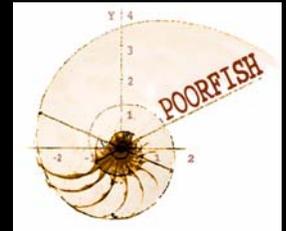


Data poor modelling towards ecosystem fisheries management



POORFISH INTERNATIONAL WORKSHOP

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8-9 September 2008

University of the Balearic Islands, Majorca Island, Spain

PROGRAM ABSTRACTS LIST OF PARTICIPANTS

Sixth framework programme
Research for Policy Support
Priority 8
Specific Targeted Research
EC Contract No. 0022745
April 2007



www.poorfish.eu

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Poorfish overview by Pierre Faille, coordinator of the Poorfish project

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Discussion and identification of research priorities

Session 3: Ecosystems

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Data requirement for modelling ecosystem-based fishery management (EBFM): Two choice experiment (CE) case studies of the English Channel and the Irish Sea by Premachandra Wattage

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Analysis of catch and effort time series of the Barcelona artisanal fishery for management through Bayesian surplus production models by Francesc Maynou

Assessment and bioeconomic analysis of the Majorca (NW Mediterranean) trammel net fishery for management purpose by Gorka Merino, Beatriz Morales-Nin, Francesc Maynou and Antoni Maria Grau

Discussion and identification of research priorities

Using FLR in data poor situations

Graham Pilling
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The FLR framework (<http://flr-project.org>) is a flexible open-source modeling framework for the development and implementation of a variety of fishery, biological and economic models. It can be used for the evaluation of alternative management strategies and procedures, allowing their robustness to different types of uncertainty (e.g. process error and alternative biological assumptions) to be tested, prior to implementation. FLR can also be used to perform exploratory data analysis and develop population parameter estimates, as well as perform stock assessments.

Case studies using FLR have generally focused on data-rich fisheries. However, the framework's flexibility allows it to be extended to data poor situations. In this presentation, the background to FLR will be given, and examples of its flexibility in data poor fisheries provided, citing applications within the POORFISH project. The lessons learned from these studies will be discussed, the adequacy and robustness of the outputs for advice for fisheries managers examined, and key issues highlighted.

The role of Bayesian inference in fisheries management under uncertainty

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In this paper we review the Bayesian methodology and its applicability to fisheries management problems. We especially focus the intension on the use of prior information to decrease the overall uncertainty in fish stock assessment, as this is an important feature of Bayesian inference. The use of prior information may be crucial especially in data poor cases, which are usual in less intensive fisheries. Moreover, the application of Environmental Approach to Fisheries Management (EAFM), becoming important also in EU, requires that the impacts of fishing are estimated also for such species where case specific data may be small or totally missing.

Bayesian approach is the most developed way to describe and implement learning processes in science. The prior information can be developed to describe the earlier findings of scientific activities, which is then updated by new data. The posterior probability can then later on be used as prior in further studies. This practice would create learning chains to science, which would replace the subjective practice of classical statistics to simply discuss the findings of other studies.

Rotating Panel Methodology for Biological Data Collection of the Small Scale Fisheries: Application to the Continental Portuguese Coast

C. Ribeiro, F. Fernandez, I. Dias, J. Pinto and L. Pereira.

General Directorate of Fisheries and Aquaculture of Portugal (DGPA), Lisbon

Small scale fisheries in continental Portugal, including vessels with an overall length < 12 m, represents ca. 90% of the total licenced fishing vessels. Around 9000 fishermen, from a total of 17000, operate in this fishing sector.

Despite the importance of this sector, the Portuguese authorities do not possess sufficient information to allow its detailed characterisation, mainly derived from the lack of obligatory filing of the daily log-book, and from the non-specific character of the sector.

In order to overcome this difficulty, the General Directorate of Fisheries and Aquaculture developed a Rotating Panel methodology, which is based on the classification of the small scale fishery fleet according to the fishing licences and area of activity. In this methodology, a fixed number of vessels is followed through time, so that different patterns of activity, specific of each type of metier, may be identified and characterised.

The follow-up is completed through an individual vessel activity report that allows to describe the specific composition of the catch by fishing gear, time of the fishing, operating area, as well as to estimate the proportion of the catch not sold in the fish auction market (e.g. that has been used for self-consumption or payment to the fishermen). From the matching of this information with the data from the sales in the auction market it is possible to determine the conversion factors used to estimate the real catch per species, fishing gear, area or time of the year. This methodology, which has low running costs, is adapted to the European guidances for the management of metiers.

**Bayesian state-space modelling in data poor environment
Contribution to stock assessment methods for Octopus (*Octopus vulgaris*) in the CECAF region**

E. Rivot^(1,*), M. Robert^(1,*), K. Ono^(2,*),
A. Faraj^(3,*), M. Ould Taleb^(4,*), E. Chassot^(5,*), D. Gascuel^(1,*), A. Solari^(6,*)

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- (*) ISTAM Project URL : <http://projet-istam.org/>

Bayesian state-space modeling (BSSM) coupled with sequential Monte Carlo methods such as Monte Carlo Markov Chains (MCMC) simulations provide a flexible framework for quantitative analysis of discrete-time dynamic fisheries models in a “data poor” environment: *i*) The dynamics of the biological system is described by a state-space model, where the true but unknown population states are modelled through a state process and linked to observations (index of abundance based on survey data or CPUE) through an observation process. All sources of uncertainty, including process variability and errors in the data are readily incorporated in the model ; *ii*) Expert knowledge can be included in the model through the use of informative prior distributions ; *iii*) Diagnostics and predictions are derived on a probability based rationale and are easily embedded within a formal decision analysis.

The value of the BSSM framework is illustrated using 2 examples of stock assessment methods applied to Octopus (*Octopus vulgaris*) in the CECAF region during the ISTAM project (<http://projet-istam.org/>). First, a dynamic biomass production model is developed based on the Mauritanian fisheries data. Catch and survey data suggest a non stationary in the annual production function. The production function is modelled as dependent on the West African coastal upwelling regime intensity. The consequences in terms of interannual variability of reference points such as the maximum sustainable yield are discussed. The second example is a BSSM of a depletion model developed on the Morocco fishery data. It describes the within year depletion of the population under fishery pressure and provides an estimation of the annual recruitment intensity. A hierarchical model is built and enables to reconstruct a time series of recruitment for the last 20 years.

Proto-moment based modelling of population dynamics, performance and data demands

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John G. Pope. England (PopeJG@aol.com)

Proto-moments form the basis of a fish population assessment modelling approach that can handle similarly complex situations and provide similar results to an age based approach but which do not have the expensive data requirements of age based methods. Thus the approach might be advantageous for those stocks where age data are poor or expensive to collect. Proto-moments are the sums of products of powers of length with numbers at length and relate both to the traditional statistical measures, the mean, the variance, the skewness, and the kurtosis of their size distribution, and also to the biologically important measures of the abundance and the biomass of the population. Population models based on this approach are constructed as matrix delay-difference equations. They model moments of the length distributions rather than the age or length distributions, and express population dynamic problems in an analytically tractable form. It is possible to convert the resulting proto-moments back to consistent size distributions when desirable. Here we explore how the proto-moment approach performs in a situation where amounts of data are limited. As an example we use single species dynamics of a fish stock currently assessed by age based approaches to see how age based and proto-moment based assessments compare and investigate how data can be saved in the proto-moment modelling approach.

Management of data poor fisheries: the Mediterranean case

Jordi Lleonart

ICM/CSIC

In this presentation the meaning of “data poor fisheries” in the Mediterranean context is discussed, in particular regarding the advice to the decision makers and their available management tools. The role of scientists as advisors of the administration, and how to handle the available data is discussed. So far some scientific advice (but not all) has been translated into management recommendations in the context of the GFCM. Due to different reasons TROM (target resource-orientated management) is hardly applicable to most of the Mediterranean stocks, however EAF (ecosystem approach to fisheries) is not easier to put in practice although it seems to be the only practicable option. We must identify the problems to be addressed in order to make an efficient transfer from data to management through fisheries science and advice.

Towards the combination of pre-season and in-season stock assessment to monitor the Moroccan *Octopus vulgaris* stock dynamics

A. Faraj ⁽¹⁾, K. Manchih ⁽¹⁾, J. Bensbai ⁽¹⁾, J. Settih ⁽¹⁾,
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The Moroccan cephalopods fishery which mainly targets *Octopus vulgaris*, started in the 60ies and is probably the best informed and the most studied fishery in Morocco. However, stock assessment methods that are traditionally implemented (e.g. surplus production models) suffer from inadequacies between the ecological features of this short-living species and the model's characteristics. Developing more adapted models would require more informative data which are not necessarily available, what led to paradoxically consider this fishery as case of "data poor fishery".

The *Octopus vulgaris* fishery has experienced several changes during the last decade in term of effort, production, monitoring procedures and management policy aspects. The stock assessment methodology has also been modified towards a more appropriate framework combining pre-season stock size assessment using trawl surveys and in-season method by means of depletion model.

In this paper we describe this new framework and show how it is intimately related to the fishery management policy. We describe the specific methodological developments made for both the pre-season assessments using transitive geostatistics, and the in-season assessments using a weekly based Bayesian state-space depletion model. Application to real data allows us to compare our results to the one proposed in CEDA software package.

Shrimp (*Penaeus notialis*) fisheries in West Africa (Senegal and the Gambia)

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In the Senegambia region shrimp fisheries are profitable and concentrate the activities of numerous fishermen: small-scale fisheries operating in the three estuaries (Gambia, Casamance and Saloum) with stow nets and canoes and industrial fishery at sea concentrating the shrimp activities on a small number of vessels. The real activities in the estuaries (number of canoes, fishermen, fishing trips) are poorly known contrary to the sea where the trawlers are well identified.

The shrimp *Penaeus notialis* lives in the sea on muddy bottoms but during several months, juveniles grow in estuaries. Post larvae recruitment in the depends on adult stock located in the south fishing ground of Senegal. Several natural variations strongly act on their abundance: the intensity of the upwelling with variable enrichment and retention processes which condition the survival rate of eggs and larvae at sea and their possibility to migrate to the estuaries; the residence time of juveniles and sub adults in the estuaries that is dependant on water current and salinity and consequently to freshwater input.

Shrimp overfishing is yet a reality leading the Senegalese authorities to establish a two months biological rest in order to preserve the resource but it is worrying because most of determining factors are badly described. Then, it appeared that the Bayesian approach could be suitable through its possibility to incorporate prior knowledge or expert knowledge and to assess the impact of natural and anthropogenic factors on shrimp abundance. An example of application is given through the Casamance study.

Probabilistic Baltic Sea herring (*Clupea harengus* L.) stock assessment

Heikki Peltonen

Finnish Environment Institute and Samu Mäntyniemi (University of Helsinki, Finland)

Probabilistic age-structured stock dynamics and assessment model was developed for the Baltic Sea herring (ICES subdivisions SD 25-29 and 32 excluding the Gulf of Riga). The modeling was conducted with the simulation based OpenBugs software. The study utilized datasets about catches-at-age, and weight-at-age material about age groups 1 to 7 during 1974-2006, and hydroacoustic abundance indices during 1984-2006. Additionally, for the different parameters of the model, informative priors were applied if possible, while some uninformative priors were also included. The model estimates were mostly inline with the recent VPA estimates from ICES: However, there were discrepancies during the years when the cod (the primary predator of herring) abundance was high. The probabilistic model produced uncertainty estimates for parameters and for missing data, and produced (posteriori) estimates e.g. for natural mortality rate, even without multispecies based modeling. The study suggested that the simulation based probabilistic modeling could be a viable alternative for the Baltic Sea herring assessment.

A probability model to estimate pelagic fish stock dynamics and biological reference points: the Bothnian Sea herring as an example

Laura Uusitalo*¹, Samu Mäntyniemi¹, Heikki Peltonen², Jukka Pönni³, Sakari Kuikka¹

Hierarchical Bayesian models were built to estimate stock size and structure, stock-recruitment relationship and limit and precautionary approach reference points for pelagic fisheries for which catch-at-age data exist. Bothnian Sea Baltic herring stock (ICES subdivision 30) was used as the example stock. Limit and precautionary approach reference points were computed for spawning stock biomass as well as fishing mortality. In case of the Bothnian Sea Baltic herring, the data included only a little information about the highest average values of stock-recruitment function, i.e. the asymptote value of Beverton-Holt function or the maximum of hockey stick curve. Uncertainty about this quantity led to large uncertainty about the limit reference point of spawning stock biomass. On the other hand, the fishing mortality limit reference point could be estimated with relatively small uncertainty.

Keywords: age-structured model, Baltic herring, Bayesian, biological reference points, Bothnian Sea, Probabilistic modeling

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Evaluating current minimum landing size (MLS) regimes in the English Channel edible crab fisheries through simulation modelling – a data poor case study

Smith, M.T., Laurans, M. & Scott, F.

Important edible crab fisheries, prosecuted mainly by France and UK, exist in the English Channel, Celtic Sea and Northern Biscay. The fisheries have existed for decades and substantial amounts of data have been collected, but these data are of variable quality. Changes in reporting systems and the distribution of fisheries make interpretation of time series of data difficult. Edible crab stock structure is poorly understood, age and growth rate estimation is difficult and crab biology and behaviour result in spatial, temporal and between sex variations in catchability. Despite large volumes of data being available, the species is considered data poor and stock assessment remains a problem. This study developed and implemented a simulation model for edible crabs using the FLR framework, to evaluate current MLS regimes under increasing fishing effort. Preparatory analyses highlighted problems due to variable quality of commercial data and reliable quantification of some population parameters. A limited set of simulations, assuming constant recruitment, indicated few yield gains and reducing equilibrium biomasses with increasing fishing effort. At reduced recruitment levels, biomasses and yields quite rapidly reduced to lower equilibrium levels, suggesting the fisheries were quite dependent on recruitment. A 2-stage natural mortality model (continuous and instantaneous on moulting) resulted in slightly reduced mortality due to infrequent moulting by some larger crabs. Despite high uncertainty the study suggested that increased effort offers few gains and could potentially compromise sustainability. Further work to improve parameter estimation is required and a meaningful stock recruitment relationship would be illuminating, although at present there is little or no evidence on which to base one.

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EcoTroph, a new tool for ecosystem modelling in data poor situations

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Abstract:

The EcoTroph model is proposed as an extension of the Ecopath with Ecosim (EwE) approach, that can be especially useful in data poor situations. EcoTroph is a trophic-level based ecosystem modelling approach based on simple assumptions and equations. It is articulated around the idea that an ecosystem can be represented by its biomass distribution across trophic levels (TL). Thus, trophic ecosystem functioning can be modelled as a continuous flow of biomass surging up the food web, from lower to higher trophic levels, because of predation and ontogenetic processes. Such an approach, wherein species as such disappear, may be regarded as constituting the ultimate stage in the use of the trophic level metric for ecosystem modelling, providing a simplified, but potentially useful caricature of ecosystem functioning and impact of fishing. Using an inverse form of the EcoTroph model, we also present the Catch Trophic Spectrum Analysis (CTSA), as a method for estimating biomass and fishing mortalities at the ecosystem scale. We show that such a method may be seen as the 'VPA' (Virtual Population Analysis) of ecosystem approaches and provides robust estimates when catches per trophic level and primary or secondary production are known.

We illustrate the usefulness of the trophic-level based approach through the Guinean ecosystem as a case study, where a fast and strong increase in the fishing pressure occurred over the past 25 years. As input, the model only uses the catch per species (or species groups) and estimates of the mean trophic level per group. Based on additional empirical functions, biomass per trophic level and the total ecosystem biomass were estimated from CTSA. Results appear consistent with those of an independent EwE model. Using the diagnostic tools of EcoTroph, we show that increasing fishing efforts led to a three-fold decrease in the biomass of the higher trophic levels, inducing an over-exploitation for these levels and a significant decrease in the mean TL of biomass and catches, which confirm and generalize previous single species assessments. Forecasting suggests that higher yields might be obtained in exploiting lower trophic levels, but this would induce a higher impact on the ecosystem and a degradation of its health.

We finally compare EcoTroph and the standard EwE model in terms of data requirements and advantages or disadvantages. We conclude on the complementarities of both approaches.

Keywords: Ecosystem Approach to Fisheries, Ecosystem modelling, Trophic-level, EcoTroph, Guinea.

Applying the Marine Trophic Index in the Greek Seas

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The Marine Trophic Index (MTI) is an ecological indicator, which can be used for ecosystem management and conservation provided that a reference point is attached to it. In this work we applied the MTI, i.e., the mean weighted trophic level for a cut-off value of 3.75, and the Fishing in Balance (FiB) index to the reconstructed landings (i.e., that include the small-scale coastal fisheries landings which are not reported by the national authorities: see Tsikliras et al. 2007, Fisheries Centre Research Reports, 15 (2): 121-137) of the data-poor fisheries from Greek waters, for the period 1964-2003. Of the 66 fish, crustacean and cephalopod species routinely recorded by the Greek authorities, 25 fish and one cephalopod species (the common octopus *Octopus vulgaris*) were included in our analysis after applying the cut-off MTI value of 3.75. For the majority of fishing subareas (i.e., 9 out of the 16 subareas examined), the MTI exhibited considerable fluctuations throughout the study period, while the MTI in subareas 13 and 14 (northern Aegean Sea) exhibited a smooth increase without any fluctuations. A negative trend, indicating fishing down, was not observed in any of the fishing subareas. Indeed, MTI showed no significant trend for ten subareas and a significant positive trend with time for the remaining six subareas. The FiB index increased with time for 11 out of the 16 subareas indicating a geographic expansion of fisheries or the exploitation of new species. However, a recent (since 1994) decline of FiB was observed in 13 out of the 16 subareas. This indicates that the beneficial effects of the expansion of fisheries (both in terms of geography and species) might have been terminated. Similar results were obtained when the original dataset, i.e. prior to reconstruction, were used with few exceptions (i.e., identifying fishing down in subareas 8 and 13, which are among the main Greek fishing grounds, and subarea 4).

Data requirement for modelling ecosystem-based fishery management (EBFM): Two choice experiment (CE) case studies of the English Channel and the Irish Sea

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EBFM is a new direction for fishery management, essentially reversing the order of management priorities so that management starts with the ecosystem rather than a target species. EBFM aims to sustain healthy marine ecosystems and the fisheries they support through policy development in fisheries legislation, environmental legislation, and a national policy on integrated oceans management. The speed of policy adoption has necessitated equally rapid development of scientific and management tools to support practical implementation.

Any resource can only be managed if sufficient good data and information are available. Unfortunately this principle has been generally overlooked in the case of preferences of management and stakeholders in fisheries where data are essentially weak and generally insufficient. This lack has contributed to the generally poor state of fisheries resources around the world. There is, therefore, a general need to collect more and better data and information on management of EBFM. Collection of data and information is expensive in that it requires people, transport and communication systems to be effective. Furthermore it requires trained people that may not always be available. Because of the cost and the demands on often scarce trained personnel it is important that any programme for the collection of fishery information be efficient. This requires a clear definition of the objectives of management and knowledge of the functions and limitations of the different types of information. This paper identifies some of the types of information and data required for management at different levels of complexity and for different purposes using case studies.

CE was used to estimate the preferences for sustainably and quality labelled fish products within the MISSFISH project (Pickering et al 2001), while it was used to evaluate three over-riding fisheries management objectives in the English Channel within the MOFISH project (Wattage et al 2005). The method employed in this project draws on this growing body of experience, while also pushing out the boundaries on its application and analysis. The CE survey conducted as part of PROTECT was designed to reflect management scenarios of MPAs, with its main aim was to establish how the Irish public would respond to different attributes of the objectives of managing MPAs. It also incorporated the key features regarded as the most important in the implementation and management of MPAs in Irish deep-sea coral areas. This paper describes data collection procedures and analysis of CE for EBFM.

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Management Considerations in Data-Poor Situations

Jake Rice

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Department of Fisheries and Oceans – Canada

This talk will have three parts.

The first will be a summary of the main provisions of the Technical Guidelines for Management of Deep-sea Fisheries on the High Seas, negotiated by States at the FAO in February 2-6 and August 25-29, 2008. Although primarily a policy document, the Guidelines include sections on Data and Reporting, Assessment, Management tools, Enforcement and Compliance, and Review of Performance. The Guidelines were developed specifically for deep-sea fisheries on the high seas, which are fisheries dominated by data-poor situations. They are germane to all of our work, because they lay out the expectations and commitments that States have actually made, and can be held accountable to fulfill (assuming they subscribe to the FAO Code of Conduct for Responsible Fishing. Moreover, although they were developed for fisheries beyond national jurisdictions, many States, including the EU and its members, Canada, the US, Australia and New Zealand have committed that they will not apply a lower standard of management nationally that they have called for in the high seas.

The second will provide a brief overview of an approach for generalizing the classic “three-stage framework” for rule-based management of fisheries, applied in various ways by ICES, Canada, US, and other jurisdictions. The classic framework was designed with some measure of biomass as the x-axis and exploitation as the y-axis. The generalization allows any index of an ecosystem property as the x-axis, any measure of impact as the y-axis, but applies the same logic that underlies the framework using SSB and F.

The third part will tell a simple story of an approach used in Pacific Canada to move from an initial extremely data-poor exploratory phase of a sea urchin fishery, to a fully operational and managed fishery that really worked. The resource has been protected, knowledge and management skill has increased, the fishery has thrived, and everyone is happy. Maybe the approach can work elsewhere.

Bioeconomic analysis of the Mauritanian cephalopod fishery.

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Cephalopods, especially *Octopus vulgaris* (Cuvier 1797), represent a significant fishing resource in Mauritania. The species shows significant inter annual variations in abundance related to varying environmental conditions. The previously conducted stock assessments indicate a state of overexploitation and growth over fishing. A bioeconomic Bayesian population dynamics model is developed to estimate the combined impact of fishing closure timing and duration with minimum landing size in various hypothetical exploitation scenarios to yearly yield, value of yield and spawning stock biomass. The results indicate that the current closure timing, September-October, is optimal and no considerable gains are likely to be attained by prolonging the duration. However, by using yield-per-recruit model, increasing the minimum size at capture seems to be profitable. To attain a high yield from the fishery, both in biomass as in value, the current level of fishing mortality needs to be reduced. The findings of this study will contribute to the sustainable use of cephalopod fishery resources in Mauritania by providing indicators for the economically optimal harvest of the species. The methodology applied here aims to be applicable also to other cephalopods fisheries. This paper was prepared as part of EU 6th framework programme project “Probabilistic assessment, management and advice model for fishery management in the case of poor data availability” (POORFISH), contract no. 22745.

Keywords: *Octopus vulgaris*, cephalopod, Bayes model, fisheries management, bioeconomic

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Analysis of catch and effort time series of the Barcelona artisanal fishery through Bayesian surplus production models

Francesc Maynou

The sustainability of the fishery practiced by the artisanal fleet of Barcelona harbour is threatened by development of harbour infrastructures related to commercial activities other than fishing. Using a time series of catch and effort data (1992-2001) for the main métiers practiced by this fleet (trammelnet and bivalve dredging) we assessed the biological and economic impact of harbour development that took place between 2002 and 2003. We fitted a Bayesian surplus production model to 10 species of fish and invertebrates accounting for 85% of the revenues of the two métiers, trammelnet and bivalve dredging. Our results show that harbour development impacted negatively on the fisheries yield of several species, reducing the profitability of the two fleets during the impact period. While some species recovered after the impact (2004-2005) others remained at very low production levels, showing that harbour development had a negative impact on the artisanal fishery. A simple bioeconomic prediction model was built to help assess the income losses directly attributable to harbour development. We conclude that Bayesian surplus production modelling is a useful tool in data-poor situations, where regular monitoring does not take place, but scientific recommendations are necessary to assess the impact of other human activities on fisheries.

Assessment and bioeconomic analysis of the Majorca (NW Mediterranean) trammel net fishery

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Abstract – Trammel net is the main fishing gear used by artisanal fishers in Majorca Island (NW Mediterranean), and is representative of Mediterranean small-scale fisheries using static gear. The use of static gears close to the coast, where seasonal variability and spatial heterogeneity are high, promotes the diversification of fishing practices or métiers. We analyze the seasonal dynamics of the nets used, target species (red and black scorpionfish, red mullet and cuttlefish) exploitation patterns and the socio-economic conditions under which this fishery takes place, based on General Fisheries Directorate daily sale records (2002–2006). Additional personal socioeconomic interviews allowed the characterization of the trammel net fishery, its fishing behaviour, cost structure and conflicts. Catch and effort data and market surveys are used to evaluate the level of exploitation of the target species and allowed describing Majorca trammel net fishery as an activity based on a sustainable resource. The main target species were found to be near their maximum sustainable yield both by means of a surplus production model (with parameters estimated by CEDA-Catch Effort Data Analysis, software) and an age structured assessment model based on yield-per-recruit analysis. Management actions currently debated by local administration and fishers focus on improving fishers' economic situation, rather than on protecting a threatened resource. One of the management actions proposed is a one day effort reduction, which was analyzed here with the help of a bioeconomic simulation model. A 15-year (2005–2020) simulation allows providing advice to local managers to focus on the commercialization aspects, in order to obtain a higher value to the fish production, rather than expecting to obtain higher profits only by a reduction of the offer.

Key words: Small-scale fisheries / Socioeconomics / Bioeconomic Simulation / Assessment

Lists of Participants: coming soon