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Simulating bio-economic management scenarios for the sea bass (*Dicentrachus labrax*) fishery in France

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Abstract: The fishery for common sea bass (*Dicentrarchus labrax*) is the fourth most important French metropolitan fishery in value terms, with approximately 5 500 tons landed, and a total turnover of about 52 million euro in 2006. Given its high market value, sea bass is targeted by a range of métiers, resulting in interactions between a large number of fleets. The annual contributions to catches and landings of each of these fleets are highly variable, as are their level of economic dependence towards the species. Sea bass is also an emblematic species for recreational fishermen.

Currently, there is no limitation on total allowable catch in this fishery, nor are catch allocations specified at the individual vessel level. The fishery thus faces the traditional difficulties of common-pool resource management, with a potential for the development of excess capacity and a risk of overexploitation. The nature and strength of externalities between fishing agents can thus be very different according to the fleets considered, and may lead to variable levels of potential support towards management decisions aimed at tackling these externalities.

The aim of this paper is to simulate the response of French fishing fleets to the introduction of alternative management scenarios for the sea bass (*Dicentrarchus labrax*) fishery. The analysis is based on a bio-economic model which includes and age-structured model of population dynamics and a detailed representation of the numerous fishing fleets which impact the stock, including the size distribution of catches per fleet and per fishing technique, and the economic status of fishing vessels. The main emphasis of the analysis is on the heterogeneity of commercial fleets in terms of both their harvesting capacity and their reliance on sea bass for their revenue; recreational fishing is also included in the analysis and adds to the heterogeneity of behaviors which are accounted for in the model. Simulation results emphasize the diversity of anticipated impacts of alternative management scenarios from both a short-term and a long-term perspective, and the associated heterogeneity of economic incentives for different fleets to support these management scenarios.

Keywords: *Bio-economic modeling, sea-bass fisheries, management scenarios*

1. INTRODUCTION

The fishery for common sea bass (*Dicentrarchus labrax*) is the fourth most important French metropolitan fishery in value terms, with approximately 5 500 tons landed, and a total turnover of about 52 million euro in 2006. It thus constitutes an important resource for the French fishing fleet, which is the primary contributor to the landings of this species at the European scale. Given its high market value, sea bass is targeted by a range of métiers, resulting in interactions between a large number of fleets. The annual contributions to catches and landings of each of these fleets are highly variable, as are their level of economic dependence towards the species. Sea bass is also an emblematic species for recreational fishermen, which have been estimated to catch at least as much of this species as commercial fishing firms according to recent studies (Fritsch, 2005).

Currently, there is no limitation on total allowable catch in this fishery, nor are catch allocations specified at the individual vessel level. The fishery thus faces the traditional difficulties of common-pool resource management, with a potential for the development of excess capacity and a risk of overexploitation. The heterogeneity of the fleets involved in the fishery however creates a particular situation compared to the traditional representation of open access fisheries. This representation usually assumes that the economic agents involved in a fishery are homogeneous in terms of both their catching capacity and their economic dependence with respect to the exploited fish stock. Hence, the interactions between owners can be described as crossed negative externalities, implying a certain symmetry with respect to the economic incentives which drive their behavior (Clark, 2006). This representation does not apply to the sea bass fishery: in this fishery, the status of economic agents varies strongly, from those who are strongly dependent on the species for their economic viability but who have only limited impacts on the fish stock, to those who weakly depend on the species in economic terms but who strongly contribute to catches. The nature and strength of externalities between fishing agents can thus be very different according to the fleets considered, and may lead to variable levels of potential support towards management decisions aimed at tackling these externalities.

Theoretical bio-economic models aimed at explicitly taking into account the diversity of uses of a common-pool resource, including recreational uses were developed as early as the 1970s (Anderson, 1979; McConnel, Sutinen, 1979; Sutinen, 1979). According to Anderson (2002), a key difficulty in moving from such models to applied simulation exercises lies in the frequent lack of biological and economic data at the required resolution. The Fisheries Information system of Ifremer (www.ifremer.fr/sih) collects extensive sets of data concerning fishing fleets, their activity, their production and their economic status, which make it possible to develop applied models of the interactions between the fleets exploiting the sea bass. The existence of a specific study of the recreational fishing of this species also allows to include this important component in the analysis (Morizur et al., 2005).

The aim of this paper is to simulate the response of French fishing fleets to the introduction of alternative management scenarios for the sea bass (Dicentrarchus labrax) fishery. The analysis is based on a bio-economic model which includes and age-structured representation of population dynamics and a detailed representation of the numerous fishing fleets which impact the stock, including the size distribution of catches per fleet and per fishing technique (metier), and the economic status of fishing vessels. The main emphasis of the analysis is on the heterogeneity of commercial fleets in terms of both their harvesting capacity and their reliance on sea bass for their revenue; recreational fishing is also included in the analysis and adds to the heterogeneity of behaviors which are accounted for in the model.

The paper is structured as follows. Section 2 presents a brief overview of the fishery. Section 3 presents the model developed and the simulated scenarios. Section 4 presents and discusses the results. Section 5 concludes.

2. THE FRENCH FISHERY FOR SEA BASS

The overall landings of common sea bass by European commercial fishing fleets were estimated to be approximately 8.000 tons in 2006 (ICES, 2007). France was the main contributing country with 5.500 tons, followed by the United Kingdom (approximately 600 tons), other countries of the European Union including Portugal, Spain, the Netherlands and Denmark (approximately 800 tons in total), and estimated unreported landings. Between 1998 and 2006, the landed quantities of common sea bass doubled in Europe. This increase in landings primarily resulted from and increase in bass fishing by French commercial fishing fleets. This increase has raised the question of the level of exploitation of sea bass stocks, which were considered as fully exploited at the end of the 1980s (Pawson, Kelley, Pickett, 1987), particularly as there is a strong suspicion of high undeclared catch rates (Ulrich, 2000). In a 2006 report, ICES scientists in charge of assessing the status of common sea bass stocks noted that there had been a probable increase in fishing mortality in recent years. This increase did not put the stock at risk, however, as it had benefited from environmental changes. In fact, the stock had continued expanding, both in size and in terms of its spatial distribution. The scientists recommended limiting the entry of new vessels in the pelagic trawl and mixed trawl fleets, as well as taking measures to protect juvenile fish.

Based on the data collected by the Fisheries Information System of Ifremer, the number of commercial fishing vessels having landed or targeted common sea bass in the North Sea, English Channel and Atlantic was estimated to be 2.498 in 2004, or two thirds of the French fleet fishing in this maritime region. Bass is caught using a variety of gears, including hook-and-line, longline, bottom trawl, pelagic trawl, and nets. Sub-fleets of vessels were identified, based on the main gears they use and their activity profile. The most important sub-fleets include polyvalent trawlers (508 vessels), netters (453 vessels) and bottom-trawlers (446 vessels). Other sub-groups include the pot-hook-and-line sub-fleet (73 vessels), the hook-and-line sub-fleet (73 vessels), the long-liners (69 vessels), the pelagic trawlers (58 vessels), the line and long-line sub-fleet (46 vessels) and the purse seiners (30 vessels). These fleets differ strongly in terms of (i) the spatial and temporal distribution of their activity, (ii) the size structure of fish landed (depending on the gears, areas and seasons fished), and (iii) the prices at first sale for bass landed, which change with the size of fish landed, but also with the gear used to catch it.

In addition, common sea bass is an important target species for recreational fishers. This activity is not subject to licensing, hence no register is available to describe the population of recreational fishers. A recent study based on stratified sampling of the entire French metropolitan population estimated that approximately 700.000 recreational fishermen were involved in the recreational fishery for sea bass, with a total catch of approximately 5.000 tons per year.

3. THE MODEL

The sea bass model was developed based on a modeling tool that aims to quickly generate standard bio-economic models based on a similar representation of a fishery (Versmisse et al., 2007). Implemented in the Virtual Environment Laboratory simulation platform[1], the tool was used to generate a discrete-time model of the sea bass fishery using the following assumptions as regards the description of the fishery. The model was then calibrated based on data collected by Ifremer concerning the activity, landings, returns and

Key model components

Technical module

We consider that there is only one stock of common bass, with *c* the age class of fish (*c* = 1 to 15+.), and *t* the simulation year.

$F_{f,m,c}(t)$, the fishing mortality per age class associated to each fleet and metier, is defined as $F_{f,m,c}(t) = E_{f,m,c}(t) q_{f,m,c}(t) nbvessels_f(t)$ with $E_{f,m,c}(t)$ a measure of nominal fishing effort per vessel and metier assumed constant over the simulation period, $q_{f,m,c}(t)$ the catchability coefficient per fleet and metier, and $nbvessels_f(t)$ the number of vessels per fleet.

Stock dynamics

Total annual mortality of fish belonging to a given age class is written:

$Z_c(t) = M_c(t) + \sum_{f,m} F_{f,m,c}(t)$ with $M_c(t)$ the natural death rate, variable according to age but constant over the simulation period. The number of fish that reaches age *c*, *c* < 15, is defined as $N_c(t+1) = N_{c-1}(t) e^{-Z_{c-1}(t)}$. For age group 15+, the number of fish is written: $N_c(t+1) = N_{c-1}(t) e^{-Z_{c-1}(t)} + N_c(t) e^{-Z_c(t)}$. Recruitment is exogenous, and assumed constant. Fish biomass per age class is written $B_c(t) = N_c(t) W_c$ with W_c the average weight of fish at age *c*.

Catches and landings

Annual catches in numbers of fish per age class by metier and fleet are written $C_{f,m,c}(t) = F_{f,m,c} . N_c(t) . \dfrac{1 - e^{-Z_c(t)}}{Z_c(t)}$

Landings in weight per age class, per metier are thus expressed

$L_{f,m,c}(t) = (1 - d_{f,m,c}) C_{f,m,c}(t) W_c$ with $d_{f,m,c}$ a discard rate, assumed to be nil in the simulations presented in this study due to lack of empirical information.

Economic returns

Gross turnover associated to landings is calculated as follows:

$G_{f,m,c}(t) = L_{f,m,c}(t) p_{f,m,c}$ with $p_{f,m,c}$ the price of bass per age class, per fleet and metier. Net returns are then calculated as:

$NR_{f,m}(t) = (1 - LC_{f,m}) \sum_c G_{f,m,c}(t)$ with $LC_{f,m}$ the landing costs.

[1] http://vle.univ-littoral.fr/fr/index.php/Accueil

costs of fishing vessels operating in the North-East Atlantic region, and has involved compilation and in-depth analysis of a large set of data.

3.1. The biological module

The model is based on an aged-structured representation of the dynamics of a single population of common sea bass (Beverton and Holt, 1957) and on the explicit representation of fishing mortality by the main French sub-fleets involved in the fishery (fishing mortality due to other fleets being regarded as a forcing factor). The population of common sea bass is assumed to form one stock. Recruitment is assumed constant, and occurs once per simulation year at the beginning of the year. Natural mortality varies according to each age class, but is assumed constant over the simulation period. Data used for calibration of the biological module was taken from Fritsch (2005), and is based on pseudo-cohort analysis.

3.2. The technical module

The technical module explains fishing mortality rates for each gear and fleet, which lead to the observed levels of catches and landings (discards being assumed to be nil in the simulations, given the lack of empirical information on the nature and extent of these in the various sub-fleets). The nominal effort of each sub-fleet with each of the five gears used (line, longline, bottom trawl, pelagic trawl, net) is described. The size structure of catches specific to each sub-fleet is calculated, based on the combination of gears used by each fleet and a catchability coefficient for each gear and each age-class. This allows calculation of the fishing mortality associated with the nominal effort of each fleet. The size structure of catches for each gear and age class were derived from the data collected at landing sites (Fritsch, 2005). The demographic structure of landings by recreational fishers is based on data presented in Morizur and al. (2005).

3.3. The economic module

From an economic perspective, each fleet is characterized in terms of its cost structure, and the share of sea bass landings in its total turnover. The analytical approach to the modeling of stock dynamics and catches allows the model to represent the economic tradeoffs associated to changes in the composition of landings, larger fish being sold at higher prices. Turnover associated to landings of sea bass is thus defined, for each fleet, as the product of quantities of fish landed per age group, multiplied by the price at first sale of fish in that age class. Differences in average prices of fish of the same age class caught by different fleets using alternative metiers are also included in the model. Landing costs are deducted from gross turnover to obtain net turnover. Shared costs, including costs which are a function of nominal fishing effort (fuel and oil), and other expenses (e.g. ice costs, bait, food) are deducted from net turnover before determining the allocation of net returns to vessel-owners and crews. Economic parameters were estimated based on the economic survey carried out since 2001 by Ifremer (Leblond and Al, 2005).

3.4. Simulation scenarios

In 2006, the British Department of Environment Food and Rural Affairs launched a consultation on the potential effects of introducing new management measures in the sea bass fishery, with the aim to improve the productive and reproductive capacity of the stock. As part of the consultation, several measures were proposed for assessment, including an increase in the minimum landing size of fish from 36cm to 45cm, throughout the entire fishery. Justification for such a measure rested in (i) the ensuing increase in the number of spawning fish in the stock by limiting the catch of juvenile fish; (ii) an increase in the potential catch of larger fish by recreational fishers; and (iii) an improvement in the size structure of landings by commercial fishers towards higher prices paid for the fish landed. In Ireland, a minimum landing size of 40cm was adopted in 1990 [Bass (Conservation off Stocks) Order, 1990].

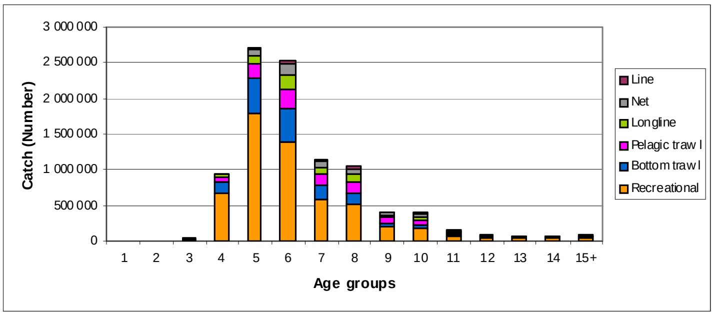


Figure 1 – Demographic structure of landings per main gear (medium values 2003-2005)

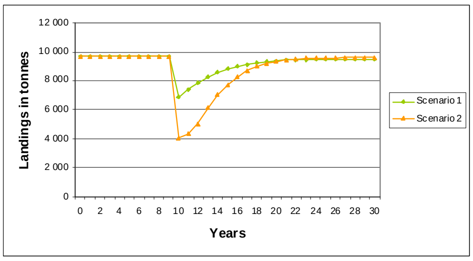
The bio-economic model was used to simulate two scenarios derived directly from these policy orientations as regards management of the sea bass fishery. The first scenario simulates an increase from a minimum landing size of 36cm to 40cm, which protects fish up to 4 years from the fishery given the growth parameters estimated for the stock. The second scenario considers an increase of the minimum size to 45cm, which protects fish aged 7 years or less. In practice, this amounts to removing age groups 4, 5 and 6 from the landings of certain fleets (see fig 1). In terms of numbers of fish caught, recreational fishing largely dominates the landings, although this can include a variety of fishing gears (Fritsch, 2005). Whereas commercial fishers harvest mainly age groups 5 to 8, recreational fishermen also catch younger fish (age group 4), and would be directly affected by the first scenario. Trawling fleets would be strongly impacted by scenario 2.

The model assumes that reducing fishing mortality of younger fish can be achieved by improving the selectivity of fishing gears. We thus assume that there would be no discards, resulting from technical difficulties to actually avoid the catch of the smaller fishes. If such discarding takes place, the longer term benefits of increasing minimum lading sizes would be strongly eroded.

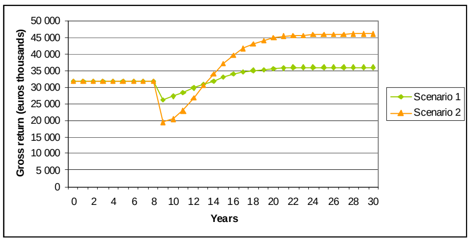
4. RESULTS

Based on simulation results, the components of the fishery for which investments in increased gear selectivity could positively impact on the overall status of fleets can be identified, as well as the distribution of costs and benefits induced in the short and long-term by such investments.

4.1. Global impacts of the two scenarios



2a



2b

Figure 2 – Effects of the two management scenarios on quantities landed (a) and gross turnover of the fishery (b). Size limit changed in year 8.

First, simulation results can be considered at the scale of the entire fishery. Figure 2 illustrates the classical tradeoff between short-term costs and longer-term benefits associated to the adoption of selectivity measures. Following a period of stock recovery after the increase of size limits, landings are restored in the long-term due to the increase in catch rates, all else equal. Higher size limits in scenario 2 leads to long-term results similar to those obtained with scenario 1 in terms of total catch.

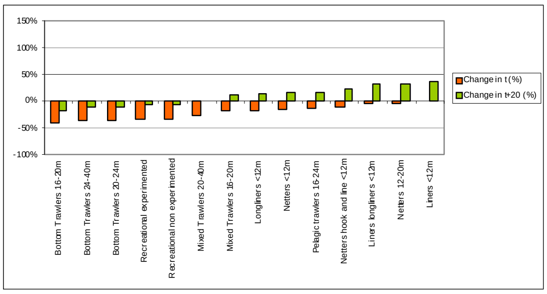
The two scenarios however differ with respect to transitional periods. While both are characterized by short-term losses, the intensity and duration of these transitional periods are proportional to the effort made to increase selectivity (Macher, 2008). The first scenario leads to a short-term drop in landings by 28% compared to the status quo, whereas the reduction is much stronger in the second scenario leading to a 58% decrease in the first year, 54% in the second, 47% in the third year, etc. (figure 2a).

Figure 2b illustrates the simulated impacts of the two management scenarios on the total gross return of the fleets modeled. In the long run, the first scenario leads to an increase of turnover by 12% compared to the status quo, while the second scenario results an increase of 43%, all else equal. These higher levels of returns are observed despite an overall level of catches comparable to that observed with the status quo. This is due to the change which the management measures entail in the size structure of landings, and to the fact that fish aged 6 years and more fetch higher prices at first sale than the smaller fish.

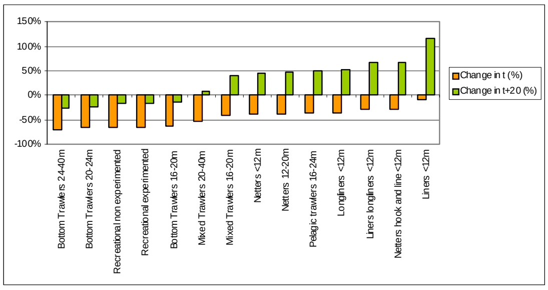
4.2. Distribution of the impacts of the management scenario

Figure 3 illustrates the heterogeneity of the impacts of the management scenarios among sub-fleets in terms of landings. In the short term ("change in t", defining the immediate effect of the management measure in the year following its adoption), the main impact of the conservation measures is to strongly reduce the landings of bottom trawlers and recreational fishers, while the reduction is very limited for the hook-and-line sub-fleet, due to the size structure of catches by these three sub-fleets. In the longer term ("change in t+20"), and under the assumption that nominal fishing effort would remain stable across sub-fleets and gears, and that gear selectivity is only modified for smaller fish, landings increase particularly for the hook-and-line sub-fleet, and to a lesser degree for trawlers and recreational fishers.

Increased size limits would therefore negatively impact landings mainly of trawler and recreational sub-fleets, with expected benefits would mainly go to the hook-and-line and longline sub-fleets. This result is however dependent on the capacity for hook-and-line fishers to actually catch the sea bass which have been allowed to grow due to greater size limits, which remain further away from the coast than younger fish, hence are less accessible to the smaller vessels currently operating in the hook-and-line sub-fleet. Given that fish accessibility to the fleets is seasonally and spatially heterogeneous, materialization of the effects described in these simulations as regards increased catch of larger sized fish would also require spatial and seasonal concentrations of fishing effort which could entail congestion problems, not accounted for in the current version of the model.



3a - Scenario 1



3b - Scenario 2

Figure 3 – Effects of the two management scenarios on selected fleets (changes in landings in %)

Figure 4 illustrates the impacts of the first scenario on the gross turnover of sub-fleets. The immediate effects on the turnover are mainly negative for a number of fleets, with small benefits for others. The most negatively impacted sub-fleets in the short term are the bottom trawlers, the long-liners and the netters and hook-and-line sub-fleet.

In the longer term, all the sub-fleets see their turnover improve compared to the status quo. There are however significant differences between sub-fleets, with those using nets or hook-and-line taking particular advantage of the change in the structure of the sea bass stock. The economic consequences of these modifications for the sub-fleets strongly relate to the importance of sea bass catches in the remuneration of commercial fishing firms and in the utility derived from fishing trips by recreational fishers.

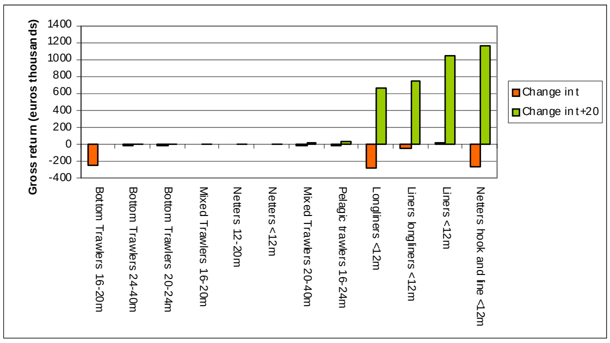


Figure 4 – Effects of the first scenario of gross returns per fleets (changes in %)

5. CONCLUSION

Due to the fact that sea bass is caught by a large number of commercial fishing vessels and recreational fishers, introduction of conservation measures aimed at improving the size structure of catches of this species can potentially impact a large number of stakeholders. The distribution of the short-term and longer-term impacts is a key for predicting the degree of support which may be expected for the measure. The analysis shows that in the short term, selectivity measures imply a strong reduction in the landings of bottom trawlers and recreational fishers, while the catches of hook-and-line fishers decrease only slightly. In the long term, landings of the latter would increase much more in relative value terms than the landings of the other sub-fleets. This allows an improvement in the total turnover generated by the same commercial fleet, hence an improvement in the overall level of profit for firms operating in the fishery.

Implementing such management measures may involve adopting fishing techniques which would also affect the catches of other species, and the benefits observed as regards catches of sea bass may be overrun by costs associated to reduced revenue from these other species. The model allows this to be accounted for, and evaluation of the overall consequences of such measures is underway.

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