Applying Multiple-Criteria Decision-Making Techniques in the Management of Small-Scale Fisheries in Andalusia (Spain)[1]

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Abstract

Fisheries management involves considering several biological, economic and political objectives. They are often contradictory. For this reason, it is almost impossible to reach them simultaneously. Andalusian regional government collaborates with the national government to establish fishing plans for local fisheries. The objectives of these plans verify the aforementioned statement. For instance, two contradictory objectives could be the employment preservation and the recovery of overexploited stocks.
In this paper, various multi-objective programming (MOP) techniques have been applied to two fisheries: the striped venus (*Chamellea gallina*) fishery in the South-Atlantic Spanish region and the Strait of Gibraltar red bream (*Pagellus bogaraveo*) fishery of Spain. The obtained results show the usefulness of these methods for the design of fishery management policies and give evidence that each group with a vested interest in the fishery has its own hierarchy of objectives.

Keywords: Goal Programming, AHP, Conjoint Analysis, Fisheries Management, Gulf of Cádiz.

1. INTRODUCTION

The main goals of fisheries management are to preserve marine resources and to organise their rational exploitation under appropriate economic and social conditions. The aim of this paper is to establish some measures on catch and trade regarding two fisheries located in the South Atlantic Spanish region. These are the striped venus (*Chamelea gallina*, Linnaeus, 1758) fishery in the Gulf of Cádiz and the red bream (*Pagellus bogaraveo*) fishery in the Gibraltar Strait. Next, we present a brief description of both fisheries.

This paper is organised as follows. Firstly, both fisheries are briefly described. In Section 2, we sum up the main objectives of each fishery. In Section 3, after applying three different decision-making techniques, we describe the results. Lastly, we summarise the main conclusions in Section 4.

1.1 Brief description of Striped Venus Fishery in the Gulf of Cádiz

Since the late 1950s the striped venus fishery has been the most important in the shellfish sector in the province of Huelva. As a consequence, it has become of great economic importance. Traditionally, the towed rake has been the most used gear to capture striped venus. It can be considered artisanal for several reasons: the striped venus captures have to be landed and auctioned only in certain ports and there exists special characteristics in the production and trade process and a special system of industrial relations where there still exist the so-called "share system".

Between 1946 and 1956 the striped venus landings were concentrated in the Bay of Biscay and the Northwest area of Spain. However, since 1956 the importance of the striped venus landings in the South-Atlantic region has risen exponentially. This dramatic increase was caused mainly by regulation imposed on trawling with regard to king prawns and plaice. This regulation made a large number of small vessels leave these trawl fisheries and move into the striped venus fishery.

Between 1960 and 1968, there was a huge increase in the striped venus captures –reaching 30,000 tonnes in 1968-. However, this intense activity brought about the overexploitation of the resource. As a result, during the period 1972-1976 the amount of landings decreased dramatically. Some vessels that used to operate in the striped venus fishery started catching other kinds of bivalve molluscs. In addition, Italian

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companies took advantage of the situation and exported large amounts of striped venus to Spain, getting a huge market share in Spain. For this reason, this fishery was only profitable during the Italian closed season. Fishermen stopped being interested in this fishery until the beginning of the current decade, after the introduction of an Italian fishing gear – the hydraulic dredge, that targets the striped venus more accurately. This new gear raised the profitability of the fishery and enabled this catch to compete in the national market. The higher fishing power of this gear and the steady increase in the number of vessels using the hydraulic dredge have provoked a huge increase in the fishing effort on the resource and consequently, the stock biomass has been reduced up to levels that do not permit the resource sustainability. Since 1991, the fishing effort has continued to increase.

1.2 Brief description of Red Bream Fishery in the Gibraltar Strait

The fishing of red bream that operates in the Gibraltar Strait Area[2] is a very recent activity. Originally some Ceuta vessels started operating in this fishery in the Seventies but it was not until 1983 that many of the Tarifa vessels saw a potential fishing ground there, especially after Morocco imposed several restrictions on its waters. During the Sixties and Seventies most of the Tarifa fleet was dedicated to the capture of pelagic species (sardine, mackerel, etc.) mainly to supply the high demand of the local canning industry. The proportion of red bream in captures in Tarifa Port increased from 10% of total landings in 1980 to 50% in 1990, reaching nearly 93% of the total landing in 1994. Since then hardly any other fishery has been developed in the area except for some line fisheries capturing tunas mainly operating for some weeks during the summer of 1996.

The fleet size has increased at the same pace as the level of captures. Today the red bream fleet is made up of 148 small, but well-equipped and 493 fishermen and is highly concentrated in Tarifa (56.1% of vessels and 57.6% of crew members) and Algeciras (31.1% of vessels and 30.6% of crew members). The rest are based in different ports along the coast which have one out of two vessels from this fleet, except for Barbate which has 9 vessels operating in this fishery. However, the red bream exvessel market is limited to the ports of Algeciras and Tarifa and the administration offers some incentives for the vessels of this fleet to be based in one of these two ports.

In a particular area of the Strait of Gibraltar fishermen usually catch red breams using a certain type of hook gear called "voracera". It is worth noting that this fishery is important due to the large number of vessels, the large level of catch and the high profitability. The area in which this fleet operates is characterised for its very strong winds. As a consequence, it is impossible to work more than half of a year. Besides, the catch exclusively consists of red breams. All these facts therefore provoke the fishing activity to be very influenced by the weather conditions.

All these reasons make it convenient to carry out a continuous analysis of the exploitation of the fishery and some regulations should be established in order to avoid the negative consequences that the resource overexploitation could bring about.

2. HIERARCHY OBJECTIVES IN FISHERIES MANAGEMENT

From a biological point of view, the main objective of fisheries management is to obtain a level of catches equal to the Maximum Sustainable Yield (MSY). Therefore, the situation of the fishery should be analysed and a management system should be adopted in order to maintain fish stock at levels capable of producing MSY. The MSY was actually recognised as the most important objective in fisheries management at the International Law Conference on the Sea Law in 1958.

Fisheries management involves considering several objectives. They are often contradictory and it is almost impossible to reach them simultaneously. For both fisheries economic, biological and political objectives have been considered. The first one focuses on economic measures which are aiming at improving the efficiency of the fishing management (economic objective). These measures are the increase of profits and the employment preservation. The second one is related to the fishing resource conservation (biological objective). In the striped venus fishery, we have considered important to distinguish between the recovery of overexploited stocks and the minimisation of the bycatch (prawn and wedge sole) because many vessels operating in the fishery use the hydraulic dredge. This is a very

[2] This is a coastal fishery using longline and most of the vessels are based in Tarifa Port although there are some others in Algeciras, Barbate, La Línea, Ceuta or Málaga.

powerful gear for the capture of striped venus and other clams. However, it presents the disadvantage that its use kills many different high-value species (shrimp, sole...) which come up to the water surface completely destroyed. Consequently, it is difficult to sell them in the fish market. Moreover, it causes a considerable decrease in the stock of those species. In the red bream fishery, the fishing gear used is very selective and, as a result, there is no point in considering bycatch. Finally, the third one deals with improving the relationships among the different interest groups (this would be the political objective).

Regarding the relation among the different groups in the striped venus fishery we have again sub-divided it into three. Firstly, we have added the relation among vessels using different gears. In this fishery vessels are clearly divided into those using the hydraulic dredge and those using towed rake. The former ones are much more modernised and they result to be much more efficient as they cover larger areas per unit of time and they are more likely to produce a situation of overexploitation of the stock. Secondly, we have included the relation among wholesalers and fishermen. It seems that only three or four companies purchase 80-90% of the captures to be then sold in the MERCAS[3], which is a source of continuous unfair situations and disagreements. Lastly, we have considered the relation between ship-owners affiliated with the Striped Venus Association and those who do not belong to that association as the former ones complain about the latter not following the agreements that take place among fishermen. Finally, in the red bream fishery the political objective concern with the proposal of measures which lead to get good relationships among ship-owners who belong to different ports, Tarifa, Algeciras, etc., between fishermen and wholesalers and, last but not least, among Spanish and Moroccan ship-owners.

After identifying the relevant objectives and sub-objectives to be tested, the two hierarchy trees that have been obtained for the analysis are shown in the Figures 1 and 2:

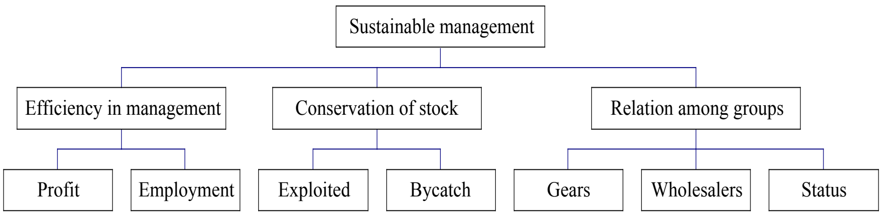

Figure 1. Hierarchy tree for the striped venus fishery

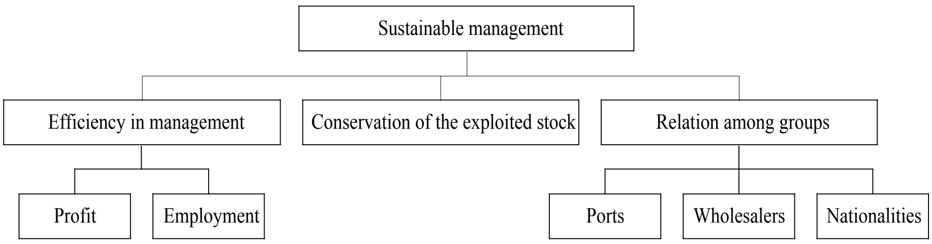

Figure 2. Hierarchy tree for the red bream fishery

3. METHODS

In order to evaluate stakeholder preferences and to assign weights to interest groups, we have applied two techniques, that is, the Analytic Hierarchy Process (AHP) and Conjoint Analysis (CA). The former, developed by Tomas Saaty (1980, 1982), is based on pairwise comparison. The latter, developed by Luce and Tukey (1964), measures overall preference judgements directly using stimulus cards. Goal Programming (GP), which was introduced by Charnes, Cooper and Ferguson (1955), has been used to establish management measures on fisheries. The following sections present the results as regards the three techniques.

In order to apply these techniques we have considered the following interest groups in both fisheries: Guilds of Fishermen, Ship-owners Associations, Trade Unions, Trade Associations, Environmental Associations, Government Organizations and Scientists. They are important because take part in the establishment of fishing laws and organise meetings or strikes which affect decision-makers.

[3] MERCAS are distribution centres which sell different products, mainly fresh fruit and vegetables, flowers and fish.

It is worth noting that in the striped venus fishery there are no environmental associations involved. Furthermore, fishermen and ship-owners have been considered a single group because they are actually quite similar. Ship-owners are usually crew members and the rest of the crew members are usually ship-owner's relatives. For this reason, Ship-owners Associations and Guilds of Fishermen have the same interests.

3.1 The Analytic Hierarchy Process

A survey, which has been based on the above hierarchy trees, has been designed to apply AHP. The survey consists of eight questions for the striped venus fishery and seven questions for the red bream fishery. Three questions are formulated to make pairwise comparisons among the objectives of each fishery using a numerical scale of 1 to 9. Several methods have been used for the interview process: face to face interviews, telephone, fax and mail. We have interviewed presidents, vice-presidents, directors of natural resources departments, directors of promotion departments, secretaries-general and biology teachers regarding the main organisations involved in the management of these fisheries.

The number of participants surveyed and the number of usable surveys in the striped venus fishery is higher than in the red bream fishery (Table 1). This is caused by the fact that there is a higher number of vessels which almost work all the year round in the striped venus fishery. Nevertheless, this situation does not happen in the red bream fishery. In fact, the number of fishing days per vessel in the striped venus fishery is about eight times higher than in the red bream fishery. In the striped venus fishery 39 questionnaires out of 43 were returned (90.7%) and 32 questionnaires out of 35 were returned (91.4%) in the red bream fishery. Participants who play two different roles in the same fishery have been considered once. In addition, it is worth noting that many individuals were reluctant to talk about the conflicts among Spanish and Moroccan ship-owners involved in the fishery. For this reason, we outlined the statistical confidentiality of the provided information and pointed out that the information would be treated as a whole.

Table 1. Number of participants

Groups	Participants surveyed	Number of usable surveys	Response percentage (%)
Striped venus fishery			
• Fishermen Guilds and Ship-owners Assocs.	21	19	90.5
• Trade Unions	8	7	87.5
• Trade Assocs.	6	5	83.3
• Government Organisations	3	3	100
• Scientists	5	5	100
TOTAL INDIVIDUALS	43	39	90.7
Red bream fishery			
• Fishermen Guilds and Ship-owners Assocs.	17	15	88.2
• Trade Unions	6	6	100
• Trade Associations	4	4	100
• Environmental Assocs.	3	2	66.6
• Government Organisations	1	1	100
• Scientists	4	4	100
TOTAL INDIVIDUALS	35	32	91.4

Individual preferences were analysed by means of the Expert Choice software. Fishermen and ship-owners responses were more inconsistent than the ones provided by the other groups. We expected this result because most of them have not clear preferences. As a consequence, we interviewed again those people whose Inconsistency Ratio (IR) was higher than 0.1 (Saaty, 1980).

In order to obtain the priorities of objectives separately by group, we have used arithmetic mean method. Results are a priori the same as we expected in the striped venus fishery (Table 2). Almost all the groups with a vested interest in the fishery consider the conservation of the exploited stock as the most important objective. This result derives from the fact that this fishing resource experienced a significant overexploitation thirty years ago (catch was quite low from 1970 to 1977). As shown in Table 3, red bream fishery results are quite similar to striped venus fishery results. All the interest groups consider the stock conservation as the most important objective.

Up to this point we have not considered the importance of the different groups. As all the interest groups are not equally important, these results may not be completely correct. As a consequence, it seems that their weights should be estimated. For this reason, we designed a second questionnaire and applied AHP again. Numbers in brackets of Tables 2 and 3 represent weights of each interest group.

We have used several methods to aggregate group preferences: aritmethic mean, weighted aritmethic mean, geometric mean and formula used by Ramanathan et al. (1995). Tables 2 and 3 show us that if the interest groups are considered as a whole, the stock conservation is still the most preferred objective followed by the efficiency and the reduction in conflicts in both fisheries.

Table 2. Importance of the objectives in the striped venus fishery

Rank	Objectives	Fishermen & Ship-owners (0.299)	Trade Unions (0.218)	Trade Assocs. (0.227)	Governm. Organis. (0.096)	Scientists (0.16)	Aritmetic mean	Rank	Geometric mean	Rank	Weighted aritmetic mean	Rank	Ramanathan & Ganesh	Rank
2	***Improve Efficiency***	0.358	0.232	0.359	0.327	0.248	0.319		0.305		0.310		0.312	
	Profit	0.177	0.081	0.250	0.121	0.130	0.156	4	0.153	3	0.160	3	0.155	4
	Employment	0.181	0.151	0.109	0.207	0.118	0.163	3	0.152	4	0.150	4	0.157	3
1	***Conservation of Stock***	0.518	0.540	0.508	0.544	0.636	0.541		0.548		0.542		0.540	
	Exploited	0.326	0.433	0.361	0.343	0.257	0.351	**1**	0.366	**1**	0.350	**1**	0.341	**1**
	Bycatch	0.192	0.107	0.147	0.201	0.379	0.190	2	0.182	2	0.192	2	0.199	2
3	***Reduction in conflicts***	0.124	0.228	0.133	0.129	0.116	0.140		0.147		0.148		0.148	
	Gears	0.054	0.101	0.075	0.052	0.032	0.061	5	0.068	5	0.066	5	0.064	5
	Wholesalers	0.038	0.026	0.025	0.033	0.063	0.038	7	0.035	7	0.036	7	0.041	7
	Status	0.032	0.101	0.033	0.044	0.022	0.041	6	0.044	6	0.046	6	0.043	6

Table 3. Importance of the objectives in the red bream fishery

Rank	Objectives	Fishermen & Ship-owners (0.167)	Trade Unions (0.231)	Trade Assocs. (0.169)	Environm. Assocs. (0.284)	Governm. Organis. (0.03)	Scientists (0.119)	Aritmetic mean	Rank	Geometric mean	Rank	Weighted aritmetic mean	Rank	Ramanathan & Ganesh	Rank
2*	***Improve Efficiency***	0.362	0.234	0.279	0.361	0.435	0.314	0.316		0.316		0.315		0.315	
	Profit	0.196	0.041	0.090	0.196	0.218	0.188	0.133	3	0.132	3	0.143	3	0.144	3
	Employment	0.166	0.193	0.189	0.165	0.218	0.126	0.183	2	0.184	2	0.172	2	0.171	2
1	***Conserv. Exploited Stock***	0.496	0.483	0.601	0.529	0.487	0.554	0.537	**1**	0.537	**1**	0.527	**1**	0.530	**1**
3*	***Reduction in conflicts***	0.142	0.283	0.120	0.110	0.078	0.132	0.147		0.147		0.158		0.155	
	Ports	0.033	0.073	0.033	0.017	0.008	0.034	0,033	6	0.034	6	0.036	6	0.036	6
	Wholesalers	0.037	0.093	0.029	0.061	0.027	0.043	0,051	5	0.050	5	0.056	5	0.053	5
	Nationalities	0.072	0.117	0.058	0.032	0.043	0.055	0.063	4	0.063	4	0.066	4	0.066	4

Note: * The order is different for Trade Unions.

3.2 Conjoint Analysis

We designed a different questionnaire which included 12 hypothetical cards (profiles) in order to apply the Conjoint Analysis (CA) technique. For both fisheries, we interviewed the same participants as before. Cards were generated by an orthogonal design (Bradley, 1991) with 2×2×3 discrete options. We used the full profile method (Green and Rao, 1971). As shown in the hierarchy trees above (Figures 1 and 2), the attributes were the three objectives proposed for both fisheries. The first attribute with two different levels concerns with the fishery efficiency. The second attribute deals with the conservation of the exploited stock. For the read bream fishery, we considered two levels (i.e. yes or no), whereas for the striped venus fishery we included the target species conservation and the reduction in bycatch as levels. Finally, we included a third attribute with three different levels to take account of the relationships among the different groups involved in the fishery.

The individuals were asked about their preferences. Each respondent ranked each profile from 1 (the most preferred) to 12 (the least preferred), that is, the total number of cards. The lower the rank is, the greater the preference is. The results were obtained by means of SPSS. Tables 4 and 5 display the averaged importance percentages for each attribute in both fisheries. In addition, the second column shows the relative utilities (*part-worth*) for each level of the attributes. For each profile, the overall utility is obtained by adding the relative utilities of its attribute levels. The Pearson and Kendall correlation coefficients, which are shown at the bottom of each output, were used as measures of the goodness-of-fit. As their values are very close to 1, the models fit the data well.

In general results are very similar in both fisheries. Most of the respondents consider the stock conservation as the most important objective followed by the reduction in conflicts and the efficiency maximisation. In conclusion, results obtained by AHP and CA are quite similar.

Table 4. Conjoint Analysis results in the striped venus fishery

Attributes and levels (Striped Venus)	Utility	Averaged Importance (%)	Rank
Efficiency in management		29.37	*3*
To maximize profit	0.2564		
To maintain level employment	-0.2564		
Conservation of stock		37.53	*1*
Exploited	0.9872		
Bycath	-0.9872		
Reducing conflicts among groups		33.1	*2*
Ship-owners using different gears	1,0513		
Fishermen and wholesalers	-0.2821		
Ship-owners affiliated Association and others	-0.7692		
Pearson´s *R* = 1	Significance = 0		
Kendall´*stau* = 0.97	Significance = 0		

Table 5. Conjoint Analysis results in the red bream fishery

Attributes and levels Red Bream	Utility	Averaged Importance (%)	Rank
Efficiency in management		17.23	*3*
To maximize profits	-0.0417		
To maintain level employment	0.0417		
Conservation of stock		54.52	*1*
No	6		
Yes	12		
Reducing conflicts among groups		28.25	*2*
Ship-owners from different ports	0.0313		
Fishermen and wholesalers	0.0469		
Spanish and Moroccan ship-owners	-0.0781		
Pearson´s *R* = 1	Significance = 0		
Kendall´s *tau* = 0.985	Significance = 0		

3.3 Goal Programming

In this section we present the specification and solutions of a non-linear weighted goal programming (WGP) model regarding management of small-scale fisheries[4]. Weights of goal deviations are fixed and they have been obtained by means of AHP. For both fisheries we have considered the number of vessels and fishing days as variables. Furthermore, in the striped venus fishery we have divided vessels into two groups: the first group includes those vessels using hydraulic dredge and the second group consists of those which do not use it. In the red bream fishery, we have two types of vessels as well, that is, those with a hauling machine and those without it.

3.3.1. Goals

Goals have been classified into three categories according to the management objectives defined in section 3: economic, biological and political goals. Economic goals consist of maximising profits and maintaining at least the employment levels. The biological goal deals with maximising the biomass of the exploited resource. Finally, the political goals are related to minimising conflicts among groups.

8 *Maximise profits*: Decision-makers should determine the maximum profit that could be obtained when all towed rake and hydraulic dredge vessels are working. Then, the profit target value is equal to 24.94 euros/day. This quantity represents the daily guaranteed minimum wage in 1999.

8 *Maximise the employment level*: In order to maintain at least the employment level, the fishing effort exerted by the fleet should be at least equal to the average fishing effort in 1999. As a result, target values are equal to 39166 and 11827 days in the striped venus and red bream fisheries, respectively.

8 *Maximise biomass*: Regarding this goal, the biomass should be at least the Maximum Sustainable Yield (MSY). As a consequence, the stock biomass should be between the MSY and the environmental carrying capacity (*K*). Target values were around 9613.2 and 2409.4 metric tonnes in the striped venus and red bream fisheries, respectively.

[4] See, for example, Tamiz M. and Jones D.F., (1995).

8 *Maintain conflicts among groups in a minimum level*: We have only considered this goal in the striped venus fishery because the conflict ratio is quite difficult to determine in the red bream fishery. Maintaining the current level of conflicts between towed rake and hydraulic dredge vessels is the same as maintaining the current distribution of allowable catch between both fleets. The conflict ratio can be defined as follows:

$$\text{Conflict Ratio} = \frac{\text{daily allowable catch of hydraulic dredge vessels}}{\text{daily allowable catch of towed rake vessels}} \times \frac{\text{no. of vessels using hydraulic dredge}}{\text{no. of vessels using towed rake}} \quad (1)$$

The maximum daily allowable catch is 0.15 and 0.1 tonnes for hydraulic dredge and towed rake vessels, respectively. The number of hydraulic dredge and towed rake vessels is 80 and 45, respectively. As a result, the target value of this goal is equal to 2.67. The higher the positive or negative deviations from the target value are, the higher the number of conflicts between both fleets is.

3.3.2. Constraints

The WGP model has the following constraints:

1. Biomass Constraint: We have combined biomass and effort objectives by means of the sustainability condition in Schaefer´s production model (1954). Parameters of this equation have been estimated for striped venus and red bream. The estimates are shown in Table 6, where K is the environmental carrying capacity, q is the catchability coefficient and r is the intrinsic growth rate.

Table 6. Estimates of parameters

Parameter	Striped venus[5]	Red bream[6]	Units
K	19226.3	4818.8	M. Tonnes
q	$1.95\cdot10^{-5}$	$2.64\cdot10^{-5}$	1/vessels-days
r	0.456	0.34	1/Tonnes

2. Effort Constraints: We have established two constraints regarding the effort. Firstly, the fishing effort exerted by the fleet can be defined as the sum of efforts, E_1 and E_2, corresponding to hydraulic dredge and towed rake vessels in the striped venus fishery and vessels using a hauling machine and those which do not use it in the red bream fishery. In addition, we have considered in the striped venus fishery that the fishing power for hydraulic dredge vessels is 3.1 times higher than for towed rake vessels. Regarding the red bream fishery, the fishing power for vessels using a hauling machine is 1.244 /0.756 higher than for those which do not use it.

Secondly, we have also included the maximum potential fishing effort exerted by the fleet. In order to compute it, we have multiplied the number of vessels by the highest possible fishing effort. The fleet size is 80 and 108 in the striped venus and red bream fisheries, respectively. The highest possible fishing effort amounts to 240 and 120[7] working days in the striped venus and red bream fisheries, respectively. Therefore, effort cannot be larger than 19200 and 12960 days in the striped venus and red bream fisheries, respectively.

3. We have also taken into account Gordon-Schaefer's profit model, which can be written as follows:

$$B(h,E_1,E_2) = \gamma_2(1-\gamma_1)p\cdot h - \gamma_2 c_1 E_1 - \gamma_2 c_2 E_2 - c_F \quad (2)$$

where, $B(\cdot)$ is a profit function which depends on γ_2 , which represents the percentage of daily expenses corresponding to ship-owners and is estimated to be equal to 0.5. We have considered as variable costs the sales costs (port costs, exvessel market costs, etc..), γ_1, which is about 0.11 and the effort costs (labour costs, fuel, feedstuffs, lubricant, etc), c_1 and c_2, which depend on the number of fishing days. The effort costs have been obtained from the ship-owners' surveys. Therefore c_1 is equal to 86.3 and c_2 amounts to 62.1 in the striped venus fishery. In red bream fishery, c_1 and c_2 are equal to 106.4. Moreover, in the striped venus fishery fixed costs (fishing gears, capital depreciation, etc.) have been considered as well. These fixed costs amount to 422.5 and 298 in hydraulic dredge and towed rake vessels, respectively.

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[5] MEMPES, (2000), p. 91.
[6] García del Hoyo, J.J., (2001), p. 193.
[7] Weather conditions have a great influence on the number of fishing days in the red bream fishery. Consequently, the number of fishing days per vessel fluctuates a great deal. It is sometimes less than 30 or it might even be more than 100.

The price *p* represents the 1999 average price before taxes in the exvessel market minus labour costs. It is interesting to note that the salary payment method is so-called "share system" in both fisheries. According to 1999 trade statistics, the striped venus price is about 2.4 euros/kg. However, it is suspected that reported prices are false. For this reason, we have carried out a sensitivity analysis in relation to *p*. Assuming that *p* is between 1.2 and 3.6 euros/kg., we have analysed all the solutions. For the read bream fishery, we have estimated an inverse demand function[8], which relates outputs and prices, because of the high price elasticity of demand.

Finally, we have considered Schaefer's model as production function. In particular, we have assumed a positive correlation between the effort and the fishing mortality ($h = q\,X\,E$).

4. Constraints for variables: We have assumed that the maximum number of fishing days amounts to 212 and 60 days in the striped venus and red bream fisheries, respectively. The maximum number of hydraulic dredge and towed rake vessels is equal to 80 and 45, respectively. Furthermore, the maximum number of vessels which use and do not use a hauling machine amounts to 53 and 55, respectively.

3.3.3. Results

Before obtaining solutions, goals have been normalised by means of the percentage normalisation method[9] because elements in objective functions are measured in different units. As a result, we eliminate the possibility that any bias could be produced towards goal achievements with high target values[10]. The WGP solutions have been determined by means of the software package LINGO and are presented in Table 7 and Figure 3.

Table 7. Sensitivity analysis in relation to *p* for the striped venus fishery

	Goals							Variables			
		Employment				Fishing Effort		No vessels		No fishing days	
p	Profits (euros)	hydraulic dredge	towed rake	Biomass (tonnes)	Conflicts	hydraulic dredge	towed rake	hydraulic dredge	towed rake	hydraulic dredge	towed rake
1.2	710518.9	22106.04	17198.32	12839.03	2.67	5653.72	2117.49	27	31	209.4	211.8
		39304.36				7771.21					
2.4	1738539.9	22028.22	17137.78	12861.52	2.67	5633.8	2110.06	41	45	137.4	145.4
		39166				7743.86					
3.6	2787929.9	22132.16	17218.64	463872.5	2.67	5660.4	2120	40	31	141.5	212
		39350.8				7780.4					

In the striped venus fishery, results of the sensitivity analysis show us the fleet composition is different. All goals are achieved for the three different prices. The higher the prices are the higher profits and biomass are. The results concerning total effort are quite similar for the three different prices. Nevertheless, there are some differences between the effort exerted by hydraulic dredge and towed rake vessels. Solutions are different because of fixed costs.

In the red bream fishery, the biological goal is achieved before the economic goal. If we consider the minimum guarantee wage as the target value, the employment goal is achieved and the effort is lower than the Maximum Economic Yield (MEY) effort. On the other hand, if we consider the average wage of workers in 1999 as the target value (51.15 euros), catch and effort increase. In addition, the effort is higher than MEY effort and it is very closed to the MSY effort. Although the economic goal is achieved for the whole fleet, it is not achieved if we consider separately the two types of vessels which compose the fleet. This is caused by the fact that vessels with a hauling machine are more efficient. As a consequence, results are influenced by the type of wage considered as the target value.

[8] García del Hoyo, J.J., (2001), pp. 236-245.
[9] Romero, C., (1991).
[10] Romero, C., (1993), p. 65.

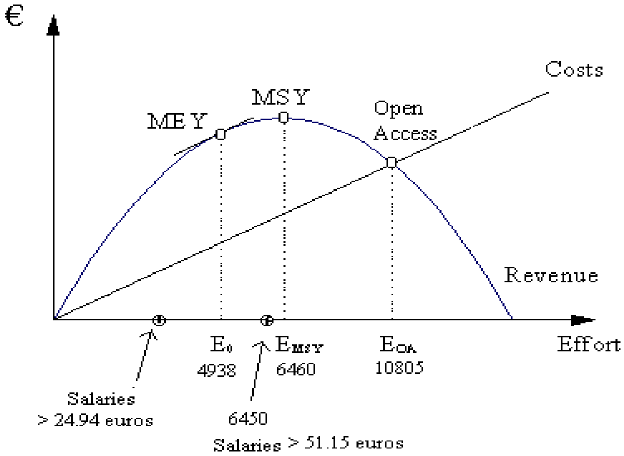

Figure 3. Results obtained for the red bream fishery

4. CONCLUSIONS AND RECOMMENDATIONS

As this study shows, multi-criteria decision-making techniques are appropriate to establish management measures for multi-objective fisheries. In particular, results have been coherent in both fisheries. Using AHP, results lead us to consider the stock conservation as the most important objective followed by the efficiency maximisation and, finally, by the reduction in conflicts. In order to verify the AHP solutions, we have also applied the CA. The stock conservation is the most relevant objective again. However, the other objectives are almost as important as the stock conservation. Finally, WGP has been applied on a more specific model. It has allowed us to establish the appropriate management measures. The goals we have considered have been profit maximisation, stock conservation and employment maintenance. In addition, the constraints we have included deal with demand, Schaefer's production model and utility functions. In the future, we intend to include other constraints and goals in the GP model. Accordingly, we could take account of other issues which have not been included in our GP model. For example, we could incorporate goals or constraints related to conflicts among the interest groups in the red bream fishery, other demand functions, etc. We could even change weights of goal deviations. In addition, as there are several GP techniques, we could use some of them such as Lexicographic GP and compare solutions.

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