Spatial and Inter-temporal economic sustainability assessment: A case study of the open oceans Basque purse-seine fleets.

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Abstract

The aim of this paper is to analyse the economic sustainability of fisheries exploitation through taking into account both the spatial and inter-temporal dimension of the Basque purse-seine fisheries targeting tuna. The Rapfish methodology is used for the analysis of Basque purse-seine fisheries operating in the Indian, Atlantic and the Pacific Ocean, between 1990 and 2006 years. In accordance with what has been observed in other Rapfish studies, the analysis shows that the contribution towards sustainability depends on many different attributes (both in the short-run and long-run), such as the average wage, subsidies, profitability and the gross added value. In general, it is stated that the purse-seine fleet operating in the Atlantic Ocean presents the worst economic sustainability, in contrast to the one operating in the Indian Ocean which usually gets the best economic performance. This paper also analyses the different contribution to the economic sustainability when fishing is around Fish Aggregation Devices (FADs) instead of free-swimming schools. FADs are increasingly used by tuna purse-seine fleets all around the world and the contribution or not to the economic sustainability could be considered to be an important determinant factor for policy makers and fishers. This paper demonstrates the influential role of FADs on the economic sustainability of the tuna purse-seine fleet operating in the Indian Ocean, but not for the other fleet operating in the Atlantic. Finally, it is for mention that the Rapfish technique is postulated as a complementary tool for defining justifiable policy recommendations and fishery management options.

Keywords: Integrated assessment, fishing resources, inter-temporal sustainability, spatial sustainability, Rapfish.

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1. Introduction

Sustainability in the fisheries sector is undoubtedly accepted as a desirable aim. The questions are then, how to define sustainability and how to measure progress towards that. Currently one of the main goals of the Common Fisheries Policy (CFP) in the European Union is to assure the long-term sustainability of fish stocks by preventing the over-exploitation of the resource by the fishing industry. Overfishing has become one of the main threats to modern fisheries and it is known that many stocks in European Union waters are now below their safe biological thresholds. The CFP promotes sustainability through implementing various stock conservation measures. These include setting targets for Total Allowable Catch (TAC), and Total Allowable Effort (TAE) as well as enforcing technical measures such as closed areas and mesh sizes.

In addition to the pressure placed on fish stocks from the high fishing effort, other factors such as biological uncertainty, socio-economic issues and technological developments may also threaten the sustainability of fisheries worldwide. In this sense, García and Staples (2000) state that “sustainability requires explicitly that both the conditions of the ecosystem and the people living in it are either good or improving as a consequence of an action”. Thus, in order to assess the sustainability of fisheries, it is necessary to integrate data from various disciplines such as economics, sociology and ecology. This data can be both quantitative and qualitative.

The main objective of this paper is to analyse the economic approach to sustainability through the use of Rapfish, a non-parametric evaluation methodology, developed by the Fisheries Centre at the University of British Columbia, Canada. Rapfish uses simple and easily scored attributes to provide a rapid, cost-effective, and multi-disciplinary appraisal of the status of a fishery, in terms of comparative levels of sustainability (Preikshot et al., 1998). It has been used to compare the sustainability status of many fisheries (Alder et al., 2000; Baeta et al., 2005; Preikshot et al., 1998; Tesfamichael and Pitcher, 2006; Murillas et al, 2008; Garmendia et al, 2010).

In this paper we apply this technique to perform both an inter-temporal and spatial analysis of the Basque purse-seine fleet, operating in the Indian, Atlantic and Pacific Oceans using real data collected between 1990 -2006[1].

This dynamic and multi-criteria analysis using Rapfish provides a useful tool. Firstly, it enables an assessment of the effectiveness of fisheries management. Secondly, the results provide information to policy makers about the best policy options for the economic sustainable management of fisheries in the future.

The paper is organised as follows. Section 2 describes the case study of the purse-seine fisheries. Section 3 introduces the Rapfish methodology and defines the attributes used in this paper. Section 4 presents the results. Comments and conclusions obtained from the analysis are detailed in the last section.

2 The Basque purse-seine fleet and fisheries

The evolution of the purse-seine (PS) fleet, in terms of the number of vessels, shows an increase in the number of vessels until the year 2006 (going from 19 vessels in 1990 to 24 vessels in 2006) and from this year onwards there has been a slight reduction of the total number of vessels in this fleet.

The Basque PS fisheries[2] are carried out by vessels with 68 meters on average, an average gross tonnage about 2,200 and an average number of fishers on board of 25. Basque PS fleet has its base-port in *Bermeo* (One of the main ports in the Basque Country), however this fleet usually develops the fishing activity in the Indian, and Atlantic Oceans. Only two vessels operate in the Pacific Ocean.

The data collection work for this particular fleet has been undertaken since year 1990 by through a survey to obtain costs and revenues of the fleet. The level of aggregation of the input data is the vessel and the used sample represents the 80%, 60% and 80% of the total Basque vessel population in 2004, 2005 and 2006 year,

[1] As far as we know there are four other papers (Alder *et. al.*, 2000; Pitcher and Preikshot, 2001; Murillas et al 2008, Garmendia et al, 2010) applying Rapfish within a dynamic framework. The two first papers refer to dynamic analyses focus on a longer but discontinuous time series data.

[2] According to the FAO, a fishery is defined as “a unit determined by an authority or other entity that isengaged in raising and/or harvesting fish. Typically, the unit is defined in terms of some or all of the following: people involved, species or type of fish, area of water or seabed, method of fishing, class of boats and purpose of the activities”.

respectively. In the same way, the sample represents the 65%, 43% and 65% of the total Spanish vessel population.

The indicator system for Basque PS fleet is presented in Table 1. In particular, the Table is now completed with the Rapfish index which next section is devoted to its estimation. Additionally, the cost structure is also presented in Table 2.

[Insert Table 1]

[Insert Table 2]

As it is observed in Table 1 economic performance over the short-run seems to be better in the case of the fleet operating in the Indian Ocean in 2004 and 2006 years, although this position in the ranking is not necessary maintained over the long-run (see 2004 and 2005 years). In particular, looking at the crew share the values for the Indian Ocean are better than for the other oceans in both 2004 and 2006 years. This result must be interpreted with the help of the cost structure presented in Table 2. Any case, it is rather difficult to extract conclusions about the best or the worst economic performance of a fleet/fishery attending only to one indicator. That is the reason why in general reference and critical values are also adopted.

Analysing the estimated critical values, it is important to note that the economic performance is in general profitable for all the fleets according to the Operating Profit Margin. In general, the gross margin is at least a 30% of the total revenues, although in same cases it goes up to a 50%. Moreover, the under-capacity is stated for each analysed fleet according to the definition from the Break even Revenue.

3. Rapfish methodology and key attributes

Rapfish has been developed using five evaluation fields (economic, ecological, technological, social and ethical) but, given the interest not only in the current sustainability status of the fisheries but also in its evolution over time, the analysis has focused on the economic field. This choice is justified firstly by the availability of data and secondly for their suitability in capturing the dynamics of these fisheries in the short-term. An analysis of the historical evolution of the fisheries and of the ethical and social, and biological issues surrounding the fisheries would require a longer time frame which, although interesting, is beyond the scope of this paper.

In particular, it has chosen four key attributes to be included in the Rapfish or economic sustainability analysis. Thus, in this multivariable approach it is necessary to assign scores to each attribute in order to make the selected indicators comparable. Kavanagh and Pitcher (2004) provide approximate scores on a scale from the worst to the best score. Following their approach, we refer to this scale system using the "good" and "bad" terminology for the minimum and maximum possible levels and always under the sustainability perspective. The overall 4 attributes that have been considered, grouped in one unique economic evaluation field are listed in Table 3.

[Insert Table 3]

Time series data for most of these attributes is available and this enables to score them annually for the period 1990-2006 (see Tables A1 in the appendix). Additional details concerning the evaluation criterion in Table 3 are offered for the attributes for which the scored process is developed using Rapfish.

- **Average wage:** An average wage earned by a person working within the agriculture and fishing sectors in the Basque Country (National Statistics Institute) has been compared with the average wage for these fisheries between 1990 and 2006. When wages exceed more than 2 and 3 times the average wage it is assigned "more" and "much more", respectively.

- Subsidy: The score for this attribute is related to the average subsidies received by fishermen between 1990 and 2006. In general when subsidy exceeds more than 150.000 and 200.000 euros/vessel/year it is assigned "large" and "heavily reliant".

- **Gross Added Value, GAV**: The score for this attribute is related to the positive or negative value of this attribute defined as the total revenues less the intermediate costs. When GAV > 1.500.000 and 3.500.000 euros/year it is assigned the "GAV>0" and GAV>>0, respectively.

- **Profitability**: The score of this attribute is related to the difference between the total revenues and the variable and fix costs. When profitability is higher than 2.000.000 euros/year, then it is assigned Profits>>0.

Once all of the attributes have been scored, Rapfish uses a statistical ordination technique, a Multi-Dimensional Scaling (MDS) to reduce the NxM matrix of fisheries (N) and attributes (M) to generate an Nx2 dimensional space that represents the sustainability status of each fishery (see Kavanagh and Pitcher (2004)).

4. Results

In this section it is presented the results obtained using Rapfish analysis for the Basque PS fisheries to get knowledge about: (i) the spatial and inter-temporal differences among fisheries in terms of their contribution to the economic sustainability, in Indian, Pacific and Atlantic Oceans. (ii) Their different contribution to the economic sustainability before and after using fishing FADs, in the Indian and Atlantic Oceans.

4.1 Purse- seine fisheries exploiting tuna in open oceans

Fig. 1 represents the results of the Multi-Dimensional Scaling (MDS) statistical analysis which shows the sustainability of PS fisheries exploiting tuna in Atlantic, Indian and Pacific Ocean during the period 2004-2006. The horizontal axis goes from 0 to 100 and represents the sustainability status for economic dimension whereas the vertical dispersion is due to different combinations of scores (i.e. the same value in the horizontal axis can be reached through different combinations of scores of the attributes).

[Insert Fig. 1]

Economic sustainability is between 55 and 90. In general, the lowest values (between 55 and 67) correspond to the PS fisheries operating in the Atlantic, while the best values (between 79 and 90) are assigned to the vessels operating in the Indian Ocean.

Dispersion along the years and oceans on the horizontal axis is then very high depending on the fishing area. But a high dispersion is also observed in the vertical axis (see for example the result for the Atlantic and Pacific Ocean in 2004 year). This means that the sustainability levels are achieved through the combination of different scores of the selected attributes, and this could have some management implications3.

The result of a Monte Carlo analysis is obtained for 100 repeats adding random zero mean normally distributed error with 95% confidence interval set to 20% of full range for each attribute. The result, plotted in the Fig. 2**¡Error! No se encuentra el origen de la referencia.** assures the robustness of the previous result (Fig. 1). Besides, it is for mention that it is important to get knowledge not only about the particular value of the Rapfish index for each fleet (Fig. 1), but about the most frequently area (between 0 and 100) covered by each fleet (Fig. 2). Attending to the last criteria, in general, it is stated that the Atlantic is located more to the left, along the abscise axe, indicating the worse economic performance of the three studies fleets. On the other side, the Indian Ocean is located more to the right which means the best economic performance in the analysed time period (2004 to 2006).

[Insert Fig. 2]

The leverage of individual attributes on Rapfish ordinations determines how much each attribute influences in the overall ordination[4]. According to this analysis (see Fig. 3) subsidy represent the most key attribute influencing sustainability scores while the other three variables have the same influence on sustainability score within the economic dimension, which undoubtedly has management implications.

[Insert Fig. 3]

4.2 Purse- seine fisheries around Fish Aggregating Devices, FADs

Guillotreau et. al, 2011 introduces that since the early 1990s, Fish Aggregating Devices (FADs; i.e. manmade floating objects) have been increasingly used around the world by the purse-seine fleets targeting the three main species of tropical tuna: skipjack

[3] Changes in one attribute to improve sustainability could have different results for each fishery.
[4] Leverage is calculated as a standard error of differences between ordinations obtained with and without including the attribute.

(Katsuwonus pelamis), yellowfin (Thunnus albacares) and bigeye (Thunnus obesus). These authors also continue clarifying that FADs, like any floating object, attract tropical tuna and other tropical species, being the main advantage of FADs for fishers that they increase their catchability of tuna, as compared to sets on free-swimming schools (FS). Firstly, they help fishers locate the fish (reducing search time). This is particularly true at present with satellite tracking buoys attached to FADs which allow the long term tracking of FADs. Secondly, fishing around FADs provides high successful set rates compared to those for FS.

This section deals to describe and analyse if there could be an economic sustainability motivation of fishers to choose FADs and/or FS when fishing. This section tries to determine if there is different economic contribution before and after using FADs by the Basque PS fleet.

With this objective in mind the 1990-2006 time- period has been divided into two smaller periods, the first one from 1990 to 1997 (FS time-period) while the second one from 1998 to 2006 (FADs time-period). The economic sustainability of both periods is shown in Fig. 4.

[Insert Fig. 4]

The economic sustainability dimension scores are around 54 for the Atlantic PS fleet whereas for the Indian operating fleet scores are adopted values in the range 50-60. In this case, dispersion in the vertical axis is not remarkable and much lower than in the horizontal axis.

The economic performance related to the Indian Ocean let to state an improvement of the economic performance of fleet from the first period to the second one. However, this result does not maintain when analysing the Atlantic Ocean index, for which the economic performance is rather similar in the two analysed periods. Any case, it is not possible to assure which is the origin of this better economic performance observed for the Indian Ocean fleet. Finally, although index is also calculated for Pacific Ocean fleet, given that the two only vessels of the sample did not operate in the first analysed period any comparison along the time is provided.

5. Discussion

This paper analyses the sustainability of three Basque PS fisheries operating in open oceans using the Rapfish methodology. This technique allows the study of the sustainability of fisheries in a multidimensional and inter-temporal framework providing relevant and useful information for policy makers. The analysis has been carried only for the economic evaluation fields between 1990 and 2006. The application of Rapfish is not straightforward, and both the attributes themselves and the definitions for scoring and criteria have been redefined to adapt them to the context of this case study.

In general, the economic dimension maintains a good sustainability status, in the time period from 2004 to 2006 year, above 79 score for the PS fleet fishing in the Indian Ocean. However, on the contrary side the economic sustainability of the Atlantic fleet might constitute the focus of future policies with the aim of improving it. Besides, the increasingly use of FADs by tuna PS fishing in the Atlantic has not contributed to improve the economic sustainability of this fleet, which should be considered as an economic determinant of FAD fishing, even if it seems to be demonstrated FAD fishing increases fishing capacity.

Thus, FAD fishing does not always assure an economic sustainability improvement (with respect to a FS fishing) and besides it could be in line with the widespread awareness that "increases in fishing-fleet capacity represent one of the main threats to the long-term survival of marine captured-fishery resources and fisheries themselves" (Pauly et al., 2002). Guillotreau et al, 2011 conclude that no effect can be demonstrated by the price difference between large yellowfin tuna and skipjack. The overall strategy of skippers remains to catch as much as possible tonnage, without paying attention to the relative price levels.

Leverage analysis shows that all the attributes considered are relevant in determining the (un)sustainability pattern of the three fisheries selected and that a single attribute, that is the subsidies, dominate the analysis. However, as Tesfamichael and Pitcher (2006) state, the attributes which scored high in leverage should be given due attention in the future planning of a sustainable fishery.

In the analysis, in general, the observed vertical dispersion is high for the three fisheries within the analysed economic dimension. This makes it difficult to predict the possible structure of the fishery and to find medium to long term policy options.

It should also be noted that although Rapfish analysis does not explain the causality relations among different variables, the results are consistent with what bioeconomic models (that do allow causality) predict (Clark, 1990). Hence both approaches may be viewed as complementary tools for defining policy recommendations and management options.

To conclude, it is for mention that one limitation of this paper is the inclusion of only one dimension in this analysis, that is, the economic dimension. However, to consider the integration of additional ecological, technological and socio-economic dimensions of the fisheries Rapfish would encompass a useful approach to reflect potential trade-offs among different dimensions. Win-win situations are hard to find and policy makers usually face complex decisions where improvements in some aspects of the fishery derive a loss for others. In this sense Rapfish is a useful tool that can make sense of the complex questions which arise when looking at fisheries sustainability as a whole whilst simultaneously considering all of the related dimensions. Looking at the other dimensions different from the economic one, and analysing compensability among all these dimensions could be an interesting field for further research, and would provide an interesting basis for current debate in relation to strong versus weak sustainability approaches in the context of natural resource management.

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Table 1. An Indicator System for Spanish PS fleet by ocean

Year	2004			2005			2006		
Ocean	**Indian (IO)**	**Atlantic (AO)**	**Pacific (PO)**	**Indian (IO)**	**Atlantic (AO)**	**Pacific (PO)**	**Indian (IO)**	**Atlantic (AO)**	**Pacific (PO)**
Indicators measured in euros (average by vessel)									
Short-run indicators									
Value of landings	6,865,727	3,740,909	5,155,208	7,211,756	3,825,703	6,300,946	9,099,782	5,228,804	5,360,391
Gross Margin or Gross Cash Flow	2,345,530	956,571	2,505,374	2,318,096	945,420	3,177,014	2,983,713	2,242,823	1,876,065
Gross Value Added	4,110,111	1,812,982	3,646,6191	4,697,877	2,029,192	4,575,005	5,052,205	3,269,770	3,289,231
Long-run indicator									
Net Result, Full Equity Profit	2,162,387	594,689	2,253,393	2,131,031	943,385	3,004,850	2,065,233	1,716,014	1,652,958
Other indicators									
Employment on board	24	26	25	25	26	25	25	26	25
Crew share by employment	47,458	33,505	45,294	52,970	58,189	57,723	54,616	30,718	38,643
GT	2,832	1,190	2,490	2,832	1,190	2,490	2,890	1,190	2,490
Reference Points									
Operating Profit Margin	0.34	0.26	0.48	0.32	0.25	0.50	0.33	0.43	0.35
Break Even Revenue, BER	2,315,189	2,386,510	1,102,068	2,191,412	2,139,640	1,034,109	3,107,386	1,359,952	1,421,867
Capacity using BER	-1.96	-0.56	-3.67	-2.29	-0.78	-5.09	-1.24	-1.67	-1.59
Rapfish sustainability index	90	61	70	79	61	79	88	55	55

Table 2. Cost Percentage Structure for Spanish PS fleet

Year	2004			2005			2006		
Cost item \ Ocean	**Indian (IO)**	**Atlantic (AO)**	**Pacific (PO)**	**Indian (IO)**	**Atlantic (AO)**	**Pacific (PO)**	**Indian (IO)**	**Atlantic (AO)**	**Pacific (PO)**
Crew	23.23	23.69	35.55	24.20	22.73	39.59	20.02	21.82	24.26
bait	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salt	1.13	1.28	0.95	1.05	1.03	0.80	1.56	1.13	0.91
Ice	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gear	5.50	5.35	0.00	4.10	5.72	0.00	4.97	4.10	0.00
Food	1.44	2.06	3.04	1.45	2.53	2.82	1.43	2.01	2.95
Drink	0.00	0.00	0.00	0.01	0.04	0.00	0.00	0.03	0.00
Lubricant	0.84	0.98	1.44	0.90	0.78	1.28	0.72	0.76	1.81
Spare	7.82	7.89	0.07	5.91	4.06	0.00	4.87	4.01	0.00
Box and packaging	0.00	0.39	0.00	0.00	0.00	0.00	0.49	0.00	0.00
Repair	5.53	10.10	13.09	6.27	14.03	11.03	4.36	7.56	12.42
Machinery Hires	1.82	0.11	0.00	0.00	0.00	0.29	2.71	0.00	12.22
Cofradía* quota	0.24	0.29	0.00	0.25	0.30	0.00	0.02	0.15	0.00
Port costs	2.86	4.01	1.41	1.65	3.38	3.14	4.99	4.37	3.68
Transports	13.08	6.76	0.21	20.46	14.98	0.31	12.49	13.11	1.17
Insurance premium	3.48	4.34	9.59	3.23	3.47	8.08	3.19	3.45	6.55
gas	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.03	0.05
Gasoil	16.47	16.51	27.07	22.52	18.76	21.62	26.37	25.90	27.32
Clearing items	0.03	0.02	0.07	0.22	0.52	0.56	0.11	0.45	0.51
comunicaciones	0.67	0.57	0.39	0.56	0.50	0.38	0.83	0.97	0.35
Expenses, travels	2.54	3.17	1.10	2.79	2.38	0.93	2.60	2.24	1.16
Port tax	0.04	0.05	1.54	0.00	0.00	0.00	0.27	1.12	0.00
Licences	3.02	4.22	4.27	3.60	2.94	3.08	1.26	2.18	2.27
Others	10.26	8.19	0.22	0.83	1.86	6.05	6.73	4.62	2.37
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

* Kind of fishermen association.

Table 3. List of attributes for the analysis

	Economic Indicator	Possible scores	“Bad” score	“Good” score	Notes
1	Average wage	0,1,2,3,4	0	4	Do fishers make more or less than the average person? Much less (0); less (1); the same (2); more (3); much more (4).
2	Profitability	0,1,2,3	0	3	Profitability: Revenues- variable costs – fix costs Profits>>0 (3); Profits>0 (2); Profits=0 (1); Profits<0 (0)
3	Subsidy	0,1,2,3	3	0	No subsidies (0), <somewhat (1), >large (2), >>heavily reliant (3).
4	GAV	0,1,2,3	0	3	GAV<0 (0);GAV=0 (1);GAV > 0 (2), GAV>>0 (3)

Table 4. Economic attributes scoring.

Fisheries	Year	Subsidy	Average wage	Profitability	Added Value
2006	Atlantic	1	3	2	2
	Indian	1	4	3	3
	Pacific	2	3	2	2
2005	Atlantic	2	4	2	2
	Indian	2	4	3	3
	Pacific	2	4	3	3
2004	Atlantic	0	3	2	2
	Indian	0	3	3	3
	Pacific	2	3	3	3

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Fig. 1. Rapfish Index Ordination for Basque PS fleet

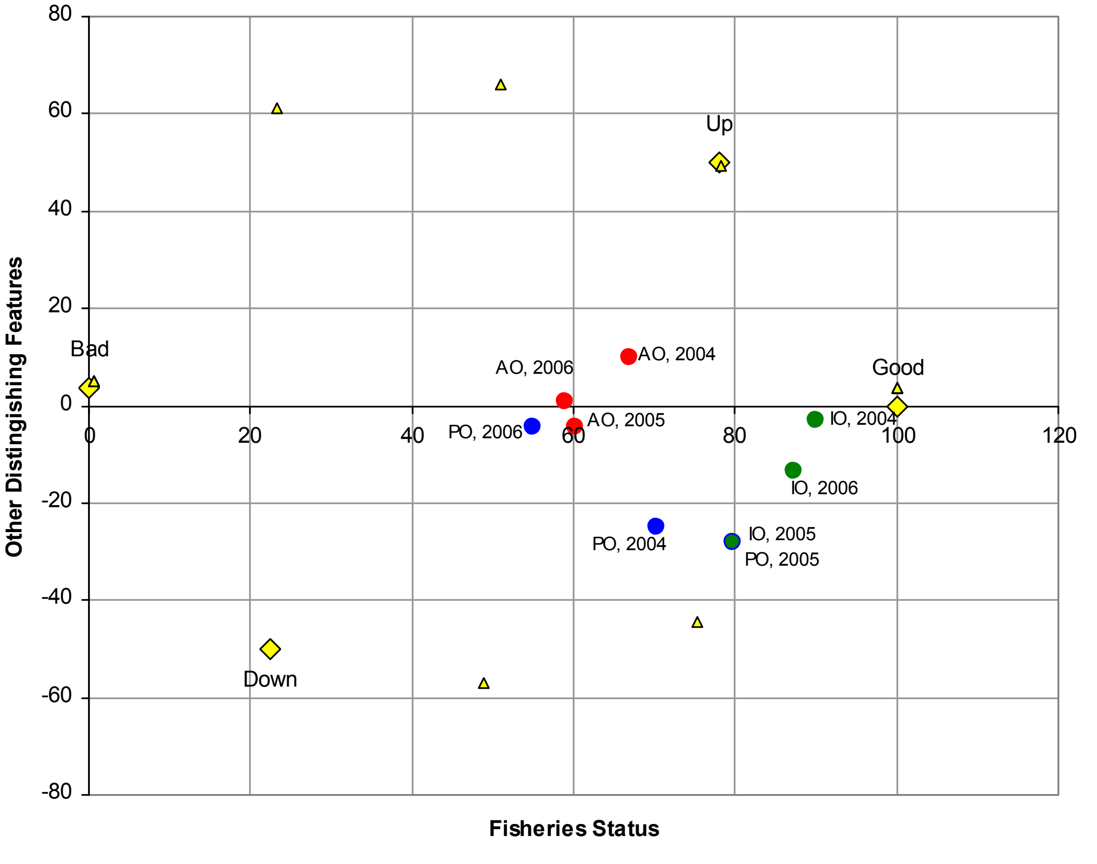

Fig. 2. Monte Carlo Analysis for Basque PS fleet

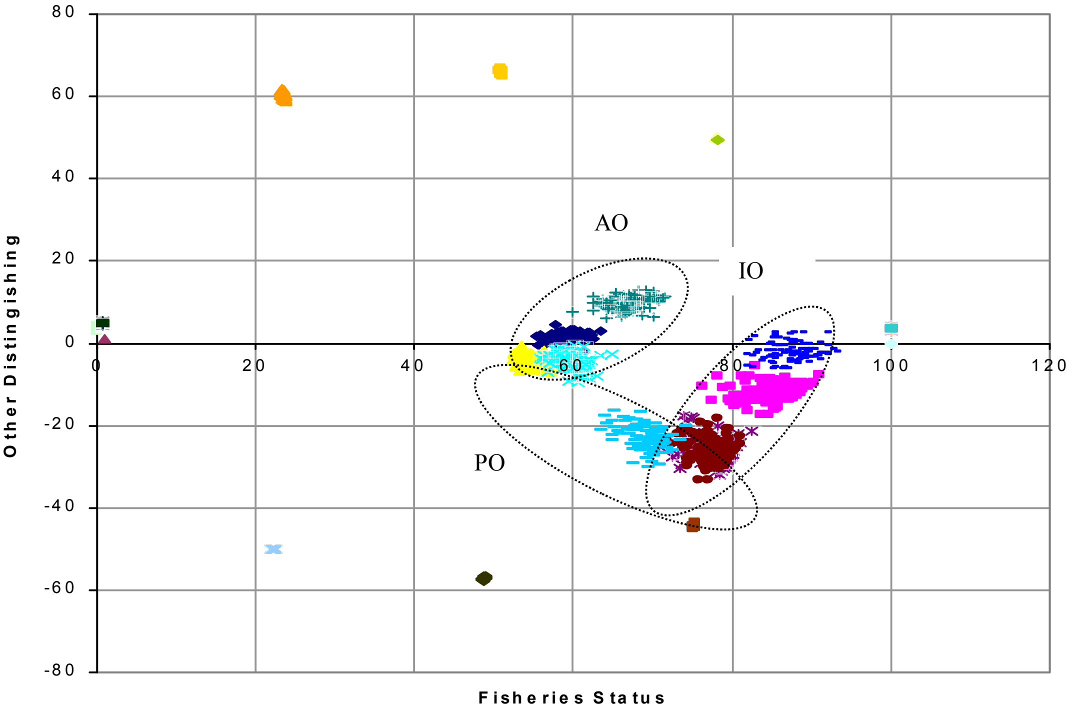

Fig. 3. Leverage analysis for the Basque PS fleet

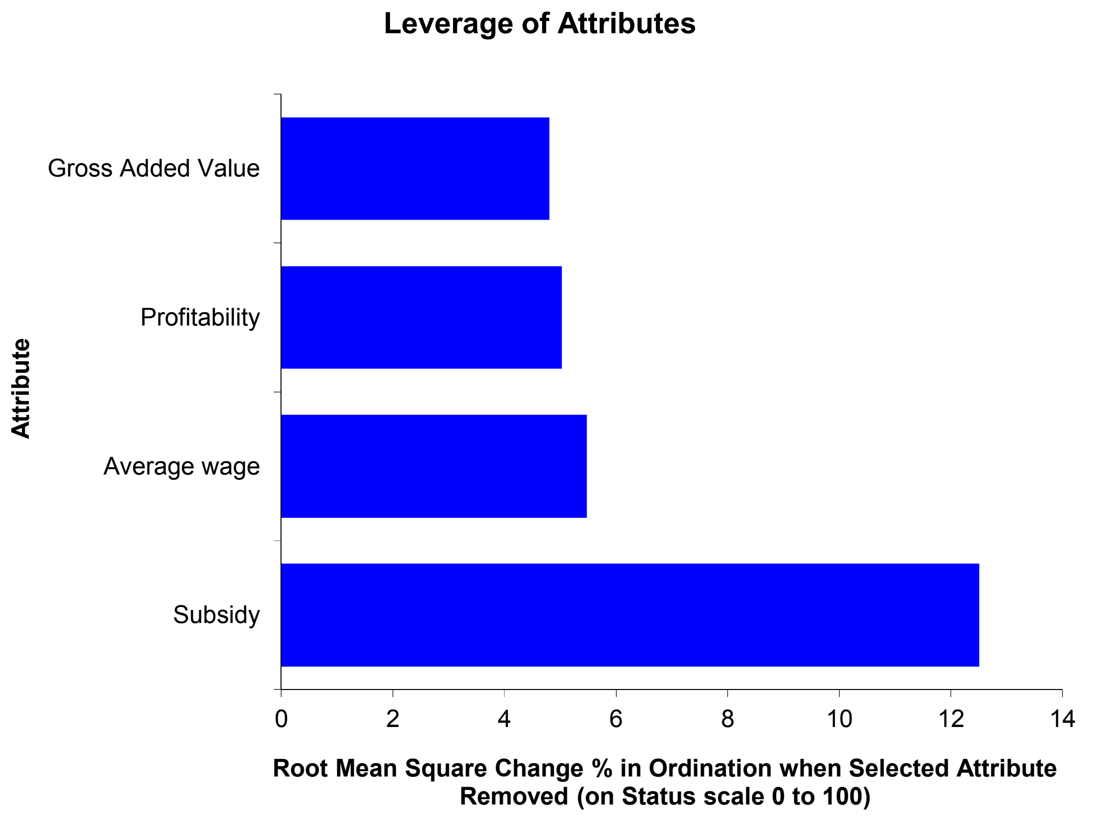

Fig. 4. Rapfish Index Ordination for PS Basque fleet before and after using FADs.