706

Pertierra, J.P. and J. Lleonart.- 1996. NW Mediterranean anchovy fisheries. In: I. Palomera and P, Rubiés, Eds., *The European Anchovy and its Environment. Scient. Mar.*, 60 (supl.2): 257-267.

Placenti, V., and G. Rizzo.- 1998. Multi-Species Bioeconomic Models. A Multivariate Analysis of the endogenous. Biological Parameters in the Moses Model Project: FAIR-CT95-0561 (mimeo)

Pope, J.G.- 1972. An investigation in the accuracy of the Virtual Population Analysis using Cohort Analysis. *Res. Bull. Int. Comm. NW Atlantic Fish*., 9:65-74

Pope, J.G. & J.G. Shepherd.- 1982. A simple method for the consistent interpretation of catch-at-age data. *J. Cons. int. Explor. Mer*, 40:176-184

Punt, A.E. & R. Hilborn.- 1996. BIODYN Biomass dynamic models. User's manual. *FAO Computerized Information Series (Fisheries).* Nº 10, Rome, FAO. 62 pp.

Quintanilla L.F., A. Garcia, A. Giraldez and A. Cuttitta.- 2000. Daily Egg Production estimate of the spawning biomass of the Sicilian Channel Anchovy during July 1998. Paper presented at WG on small Pelagics. Fuengirola (Spain) 1-3 March 2000: 43 p.

Regner, S.- 1990. Stock assessment of the Adriatic sardine and anchovy using egg surveys. Atti di seminario "Reproductive biology of small pelagics and stock assessment through ichthyoplanktonic methods. *ICRAP Quaderno Pesca*, 4: 17-31

Ricker, W.E.- 1975. Computation adn Interpretation of Biological Statistics of Fish Populations. *J. Fish. Res. Bd. Can. Bulletin* 191.

Rose, K.A., J.A. Tyler, D. SinghDermot & E.S. Rutherford.- 1996, Multispecies modeling of fish populations. In: B.A. Megrey & E. Moksness. *Computers in fisheries research.* Chapman & Hall. 254 pp. 194-222.

Rothschild, B.J.- 1986. *Dynamics of Marine Fish Populations*. Harvard University Press. 277 pp.

Rothschild, B.J., S.G. Smith and H. Li.- 1996. The application of time series analysis to fisheries population assessment and modeling. In: Gallucci, V.F., S.B. Saila, J. Gustafson and B.J. Rothschild. (Eds,). *Stock Assessment: auntitative methods and applications for small-scale fisheries.* CRC Press. Lewis Publishers. 527 pp. 354-402

Sanders, M.J.- 1995. Introduction to Thompson and Bell yield analysis using excel spreadsheets. *FAO Fish. Circ*., No 895. 21 pp.

Seijo, J.C., J.F. Caddy & J. Euán.- 1994. SPATIAL Space-time dynamics in marine fisheries. A software package for sedentary species. User's manual. *FAO Computerized Information Series (Fisheries).* Nº 6, Rome, FAO, 116 pp.

Seijo, J.C., O. Defeo & S. Salas.- 1997. Bioeconomía pesquera. Teoria, modelación y manejo. *FAO Documento Técnico de Pesca* nº 368. 176 pp.

Shepherd, J.G.- 1999. Extended survivors analysis: an improved method for the analysis of cath-at-age data and abundancd indices. *ICES J. Mar. Sci.*, 56:584-591.

Somarakis, S. and N. Tsimenides.- 1997. A daily egg production method biomass estimate of the northern Aegean sea anchovy stock. *Ozeanografika*, 2:133-148

Sparre, P., E. Ursin & S.C. Venema.- 1989. Introduction to tropical fish stock assessment. Part 1, Manual. *FAO Fish. Tech. Pap*. 306/1

Sparre, P.- 1991. Introduction to multispecies virtual population analysis *ICES Mar. Sci. Symp*., 193:12-21

Sparre, P. & R. Willmann.- 1993. BEAM4 Analytical bio-economic simulation of space structured multispecies and multifleet fisheries. Vol. 1 Description of the model.

Vol. 2 User's manual. *FAO Computerized Information Series (Fisheries).* Nº 3, Rome, FAO. 186 and 46 pp.

Stergiou K.I. and E. Christou. - 1996. Modelling and forecasting annual fisheries catches: comparison of regression, univariate and multivariate time series methods *Fisheries Research* 25: 103-138.

Stergiou K.I., E. Christou and G. Petrakis. - 1997. Modelling and forecasting monthly fisheries catches: comparison of regression, univariate and multivariate time series methods *Fisheries Research* 29: 55-95.

Thompson, W.F. and F.H. Bell.- 1934. Biological statistics of the Pacific halibut fishery. 2. Effect of changes in intensity upon total yield and yield per unit of gear. *Rep. Int. Fish. (Pacific Halibut) Comm.,* 8:49 pp

Ulrich, C, D.Gascuel, M.R. Dunn, B. Le Gallic and C. Dintheer- 2001. Estimation of technical interactions due to the competition for resource in a mixed-species fishery, and the typology of fleets and metiers in the English Channel. *Aquat. Living Resour.* vol. 14, no. 5, pp. 267-281

Verdelhan, C.- 1993. Gérez vos pêcheries, Un logiciel pédagogique pour le secteur de la pêche. *Bulletin CE Coopération Pêche*. Septembre 1993.