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Analysis

Weak and strong sustainability assessment in fisheries

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ABSTRACT

The present paper analyzes the suitability of weak and strong sustainability assessment in the context of fisheries management. This topic is a mainstream issue in the field of ecological economics, but its application to fisheries is rather unexplored, even though fisheries have been the focus of many pioneering studies related to natural resource management. An overview of the current debate in the topic together with an application of a multi-disciplinary technique designed to assess fisheries sustainability (Rapfish) allows the closing of this gap. This is achieved by looking to the potential trade-offs among the multiple dimensions of fisheries sustainability and by analyzing the role of critical thresholds in such an assessment. The study of the Basque trawl fisheries operating in the North East Atlantic in the period 1996–2005 shows that the utility of weak sustainability is limited to the comparison of sustainability between fisheries. In contrast it is found that it is the strong sustainability concept together with the definition of critical thresholds that provides management with the tools for improved management and policy within a fishery.

1. Introduction

According to the UN Millennium Ecosystem Assessment (2005), depletion of fish stocks is one of the significant examples of potentially irreversible changes to ecosystems that result from present unsustainable practices in marine ecosystems.[1] The World Summit on Sustainable Development also establishes that fish stocks should be recovered to sustainable levels, 2015 being the deadline for reaching the objective of Maximum Sustainable Yield (MSY). At the European level, the “Green Paper on a reform of the Common Fisheries Policy (CFP)” was adopted in 2009 with the aim of defining, in a clear and prioritized manner, the objectives regarding ecological, economic and social sustainability, so as to provide guidance in the short term and to ensure sustainability of fisheries in the long term.[2]

The questions are how to determine and measure whether fisheries exploitation is sustainable and how to gauge sustainability. As stated by the Green Paper of the CFP, one of the main issues that need further analysis is how to define indicators and targets for implementation in order to provide proper guidance for decision making and accountability.

The concept of Maximum Sustainable Yield (MSY) has a long tradition as a guide on fisheries management worldwide (e.g. Schaefer, 1954; Beverton and Holt, 1957; Gulland, 1977). However this approach is subject to great uncertainty and has been criticized for ignoring the multidimensional nature of fisheries. For instance, the MSY objective does not take into consideration important economic variables such as prices, cost of effort, profits, or discount rates. But obviously, there are more dimensions to be considered and it is recognized that fisheries sustainability is a multidimensional human endeavor that has socio-economic, technological, ethical or institutional implications (McGoodwin, 1990; Charles, 1994; Hanna, 1999; Garcia and Staples, 2000; Garcia and Charles, 2007). From this multidimensional perspective, fisheries sustainability cannot have a proper analytic or empirical treatment unless the multidimensional and uncertain nature of these systems is considered. But this, in turn, poses the question about how to compare these different dimensions and whether some compensability among them can be allowed.[3]

The debate concerning the compensability and substitutability among different dimensions is widely discussed in the literature related to sustainability and is behind the distinction between the concepts of weak and strong sustainability (Ayres et al., 2001; Ekins et al., 2003; Dietz and Neumayer, 2007; Ayres, 2007, 2008; Neumayer, 2010).

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[1] For a comprehensive historical overview see Jackson et al. (2001), Pitcher (2001) and Pauly et al. (2002).

[2] Review of the Common Fisheries Policy: http://ec.europa.eu/fisheries/cfp/review_en.htm.

[3] “Compensability refers to the existences of trade-offs, i.e., the possibility of offsetting a disadvantage on some criteria by a sufficiently large advantage on another criterion, whereas smaller advantages would not do the same” (Munda, 2006:68).

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In this paper we compare the implications of applying these ‘opposing’ paradigms in the context of fisheries sustainability assessment. For this purpose Rapfish is used, a non-parametric and multi-disciplinary evaluation method developed by Pitcher and Preikshot (2001). By means of Rapfish, it is possible to analyze the status of a fishery in terms of comparative levels of sustainability under two assumptions: when substitutability among different dimensions is allowed (weak sustainability) and when such substitutability is constrained (strong sustainability). That is, we analyze explicitly the issue of the trade-offs among different dimensions. Besides this, we introduce critical values for each of the dimensions included in Rapfish, to determine the suitability of weak and strong sustainability in the formulation of policy recommendations and actions.

The paper is structured as follows: In Section 2 we address the issue of compensability looking at the concepts of weak and strong sustainability. Section 3 describes briefly the case study considered. In Section 4 we present the so-called Rapfish methodology and, introduce plausible critical values within this framework. Section 5 contains the results obtained by means of Rapfish under the weak and strong sustainability paradigm. Finally in Section 6 we discuss the potential of both approaches and present the main conclusions of our study.

2. Weak and Strong Sustainability

There is a vast literature related to the assessment of sustainability in the case of fisheries. Seminal papers included Gordon (1954), Clark (1990) and Munro and Scott (1985) and more recently important references can be found in FAO (1999), Alder et al.(2000), Garcia and Staples (2000), Garcia et al. (2000) and Fletcher et al.(2002). In these works, a large number of indicators are presented but there is a lack of explicit analysis with regard to the issue of substitutability or compensability (i.e., potential trade-offs among the dimensions remain unresolved).

The debate concerning the substitutability among environmental assets and man-made capital has been deeply discussed in the literature related to ecological and resource economics (for a recent revision of this literature see Neumayer (2010)), but its application to fisheries is rather unexplored, although fisheries have been the focus of many pioneering studies related to resource management. In fact fisheries have been the paradigmatic case in the analysis of optimal management of renewable resources.

The weak sustainability position held by many mainstream neoclassical economists demands that the overall welfare of society should not decline overtime. It is based on the work of Solow (1974) and can be labeled as the ‘perfect substitutability paradigm’ (see also Stiglitz (1974), Solow (1993), Weitzman (1997, 1999), Beckerman (1994), and Pearce and Atkinson (1993)). It implicitly assumes that savings are invested in manufactured capital and that the latter is a substitute of natural capital (Gowdy and O'Hara, 1997).[4] Under this approach, usually the strong comparability hypothesis is assumed, i.e., the possibility to measure all objects under concern with the same quantitative scale (e.g., money) (Martinez-Alier et al., 1998). In the context of fisheries, this approximation might be interpreted as allowing a virtual substitution between stock reduction and favorable economic performance, and would not consider irreversible impacts in the ecological, socio-economic or cultural domain. In other words, under the weak sustainability approach “natural capital can be safely run down as long as enough human-made capital is built to in exchange” (Neumayer, 1999:34).

In contrast, the strong sustainability paradigm, which owes much to the pioneering work of Daly (1992, 1996), holds that many fundamental services provided by nature cannot be replaced at any level by man-made capital. Under this approach a minimum amount of different types of ‘capital’ should be independently maintained if a system aims to be sustainable (Daly and Cobb, 1989; Daly 1990; Pearce et al., 1990; Brekke 1997).[5] This approach has also been labeled as ‘complementary paradigm’ (Neumayer, 2010). In this context it is usually assumed that some environmental components are unique and that functions related to them might be irreversibly lost over relevant time horizons.[6] With a similar reasoning we could add that, for instance, in traditional fishing communities, social and cultural artifacts (i.e., social networks or other informal institutions) are often unique and might be irreplaceable by the accumulation of other types of ‘capital’. Under this approach compensability among different types of ‘capital’ (natural, social, etc.) is constrained by certain limits. The concept of Critical Natural Capital proposed by Ekins et al. (2003) is of particular interest in this discussion. According to this concept, a certain amount of natural ‘capital’ should be insured if relevant environmental functions are to be maintained over time. In the case of fisheries, although we are dealing with renewable resources, a continued exploitation in excess of natural regeneration rates can turn potentially renewable resources into non-renewable and lead the fishery to extinction. Therefore, the need to safeguard certain critical conditions is still meaningful. Similarly, a depletion of fish stocks compromises certain socio-economic standards and the integrity of the social functions (e.g., diversity of formal and informal institutions that sustain the livelihood of fishing communities).

In operational terms, the rationality behind the adoption of the strong sustainability approach can be captured by the assumption of weak comparability, which states that value conflicts are unavoidable when dealing with complex socio-ecological systems but compatible with a rational choice employing practical judgment (Martinez-Alier et al., 1998).

3. Case Study: Basque Trawl Fisheries Operating in ICES Division VIIIabd

The paper is focused on the trawl fishing fleet of the Basque Country operating in ICES Division VIIIabd (see Fig. 1), which accounts for 30% of the international northern hake catches (for further information see Murillas et al. (2008)). Since mid last century, hake (*Merluccius merluccius*) has been the main demersal species supporting trawl fleets on the Atlantic coasts of France and Spain. In recent years Spain has taken around 60% of the landings, France 30%, UK about 5%, Denmark 3%, and Ireland 2%. Following Prellezo et al. (2004) this fleet can be divided into six different fisheries. In this paper we analyze the ‘Baka’ trawlers fishing hake in ICES Divisions VIIIabd which is one of the most important according to its size.

Baka trawlers can be defined as a single vessel which trawls a ‘bottom net’. In this case trips last an average of six days depending on the area being fished, and the haul duration is between four and five hours. Catches are generally landed in Basque ports (Ondarroa and Pasaia) and in French, Scottish and Irish ports, from where the catch is transported by trucks to be sold in local Basque markets.

4. Methodological Framework: Rapfish Analysis

For the comparison of weak and strong sustainability in the context of fisheries the Rapfish technique is adopted here. This is a non-parametric evaluation method which uses simple and easily

[4] For further detail on the meaning of Natural Capital see Harte (1995).

[5] For a list of environmental goods and services that cannot be substituted see Neumayer (1999:39) and Pearce et al. (1990:37).

[6] For a brief discussion about whether natural capital should be declining in value or physical terms see Traeger (2007).

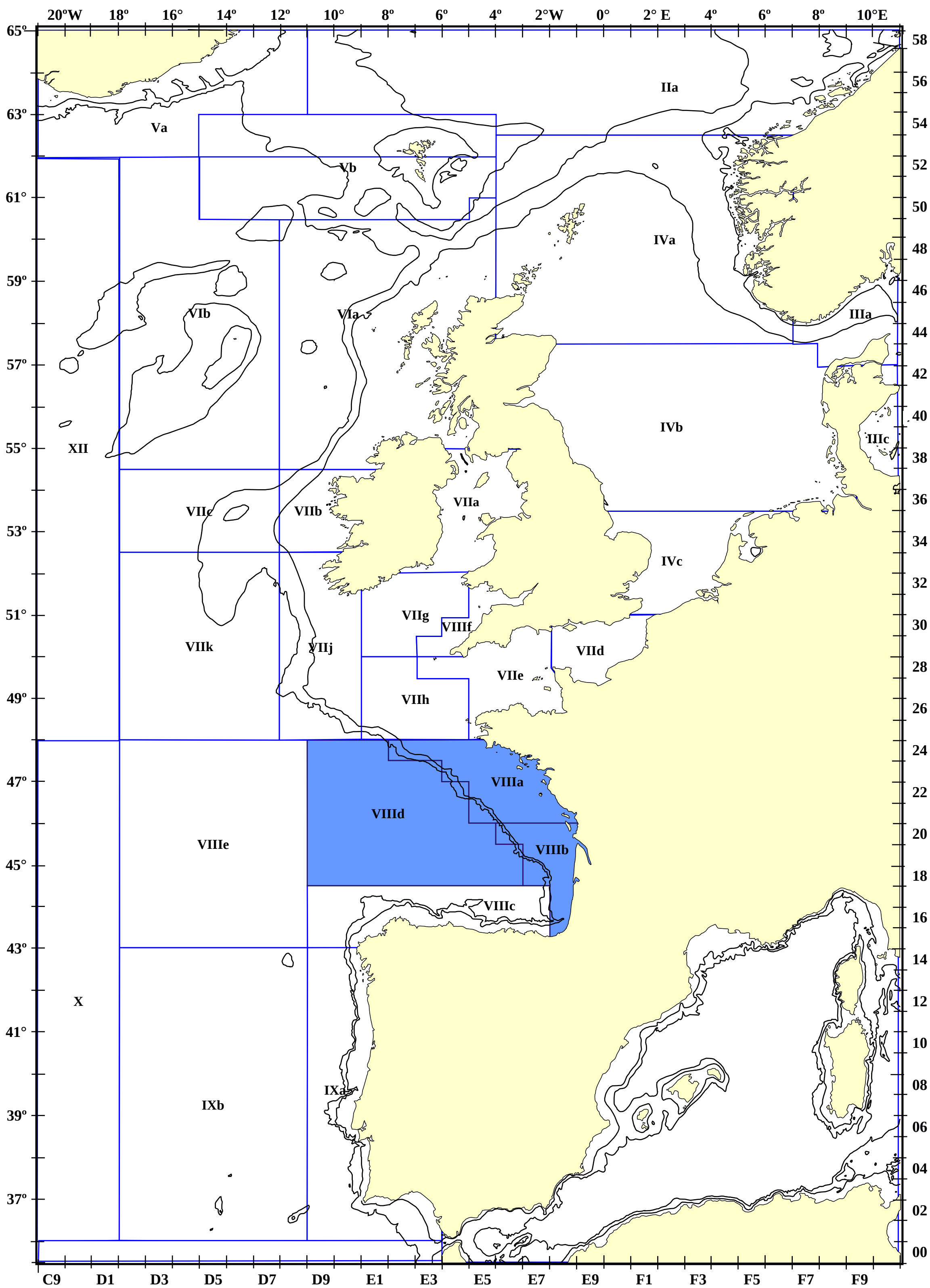

Fig. 1. ICES divisions in North East Atlantic.

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). This choice is supported by the good rating obtained by Rapfish in a recent comparative study of similar techniques that aim the integrated assessment of capture fisheries (Leadbitter and Ward, 2007). The Rapfish approach has been used to assess the sustainability status of several fisheries around the world (Preikshot et al., 1998; Alder et al.,

Table 1
Attributes used for Rapfish analysis.

	Possible scores	"Bad"	"Good "	Notes	Refer. value
Ecological dimension					
Status exploitation	0,1,2,3,4,5	5	0	ICES WGHAM criterion: MSY (0); within PA values — (1); F too high (2); SSB too low (3); F too high and SSB too low (4); probably unsustainable (5)	1
Recruitment variability	0,1,2	2	0	Coefficient of variability: low <40% (0); medium 40–100% (1); high >100% (2)	1
Change in T levels	0,1,2	2	0	Trophic level of the catch in the ecosystem in which this fishery is embedded, decreasing: no (0), somewhat slowly (1); rapidly (2)	1
Change in fish size	0,1,2	0	2	Council Regulation (EC) No 850/98 of 30 March 1998 for the conservation of fishery resources through technical measures for the protection of juveniles of marine organisms. Criterion: ≤ legal size 27 cm(0); ≤ maturity (42 cm)(1); > 42 cm (2)	1
Economic dimension					
Price	0,1,2,3	0	3	Price<average (0), =average (1), >average (2), ≫ average (3). We assign "≫ average" to prices that exceed 1.5 times the average price in 1995–2005 period, and "> average" to prices between the range of 1 to 1.5 times the average.	1
Profitability	0,1,2	0	2	Profitability: revenue minus variable and fix costs Profits>0 (2); Profits=0 (1); Profits<0 (0)	1
Average wage	0,1,2,3,4	0	4	Do fishers make more or less than the average over last decade, 1995–2005? Much less (0); less (1); the same (2); more (3); much more (4)	2
Landings	0,1,2,3	0	3	Low<average (0), =average (1),>average (2), ≫ average (3)	1
Institutional dimension					
Limited entry (Input control)	0,1,2,3	0	3	Open access (0), access right (1), limits on effort (2), transferability of rights (3)	2
Output control compliance(TAC)	0,1,2,3	3	0	Deviation between Advice and TAC. Deviation <0 (0), deviation=0 (1), 0<deviation<average (2), deviation>average (3)	1
Just management	0,1,2,3,4	0	4	Inclusion of fishers in management none (0), consultation (1) co-management/government leading(2), co-management/community leading (3), genuine co-management/equal participation (4)	1
Subsidy	0,1,2,3	3	0	Related to the average subsidies received by fishermen between 1996 and 2005. We assign: no subsidies (0), <somewhat (1), >large (2), ≫ heavily reliant (3)	1
Social dimension					
Socialization of fishing	0,1,2	0	2	Not organized (0) somewhat organized (1) organized (2)	1
Fishing community	0,1,2	2	0	Growth of local community: <decrease (o); maintain (1); > increase (2)	1
Trend of employment	0,1,2	2	0	Loss of employment in one year (measured by means of the Annual Variation Rate) in the fishery in comparison with the rest of the Basque fleets: < average (0); = average (1); > average (2)	1
Gross Added Value	0,1,2	0	2	GAV<0 (0); GAV=0 (1); GAV>0 (2)	2
Technological dimension					
Number of vessels	0,1,2	2	0	The Annual Variation Rate of the number of vessels. Decrease (0), constant (1), increase (2)	1
Vessel size	0,1,2	2	0	The Annual Variation Tax of the fishery total average length. Decrease (0), constant (1), increase (2)	1
Change in catching power	0,1,2,3,4,5	5	0	TMV reduction (0), constant (1), increase: </=1% (2), increase <1–2% (3) increase<2–5%(4) increase >5% (5)	1
Selectivity device	0,1,2	0	2	Device(s) in gear to increase selectivity Few (0); some (1); lots (2)	1

2000; Baeta et al., 2005; Tesfamichael and Pitcher, 2006; Murillas et al., 2008). Nevertheless, to our knowledge, this is the first article providing a comparative analysis of a fishery under the weak and strong sustainability approach, according to different degrees of compensability. Besides, we introduce reference values and critical thresholds as a way to bridge the gap between weak and strong concepts of sustainability.

4.1. Attributes and Scores

In this paper, Rapfish has been developed using five evaluation fields: economic, ecological, technological, social and institutional. This choice is justified firstly by the availability of data and secondly by their suitability in capturing the dynamics of this fishery over the selected period. In this 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 that goes from the worst to the best situation. Following their approach, we refer to this scale system using the 'good' and 'bad' terminology for the minimum and maximum possible levels while maintaining sustainability. Overall 20 attributes have been considered and grouped into the five evaluation fields. In this case, in order to adapt the Rapfish analysis to the present case study, new attributes were added and the scoring criteria of some of the attributes were reconsidered with respect to previous literature (Pitcher and Preikshot, 2001). Table 1 shows the list of attributes used in this paper.

Given the time series data availability for all the attributes, it was possible to score them annually for the period 1996–2005 (see Appendix A). Once all the attributes have been scored, Rapfish uses a statistical ordination technique, a Multi-Dimensional Scaling (MDS) to reduce the N×M matrix of fisheries (N) and attributes (M) to generate an N×2 dimensional space that represents the sustainability status of each fishery (see Kavanagh and Pitcher (2004)).

4.2. Critical Thresholds and Reference Values

In addition to the standard Rapfish analysis, in this study reference values for each attribute were also defined. A reference value indicates a particular state of a fisheries indicator (single or composite) corresponding to a situation considered as desirable, or undesirable and requiring some action (Caddy and Mahon, 1995; Garcia and

Cochrane, 2005).[7] The purpose of the reference values or critical thresholds is to acknowledge the limits to substitution and to guide the long-term survival of a given fishery. In a situation of potential irreversibility the precautionary principle guides the determination of these values. Note that these values could vary over time as long as there are improvements on available data.

At a higher level of aggregation, these reference values serve to establish 'critical' sustainability thresholds for each of the dimensions. A methodology for calculating these values is explained in Murillas et al. (2008). In this paper the sustainability of a 'dummy fishery' is estimated for each of the dimensions according to the reference values defined at the level of an attribute. These critical thresholds determine the limits below which assuming compensability among dimensions becomes too risky, and therefore should be interpreted as a necessary condition for insuring a sustainable fishery.

With a similar basis we define a weak sustainability reference index (a composite indicator), by aggregating all the reference values defined for each attribute in a single indicator.

Briefly speaking, the critical ecological threshold should be capable of (a) maintaining individual stocks and species at levels that do not foreclose future option values and (b) maintaining or enhancing the capacity and quality of the ecosystem. In the same way, taking into account that fisheries sustainability also encompasses a human and technological endeavor certain socio-economic, technological or institutional standards are also considered as a prerequisite to keep sustainability of the fishery in the long run.

4.2.1. Rationale for Defining Reference Values

In this section we describe the underlying assumptions for assigning reference values for each attribute. Obviously the reference values assigned in this case study may not be the optimal for another fishery that has different characteristics. The assignment of reference values should be adapted to the context of each fishery.

4.2.1.1. Ecological Dimension. The precautionary approach is one of the main drivers of the fisheries policy. In that sense all the policies that are not considered as precautionary have to be considered as critical. Consequently, the status exploitation's critical value has been defined exactly at this point (within PA values or score 1). Recruitment variability and changes in T level reference values have been determined at the medium point. In the same way we define a critical situation beyond medium recruitment variability (score equal to 1) and slow changes in T levels (score equal to 1). In terms of fish size, we define as critical the fishing of non-mature individuals. Hence, reference value will be set at 1 (maturity).

4.2.1.2. Economic Dimension. The economic analysis of the fishery's sustainability has focused on the evolution of the following: prices, wages, landings and profitability. Given the difficulty in establishing objective critical values for the first three variables, average values over a long period of time have been considered. In this analysis, the score for each attribute improves as long as the value for each variable is above the average value for the period considered. Regarding profitability, on fishery models, sustainable management is compatible with positive profits; this, in turn, implies that the exploitation of the fishery is undertaken under an appropriate institutional context that avoids not only overexploitation but also excess capacity of the fishery (i.e., the familiar type I and type II problems of fisheries management). However, from the pure economic perspective, non-negative profits would be enough to sustain economic activities and therefore the fishery. Therefore non-negative has been assigned in this case as a critical value for this attribute. These economic profits include returns on effort and capital (the opportunity cost of these two inputs of production).

4.2.1.3. Institutional Dimension. Most of the world's fisheries are overexploited due to lack of compliance with input and output regulations (and in some cases e.g. tuna due to lack of scientifically-based regulation by regional fisheries management organizations (FAO, 2008)). We consider input regulation as a necessary measure. If transferable fishing rights are not accepted, then at least a limit on effort must be present (score equal to 2). In terms of output regulation any deviation, for example, between the TAC (Total Allowable Catch) and the advice (that is based in the MSY) must be avoided (score equal to 1). In addition, approaches based on decentralization and bottom-up style fisheries management are becoming increasingly popular and are thought to hold the key for sustainable exploitation of marine resources. It is in this context that it is necessary to introduce a consultation with the fishing sector within the decision process (score equal to 1). Finally, subsidies must be understood as timely help to the fishing sector but cannot be considered as a structural measure, hence we assigned the maximum accepted for this indicator (score equal to 1).

4.2.1.4. Social Dimension. It is recognized that when fishers work in an organized and cooperative way there are more opportunities to settle common rules that help the regulation and sustainable management of resources (Ostrom et al., 1994). On this basis some form of organization, in contrast to 'free entry' situation, is recognized as the desirable reference value for achieving fisheries sustainability (score equal to 1). The same score is used for the fishing community indicator. Taking into account the high population density of the communities under study (and the dependency on fishing), it is assumed that population growth would increase pressure on resources and affect negatively the situation of the community. With regard to the trend of employment it is considered that a higher loss of employment in this fleet than in other fleets operating in the same area reflects an unsustainable situation within the sector (score equal to 1). Finally, in terms of the Gross Added Value variable, a positive contribution to the local or regional socio-economic situation is used as a critical value (score equal to 2). Notice that this indicator could be considered as a mix indicator as it combines economic and social conditions.

4.2.1.5. Technological Dimension. In this dimension the critical values have been determined in terms of not creating shifts in the positive trend of the selected period. In that sense, due to overcapacity of the fleet, it is defined as critical to not increase the number of vessels, their size or catching power. Thus the score of 1 (constant) has been set as the reference value. In terms of selectivity[8] of the fishing gear, a minimum requirement is to have at least some. Obviously some selectivity devices (e.g. grids, changes in the geometrics of the mess) can change without necessarily improving the selectivity of the gear, but given that this situation is not easy to score, we consider again that 1 (some) can be set as reasonable minimum critical value. Note that in all these cases the reference values have been defined specifically for this fishery.

5. Results of Alternative Sustainability Appraisals

Once the relevant set of attributes and the corresponding reference values are defined, it is possible to run the sustainability assessment of the Basque trawl fishery under the weak and strong sustainability paradigm by means of Rapfish.[9]

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[7] Note that these values differ from the concept of 'killer' defined by Pitcher and Preikshot 2001. They use 'killers' to refer to those attributes whose status puts at serious risk the resilience of the fishery.

[8] Selectivity refers to the fishing method's ability to target and capture organisms by size and species during the fishing operation allowing non-targets to be avoided or released unharmed.

[9] The mainstream Rapfish version allows the estimation of uncertainty through a Monte Carlo routine. In this case, the Monte Carlo analysis confirmed that the results obtained are statistically supportable.

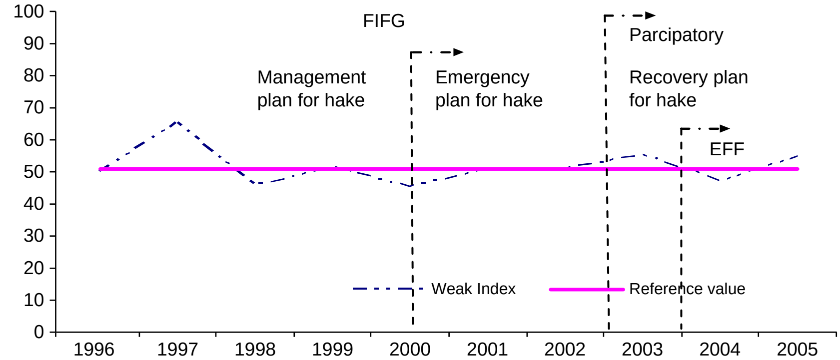

Fig. 2. Evolution of weak sustainability index.

5.1. Weak Sustainability

In order to run the weak sustainability analysis, here all selected attributes are merged in a single index or composite indicator. It means that compensability among all attributes pertaining to the five dimensions is allowed when considering the sustainability of the fishery. Results of this approach are shown in Fig. 2.

The main management actions affecting this fishery have been included in Fig. 2. In chronological order, before 2001 the management system was based on a combination of TAC and individual quotas and some technical measures (such as minimum mesh size and minimum landing size). Also in terms of the structural funds the Financial Instrument for Fisheries Guidance (FIFG) was in force allowing for subsidies on scrapping, modernization and construction of new vessels. An emergency plan for hake was put into force in 2001 and according to the weak index, sustainability was improved. This emergency plan turned into a recovery plan in 2003 which can be described as a more relaxed – in terms of the measures taken – version of the emergency plan. At the same time FIFG was cancelled and structural actions were taken under the European Fisheries Fund (EFF). The main difference being that the constructions of new vessels was no longer subsidized.

In overall terms it can be observed how, with the exception of 1997, the weak sustainability index shows values around the sustainable reference value. There are no big changes between years and the weak index has been relatively constant since 1998.

While the compensability allowed (weak sustainability) makes it impossible to measure the success of each individual action the composite sustainability of the fishery has been maintained. This conclusion can vary dramatically if we assess the sustainability from the strong perspective (each dimension separately). The evaluation of each policy measure can shift according to different degrees of compensability among parameters.

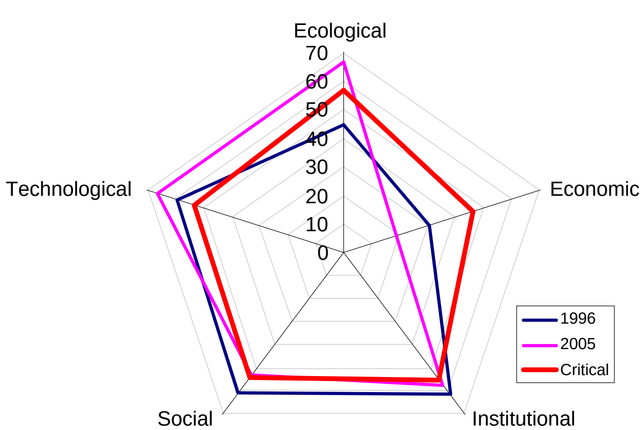

Fig. 3. Fisheries sustainability according to different dimensions in 1996 and 2005 and critical reference value for each dimension.

5.2. Strong Sustainability

In this section, the performance of the fishery in sustainability terms is assessed considering the criteria defined for each of the dimensions separately. In this case, the results of strong sustainability assessment for each of the dimensions are accompanied by its corresponding critical threshold, estimated according to the reference values defined in Table 1.

The main management actions taken in this fishery are also considered, but only in terms of the targeted dimension to which the action was designed. This allows the effectiveness of each individual action to be evaluated separately.

Using the strong sustainability criteria we can identify two dimensions, (a) the economic and (e) the institutional, which are below the reference values in most recent years.

The economic dimension has not been directly affected by any specific management action, although restrictions on catch like those derived from the emergency plan could have had an influence. Overall the fishery does not improve in economic terms. This deterioration of the fishery in economic terms is related to low prices and profitability in general. Note that in this case low prices are strongly influenced by increasing imports of hake in Spain from extra-communitarian waters. According to FAO,[10] these imports have multiplied by five in the last 20 years from 7.532 tons in 1985 to 143.484 tons in 2005. Thus, it seems necessary to consider management actions directed to this dimension in particular.

The institutional dimension tracks below the reference value but the management action taken through the establishment of the Regional Advisory Council (RAC) seems to have shifted the trend of this index towards the sustainable reference value. The European Council established the RACs as a participatory management system to increase stakeholder involvement in the development of a successful Common Fisheries Policy. In this context it is usually acknowledged that fishers can be a valuable source of information about traditional and current patterns of exploitation and consumption, and can provide insight into potential problems with management plans.

In contrast, in the last part of the selected period, the ecological (b) and social (c) dimensions fall above the reference values but with different patterns. In the ecological dimension the index value

[10] Source www.fao.org.

is, in recent years, above the reference value. This cannot be related to the management actions considered (the emergency and recovery plan). The reason is that these management actions are only affecting one of the attributes of this dimension (stock status) whereas the others remained unaffected by this action. The social dimension is above the reference value but the most recent decreasing trend has created a threat that will require a management action.

Finally the technological (d) dimension presents also a sustainable perspective in the last periods. The management actions considered (FIFG and EFF) have recovered and maintained the sustainability index of this dimension.

To summarize, from the strong perspective and in contrast with the weak, the fishery is not sustainable. Furthermore there are some dimensions that are under serious risk, against which direct management actions have not been considered. The kite diagram (Fig. 3) illustrates these differences by comparing the performance of the fishery in 1996 and 2005 respectively. In these two years the fishery obtained a similar value according to the weak index (see Fig. 2). In contrast, when we constrain the possibility of substitutability within each dimension, the trends in each dimension become clear.

We can observe a clear deterioration of the fishery in economic and social terms while there are some improvements in the ecological and technological dimensions. Very often we face the opposite situation, in which, guided by short-term economic profits and inadequate institutions, fisheries are overexploited to irreversible limits (Dulvy et al., 2004; Hilborn et al., 2004; Ostrom, 1990; Pauly et al., 2002; Pitcher, 2001). Under the weak sustainability assumption, if the performance in economic terms is sufficiently good to 'compensate' declines in ecological terms (assuming that the rest remain unchanged), the fisheries sustainability according to the weak index would remain unchanged. To avoid this kind of misrepresentation there is a need to acknowledge the limits of substitution and, the role of 'reference values' or 'critical thresholds' becomes important. They serve as reference points to guide the long-term survival of a given fishery. These values determine the limits below which assuming compensability becomes too risky and can be interpreted as a necessary condition for achieving a sustainable fishery. From the strong perspective, we could say that the fishery has not yet reached an economic sustainability.

6. Discussion and Conclusions

Natural resource managers and policy makers require decision support tools to determine the sustainability status of fisheries. Moreover, given the multidimensional and uncertain nature of fisheries these approaches should be capable of integrating multiple perspectives in the analysis (i.e., ecological, socio-economic, technological or institutional). However, through a comparison of weak and strong paradigms we show that the inclusion of multiple dimensions in the integrated assessment of fisheries can be misleading.

There are at least two approaches for responding to this challenge. Under the weak paradigm, substitutability between natural and human-made capital is assumed, allowing compensability among dimensions. In contrast, under the strong perspective, compensability is constrained to those attributes within the same dimension. The key issue is to determine which approach is more suitable and under which conditions.

The Basque fleet has served to illustrate the scope of each approach and the potentiality of combining both under certain conditions. In this case study we observe that when we aggregate the multiple indicators in a weak index (Fig. 2), without any other premise, we lose track of the significant changes over time leaving at risk the sustainability of the fishery in the long-term. This is so because under the weak approach on its own we include and compute as shares of total output all the variables together, regardless of their economic, social, technological, institutional or ecological nature.[11] In contrast, using the strong assessment (Fig. 4) gives a more realistic picture of the evolution of the fishery according to multiple perspectives and helps decision making reducing the risk of failure under uncertain situations. In this framework the definition of reference values and critical thresholds enriches the assessment and can guide sustainability of the fishery in the long term (see Section 4.2). These values determine the limits below which assuming compensability becomes too risky, and they should therefore be interpreted as necessary conditions for achieving a sustainable fishery.

On the other hand, if the fishery obtains values over a critical threshold in each of the considered dimensions the weak index can provide complementary information with regard to the overall performance of the fishery. This additional measure facilitates an inter-temporal assessment and can also be useful for the comparison of various types of fisheries (i.e., artisanal and industrial, demersal or trawl fisheries, etc.) which otherwise would be difficult to contrast. At this point a caveat is in order. The weak sustainability analysis in its own should be taken as an illustrative only given that it is obtained by means of a mix of disparate criteria. Nevertheless, if applied together with the strong sustainability approach, the weak index provides the basis for identifying potential trade-offs among the multiple dimensions of a given fishery. This in turn can facilitate discussion of the most efficient policies taking account of risk (see Fig. 5). Thus it could be said that the weak sustainability analysis can be useful for comparing fisheries but is of limited value in providing insights into management and policy for individual fisheries. This is so, because of the danger of unacceptable trends, or trends in parameters below the reference value, being hidden by trends above the reference value. Strong sustainability analysis, in contrast, allows the trends to be identified and facilitates correction, either through trade-offs or by measures to improve performance of one dimension.

In the present case study, it seems that the fishery has experienced an improvement in ecological and technological aspects. In contrast it is worse off in economic terms (Fig. 4). An effective policy should take into account these trade-offs but also examine the possibility of achieving greater economic performance without the need for a trade-off. An option might be to enhance a higher added value of landings without undermining the status of the stocks. Promoting initiatives such as eco-labeling or the creation of direct markets that avoid the need of 'middlemen' (e.g. by means of fisher marketing cooperatives) are a few examples to improve the income of fishers without increasing the pressure over the resources.

To conclude, we agree with Ekins et al. (2003) in the sense that starting from a strong sustainability assumption of non-substitutability in general it is possible to shift to a weak sustainability position where that is shown to be appropriate. From this perspective, the weak and strong sustainability approaches should be understood as complementary measures and when applied jointly, with the help of reference values, can enrich the understanding of the unavoidable trade-offs that decision makers have to face (Fig. 5). However for such a shift, first we have to make sure that the critical thresholds for each of the dimensions are guaranteed. To neglect the very diverse nature of the multiple dimensions and to ignore the limits to substitution within this evolving system, might erode the validity of the assessment, leaving at risk the fishery. Understanding trade-off relationships between ecological, economic and social objectives is essential for designing policies to manage or restore ecosystems (Cheung and Sumaila, 2008). We believe that the usefulness of sound fisheries sustainability assessment tools lies in

[11] An illustrative example of extreme implications of weak sustainability in practice in the small Pacific island nation of Nauru is provided by Gowdy and McDaniel (1999).

supporting social debate and rising awareness about the critical trade-offs embedded in sustainable fisheries management. In this sense, further effort is required to develop integrated assessment protocols like the ones presented above, in which the implication of assuming different degrees of compensability are considered explicitly, according to the boundaries of our surrounding socio-ecological systems. Further research avenues could also consider the active participation of those stakeholders involved in fisheries management in the assessment. The direct participation among all the affected parties, i.e., fishers, scientists and policy makers, could create great opportunities for an adaptive learning process among all the counterparts and enrich the assessment with the identification of past failures and a discussion with regard to unavoidable and avoidable trade-offs in the transition to more sustainable fisheries.

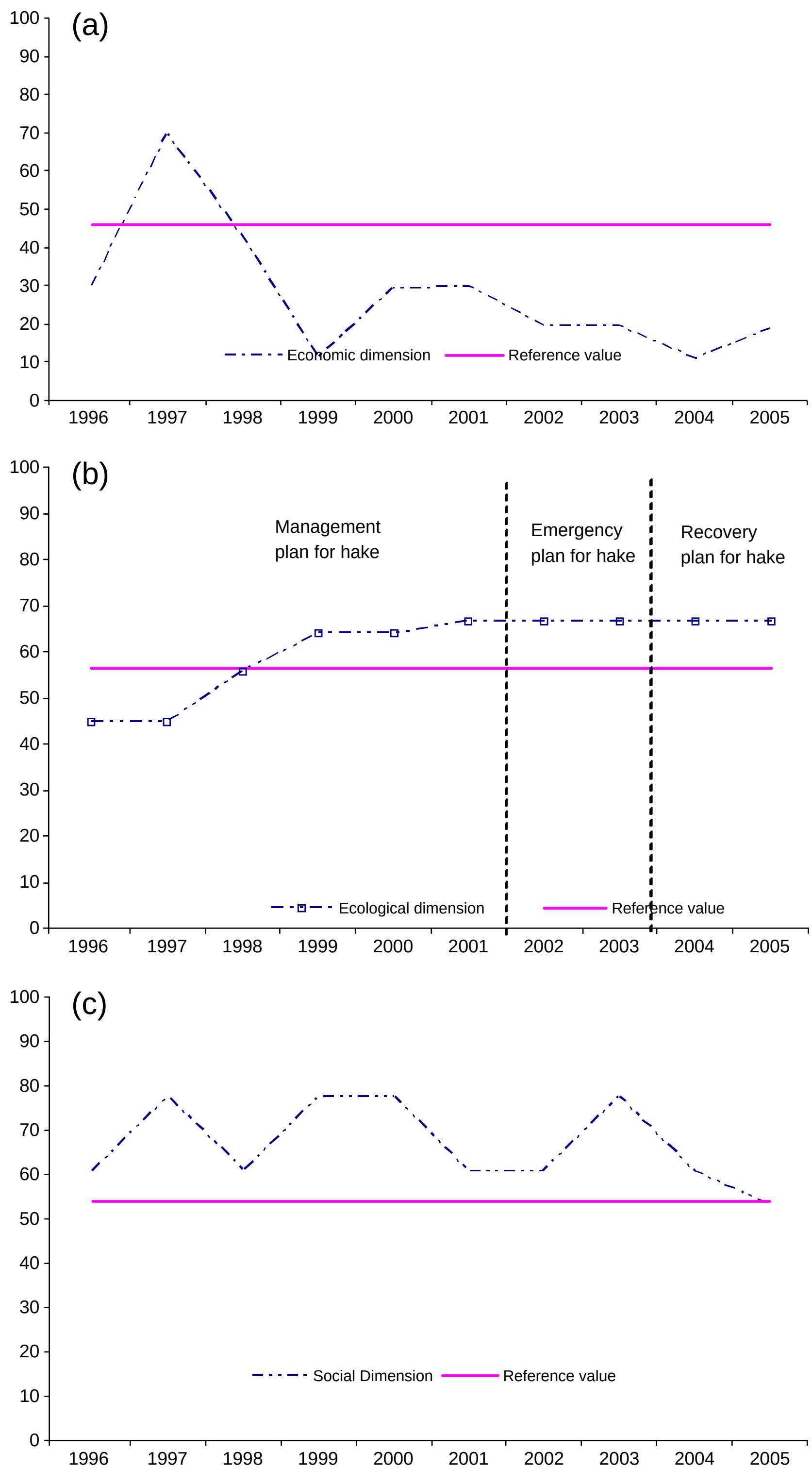

Fig. 4. Evolution of the fishery's sustainability in the (a) economic, (b) ecological, (c) social, (d) technological and (e) institutional dimensions.

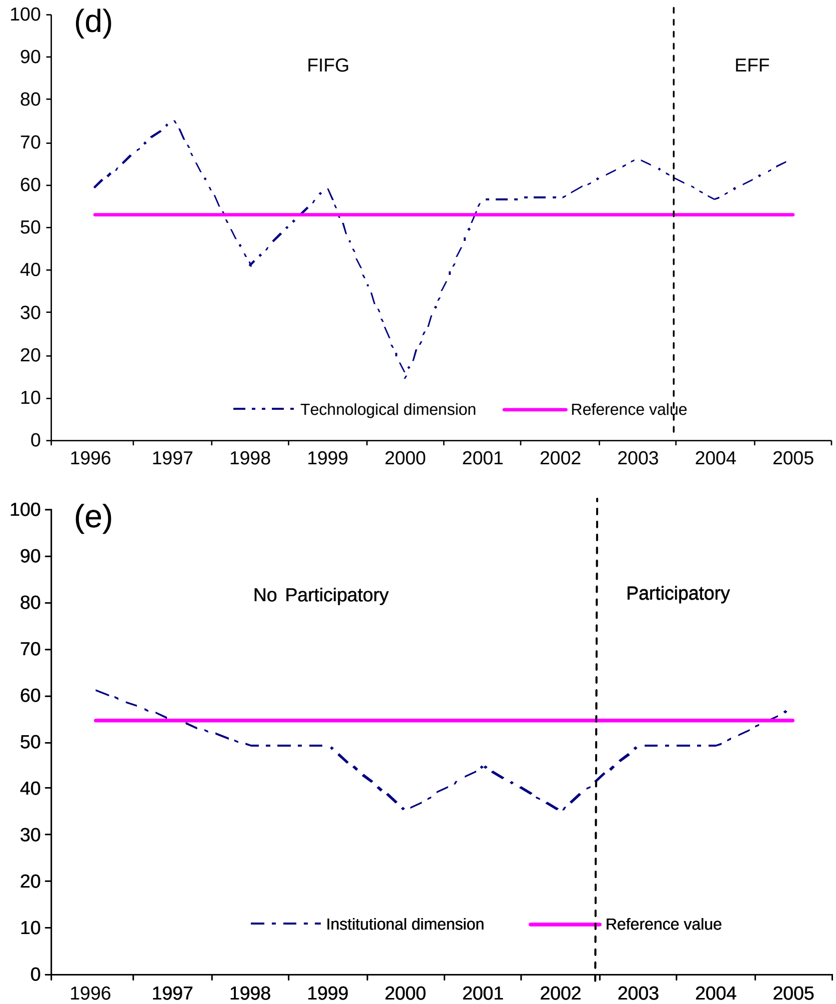

Fig. 4 (*continued*).

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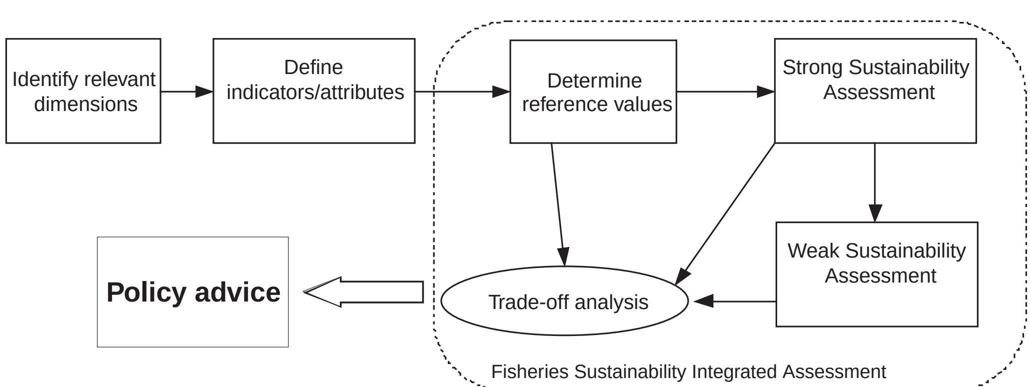

Fig. 5. Procedure for identifying plausible trade-offs in support of policy advice. The process starts by identifying relevant dimensions and the criteria to assess the performance of such dimensions. Then critical values for each attribute are estimated as a reference value. The fulfillment of these reference values will condition the sustainability of the fishery in strong terms. Once we run the strong assessment the weak assessment helps to make explicit potential trade-offs among the dimensions and facilitates complementary information regarding the overall performance of the fishery. The combination of multiple measures (box with discontinued line) encompasses the basis for the formulation of policy advice.

Appendix A. Scores for each attribute (1196–2005)

	Ecological			Economic				Institutional				Social				Technological				
	Exploitation status	Recruitment variability	Change in T level	Change in fish size	Price	Average wage	Profitability	Baka landings	Input control	Output control compliance	Just management	Subsidy	Socialization of fishing	Fishing community growth	Trend of employment	VAB	Number of vessels	Vessel size	Change in catching power	Selectivity device
1996	4	0	1	0	0	1	0	3	2	0	1	1	1	0	2	2	0	1	0	0
1997	4	0	1	0	2	2	2	3	3	2	1	1	1	0	0	2	0	0	0	0
1998	4	0	0	0	2	0	2	0	3	3	1	1	1	0	2	2	2	1	0	0
1999	4	0	0	1	0	1	0	0	3	3	1	1	1	0	0	2	0	1	0	0
2000	4	0	0	1	0	2	0	1	3	3	1	3	1	0	0	2	2	2	3	0
2001	3	0	0	1	2	1	0	0	3	3	1	2	1	0	2	2	1	0	3	1
2002	3	0	0	1	2	0	0	0	3	3	1	3	1	0	2	2	0	1	2	1
2003	3	0	0	1	2	0	0	0	3	3	1	1	1	0	0	2	0	1	0	1
2004	3	0	0	1	0	1	0	0	3	3	1	1	1	0	2	2	1	1	0	1
2005	3	0	0	1	0	2	0	0	3	2	2	1	1	0	1	0	0	1	0	1
Good	0	0	0	2	3	4	2	3	3	0	4	0	2	0	0	2	0	0	0	2
Bad	5	2	2	0	0	0	0	0	0	3	0	3	0	2	2	0	2	2	5	0

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