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Analysis

Weighting social preferences in participatory multi-criteria evaluations: A case study on sustainable natural resource management

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ABSTRACT

The use of multi-criteria evaluation tools in combination with participatory approaches provides a promising framework for integrating multiple interests and perspectives in the effort to provide sustainability. However, the inclusion of diverse viewpoints requires the "compression" of complex issues, a process that is controversial. Ensuring the quality of the compression process is a major challenge, especially with regards to retaining the essential elements of the various perspectives. Based on the lessons learned during a case study that assessed sustainable management options for the Urdaibai Estuary (Basque Country-Southern Europe), we propose a process in which the explicit elicitation of weights (the prioritisation of criteria) within a participatory multi-criteria evaluation serves as a quality assurance mechanism to check the robustness of the evaluation process. The results demonstrate that diverse individual priorities can be grouped in a reduced set of social preferences by means of cluster analysis reinforced with a deliberative appraisal among a wide variety of social actors. The approach presented retains relevant information regarding extreme and sometimes irreconcilable positions, allows an explicit social sensitivity analysis of the MCE process, and enables participants to learn from and reflect upon diverse social preferences without forcing their consensus.

1. Introduction

The demand for deliberative approaches to decision-making with respect to sustainability related issues has grown in recent years. Complex, evolving socio-ecological systems affect decision-making because of the associated high degrees of uncertainty, incommensurability of values, and non-equivalent descriptions of the same system (Funtowicz and Ravetz, 1990; Gimarães-Pereira et al., 2006; Kasemir et al., 2003). Traditional scientific approaches and the hegemony of science, which search for unique and objective truths, have been questioned (Harremoës et al., 2001; Wynne, 1992). These are not sufficient for the social resolution of sustainability issues (Giampietro et al., 2006). Consequently, new decision support methods have emerged to engage the public in decision-making processes (Antunes et al., 2009; Santos et al., 2006; Stagl, 2007; Videira et al., 2009). These include the increased use of participatory and deliberative approaches in multi-criteria evaluation processes related to sustainability and natural resource management (Gamboa, 2006; Gamboa and Munda, 2007; Hajkowicz, 2008; Hermans et al., 2007; Kowalski et al., 2009; Liu et al., 2010; Monterroso et al., 2011; Munda, 2004; Proctor, 2004; Roca et al., 2008; Stagl, 2006). Increased participation and/or deliberation allow complex issues to be structured systematically to consider the multidimensional, incommensurable, and uncertain effects of decisions (Banville et al., 1998; Munda, 2004; Munda, 2008; Proctor and Drechsler, 2006; Stirling, 2006). However, the inclusion of social preferences in these processes is still controversial.

Numerous transformations (and in some cases simplifications) are required to convert social preferences into (technical) problem structuring (i.e., the construction of alternatives and definition/evaluation of criteria) and the quality of the transformation process is critical to assure high quality outcomes and sound policy advice (Giampietro et al., 2006). Quality assurance, understood in this context to be a reflexive mechanism for ensuring that the relevant properties of a given system have been incorporated adequately in the assessment, should be based, at a minimum, on scientific, political, and practical criteria (Giampietro, 2010; Millennium Ecosystems Assessment, MEA, 2005). This requires validating the robustness of the analysis from a technical perspective, including non-equivalent descriptions of the same system and the application of sensitivity analyses (Saltelli et al., 2000). At the same time, and more interestingly in the context of this paper, quality check mechanisms should allow for the validation of results from a social perspective, taking into account the diversity of social preferences.

The aim of this study was to explore the issue of criteria weighting from a new perspective, drawing on the extensive body of literature focused on sophisticated toolkits and mathematical algorithms for the elicitation of weights. In this paper, we briefly address the critical "compression" phases of participatory multi-criteria evaluation (MCE)

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processes and, using a case study as illustration, provide an approach to criteria weighting that enhances the social sensitivity aspects of group decision making, while facilitating critical reflection upon social preferences without forcing consensus.

2. Reducing Complexity and Determining Weights in MCE

Public decision-making for sustainability must deal with multiple legitimate but often contrasting priorities. Such decision-making processes are usually characterised by high degrees of uncertainty, values in dispute, and urgency (Funtowicz and Ravetz, 1990) and require some form of deliberative institutions within which the weight of different reasons can be considered (Holland et al., 1996). In other words, taking into account that the environment is characterised as a site of conflict between competing values and interests and the different communities that represent them (Martinez-Alier et al., 1998), decision-making processes that search for pathways towards a more sustainable future require holistic approaches that are capable of integrating multiple fields of knowledge (e.g., political science, environmental science and ecology, economics or sociology) with the diversity of perspectives that coexist in the society (Munda, 2008). Among others, the latter requires the inclusion of multiple social actors including representatives from civil society and policy-making authorities at various levels, NGOs, interest groups from industry and those that represent marginalised groups and the voiceless (e.g., future generations) (O'Neill, 2001).

Participatory and social multi-criteria evaluation frameworks were developed to aid this type of decision-making. MCE has evolved since the early 1970s and is now considered a well-developed scientific field with abundant literature (Figueira et al., 2005; Kangas and Kangas, 2005; Ananda and Heralth, 2009). The origins of MCE lie in the fields of mathematics and operational research. When first developed, MCE was characterised by the methodological principle of multi-criteria decision making (MCDM) with little or no participatory mechanisms included (Zionts, 1979; Zionts and Wallenius, 1976). The primary objective was to elicit clear preferences from a (mythical) decision maker and then to solve a well-structured problem by means of mathematical algorithms (e.g., designing an engine taking into account power, weight, efficiency). Progressively, ideas about procedural rationality (Simon, 1976) and the constructive or creative approach (Roy, 1985) led to the development of multi-criteria decision aid (MCDA), in which the quality of the decision-making process became central. Investigators began to emphasise the need to include public participation in MCE (Banville et al., 1998; de Marchi et al., 2000; Proctor, 2004), thus fostering the emergence of participatory multi-criteria evaluation (PMCE) (Banville et al., 1998; Proctor and Drechsler, 2006) and social multi-criteria evaluation (SMCE) (Munda, 2005, 2008), in which context appropriate deliberation is a prerequisite to assure a quality outcome.

In operational terms, the application of a participatory or social MCE usually entails the following steps (Munda, 2004, 2005):

(i) Identification and classification of relevant social actors by means of institutional analysis, individual interviews with key agents, focus groups, etc.;
(ii) Problem definition, which follows a similar procedure as that outlined above;
(iii) Creation of alternatives and the definition of evaluation criteria. This process must be the result of a dialogue between the scientists and the social actors.
(iv) Valuation of criteria in a multi-criteria impact matrix. The matrix synthesises the scores of all criteria for all alternatives. Each criterion score represents the performance of each alternative according to each criterion;
(v) Selection of the multi-criteria evaluation method. Many multi-criteria models have been formulated in the last decades (Figueira et al., 2005), each one with advantages and disadvantages (Montis et al., 2004) . In each case, the most appropriate model must be chosen by weighing their pros and cons;
(vi) Assessment of social actors' preferences and values: preference and indifference thresholds, and prioritization of criteria (i.e. weights). This step is done mainly through in-depth interviews, surveys and focus groups;
(vii) Application of the model through a mathematical aggregation procedure. The criterion scores must be aggregated by means of a mathematical algorithm that ensures that the ranking of alternatives are consistent with the information and the assumptions used.
(viii) Social analysis and discussion of the results to check the robustness of the analysis. Results are exposed to public debate and validation. This step also entails a sensitivity analysis in which some of the assumptions or parameters included in the model are given a different value, to test whether the final ranking of alternatives changes and the results are robust.

2.1. Reducing Complexity in Multi-criteria Evaluations

The process outlined above entails a compression process that transforms a complex reality into a simplified representation of it. This process encompasses the following steps: first, a virtually infinite information space is reduced to a limited set of narratives, expectations and goals that delimit the “problem” at hand. Next, a further compression is accomplished through the representation of the “problem” through a multi-criteria structure, in which a finite number of alternatives is evaluated according to a set of multi-dimensional criteria. The validity of the (multi-criteria) representation depends on how well the virtually infinite information about the external world is compressed into a finite representation (Giampietro, 2010). Because of its normative nature, this process cannot be addressed from a purely technical perspective; participation and collaboration among all relevant social actors is needed. Complex decisions must be made about who participates in defining and structuring the problem, the choice of the aggregation procedure, and the corresponding parameters for the MCE (i.e., preferences and indifference thresholds, weights, operators, degree of compensation) (Munda, 2008).

2.2. Use of Weights in Public Policy Decisions Related to Sustainability

The definition of weights in PMCE is a means of reflecting on social preferences/priorities in the assessment. Allowing social actors to express their priorities explicitly can also help identify areas of conflict critical to analysing plausible compromise solutions. The elicitation of weights can greatly influence the results of the MCE (Strager and Rosenberg, 2006; Triantaphyllou and Sanchez, 1997) and has been the focus of many studies (Al-Kloub et al., 1997; Ananda and Heralth, 2009; Choo et al., 1999; Hajkowicz et al., 2000; Hämäläneinen and Alaja, 2008; Hämäläneinen and Salo, 1997; Jacobi and Hobbs, 2007; Roy and Mousseau, 1996; Stillwell et al., 1987; Tzeng et al., 1998; Vansnick, 1986). Nevertheless, how to define weights in the context of public policy for sustainability, where numerous social actors with confronted interests interact and negotiate, is not an easy task.

2.2.1. Compensation among Criteria

According to Choo et al. (1999) the true meaning and validity of criteria weights are crucial in order to avoid improper use of the MCE models. Unfortunately, criteria weights are often misunderstood and misused, and there is no consensus on their meaning. Broadly speaking, we can distinguish between two types of weights: importance coefficients and trade-offs. The main difference between weights as importance coefficients and weights as trade-offs is that of compensation between criteria (i.e., the possibility that a good performance related to some criteria can offset bad performance related to other criteria). Weights must be derived in a manner that is coherent with the multi-criteria model used (Choo et al., 1999). On the one hand, the use of weights as importance coefficients reflects the relative importance—given by the stakeholder, the analyst, or other social actor—to one criterion in relation to the others and requires non-compensatory aggregation procedures. On the other hand, weights as trade-offs reflect the substitution rate among criteria and therefore are suitable to use in aggregation procedures that are completely compensatory. For sustainability issues, non-compensatory multi-criteria methods are the most suitable for ensuring that all dimensions considered important by one or more stakeholder groups are included in the process (Janssen and Munda, 1999; Munda, 2005). Outranking multi-criteria methods (e.g., ELECTRE, REGIME, PROMETHEE or NAIADE) are partially or non-compensatory, which makes them more suitable to assess sustainability from a strong perspective. That is, they take into account that many fundamental services provided by nature cannot be replaced at any level by man-made capital (Daly, 1990; Neumayer, 2010; Garmendia et al., 2010b).

2.2.2. Determination of Weights in a Social Setting

Another critical question regarding the use of weights in sustainability decision-making relates to their use in a social context. When an analysis involves only one decision-maker, the incorporation of preferences by means of weights into the MCE model is straightforward, although the method used and the way it is applied can yield different results (Borcherding et al., 1991; Pöyhönen and Hämäläinen, 2001; Schoemaker and Waid, 1982; Weber and Borcherding, 1993). However, in the public policy domain, decision processes often include many social actors, and thus the elicitation of social preferences becomes more complex. Several approaches for defining weights in a social setting have been described in the literature; these are summarised in the following paragraphs.

The first group of approaches is extensively used in mainstream economics and borrows from decision theory and risk assessment work. Based on the principle that social preferences can be obtained by aggregating individual preferences, these approaches typically assume that preferences are fixed and independent of social conditions. Studies that fall within this category obtain social weights as the average of the individual weights. This perspective usually assumes that the satisfaction of individual preferences is good for both the individual and the society (Zografos and Howarth, 2008).

A criticism of this approach is that important trade-off information related to extreme priorities can be lost when several prioritisations are reduced to a single vector (by using a modal or even a median value). Moreover, "such a technocratic enforcement of consensus might increase the disagreement of those participants whose values are very different from the calculated average value and may not wish to participate in the process any more" (Proctor and Drechsler, 2006: 175).

A second group of approaches aimed at defining weights in a group setting is prone to the ideas of deliberative and discursive democracy (Dryzek, 2000; Habermas, 1996). According to this perspective, social groups and individuals involved in a decision should engage in a deliberative process wherein individuals can reframe their personal beliefs, value judgements, and underlying assumptions through the exchange of information, rational reflection, and social learning (Howarth and Wilson, 2006). This approach acknowledges that preferences are socially constructed and can evolve over time (Norton et al., 1998; O'Hara, 1996; Slovic, 1995). Studies that fall in this group usually obtain individual weights following some type of deliberative process and then aggregate them by means of a modal or mean value (Hajkowicz and Collins, 2009; Proctor and Drechsler;, 2006; Wei et al., 2000); they also try to reach a consensus on the set of weights through a group discussion.

Deliberative approaches address some of the criticisms of the standard aggregate/averaging approaches in that they allow that preferences can be changed and formed through deliberation. However, forcing consensus and searching for a unique prioritisation scheme can erode the legitimacy and effectiveness of participation as a learning process to solve complex issues (van den Hove, 2006). Irreducible value conflict cannot be ignored or oversimplified; value disparities and conflicts must be recognised and managed.

Finally in the context of social multi-criteria evaluation, Munda (2004, 2008) has argued against the elicitation of weights. His view is that criterion weights in the evaluation of public policies for sustainability should be derived only from a plurality of ethical principles (e.g., economic prosperity, ecological stability, or social equity).

In Section 3, we use a case study to present an alternative approach for the weighting of diverse viewpoints and criteria in participatory approaches. Drawing on the rationality of the deliberative approaches presented above, this approach centres on a quality assurance mechanism that serves to validate—or, if necessary, redefine—the inclusion of social preferences and expand the social learning process, without forcing consensus.

3. Case Study

Our case study focuses on the sustainable management of the Urdaibai Estuary, located in the Basque Country of Southern Europe (Fig. 1). This small area embodies many of the challenges decision-makers are faced with when dealing with complex socio-ecological systems. The estuary is the heart of the Urdaibai Biosphere Reserve and has been subject to human activities that have modified it since prehistoric times. At present, a variety of interests (tourism, agriculture, fishing, industry, recreation, and conservation) coexist in the area.

The Urdaibai Estuary is recognised for its natural and cultural value. In 1984, it was accepted as part of the World Network of Biosphere Reserves by UNESCO (Man and Biosphere Programme) and in 1989, the Basque Country Parliament adopted the Urdaibai Biosphere Reserve Protection and Planning Act (Law 5/1989). Later, in 1992, the estuary was included on the Ramsar Convention's List of Wetlands of International Importance; in 1994, it joined the network of Special Protection Areas (SPAs) for Birds; and finally, in 2006, the Urdaibai littoral zones and marshes were declared a Site of Community Importance (Natura 2000 Network).

Despite all these regulations, coexistence of the various interest groups in the area is not always easy, and many conflicts have risen in recent decades. In 2007 a diverse group of researchers (including a marine scientist, biologist, sociologist, economist, engineers, lawyers, and an ecologist) together with local, regional, and national social actors concerned with the current situation of the area started a collaborative research process. The aim was to evaluate different sustainable management options for the estuary from an integrated (with regard to different fields of knowledge) and inclusive (by considering all the involved actors) perspective. A participatory MCE was carried out from 2007 to 2008 (Garmendia et al., 2010a). The process used to elicit social preferences, with an emphasis on the prioritisation of criteria, is described in detail in Section 3.1, below.

3.1. Inclusion of Social Preferences in the Participatory Multi-Criteria Evaluation

To assure the inclusion of diverse social preferences in the evaluation process, the following activities were conducted:

- Over 30 in depth, personal interviews during the identification phase and subsequent consultations with external experts and authorities (Jan–May, 2007)
- A preliminary open meeting to set the scope and methodological framework of the evaluation process (5 July 2007): 20–25 participants
- A participatory workshop to define criteria (11 July 2007): 25–30 participants

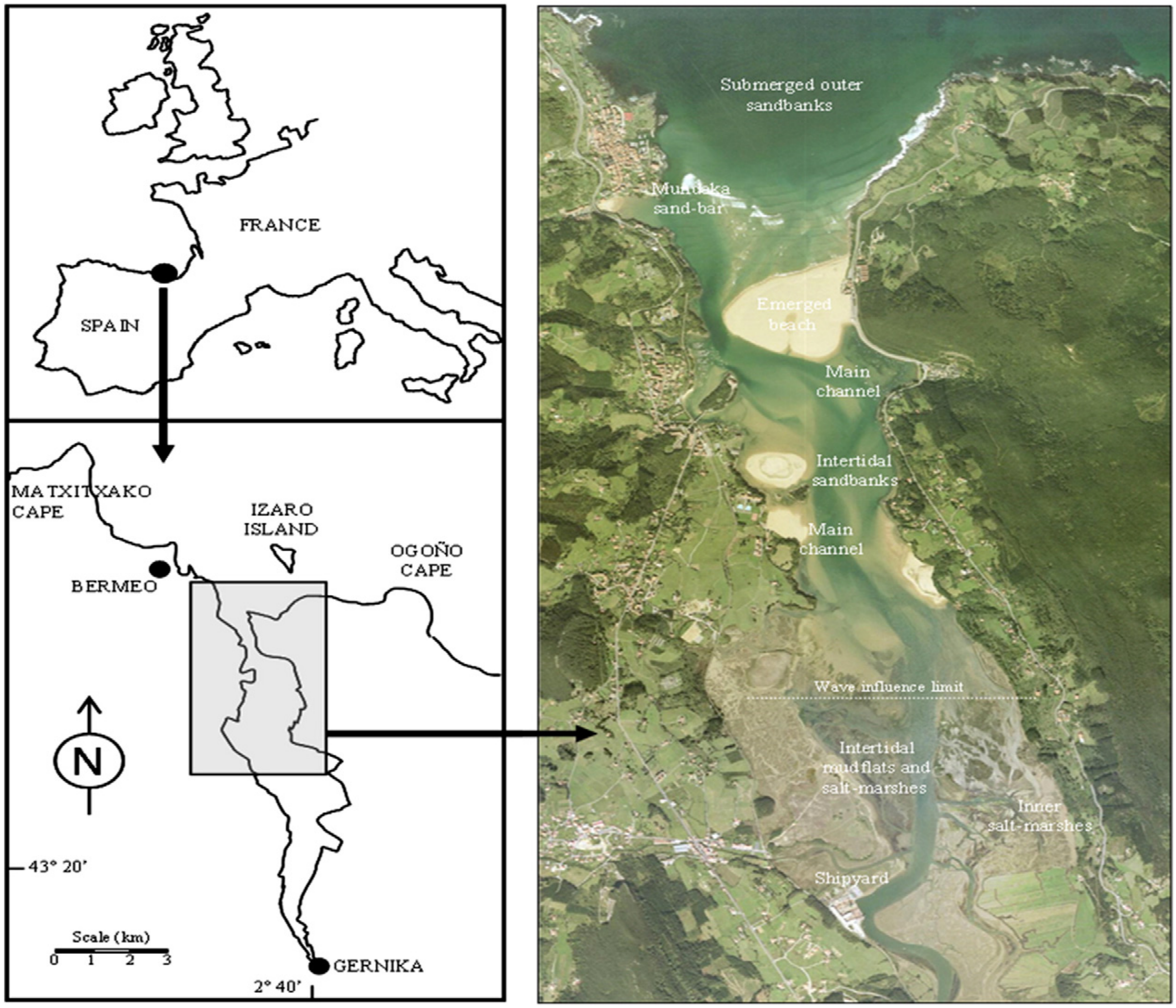

Fig. 1. Location of Urdaibai Estuary and the main habitats in the estuary.

- A participatory workshop to establish weights and define different management options (alternatives) (13 December 2007) 25–30 participants
- Two final workshops to validate results (13 December 2007 and 3 July 2008): 40 participants

3.1.1. Social Actors

To identify relevant social actors, the so called snowball sampling method was adopted. The snowball technique consists of identifying social actors who then refer researchers to other social actors (Vogt, 1999). Note, that in this case the snowball strategy was adopted as a method of contact rather than a method of sampling in a more formalised and statistical sense (Atkinson and Flint, 2001). To overcome the limitations of the snowball technique, and avoid the potential exclusion of unknown actors, we complement it with an institutional analysis (i.e. detailed revision of existing legislation, historical and technical documents, newspaper articles, minutes of the city council sessions, among other documents) and with open meetings in the affected municipalities.

To ensure a broad scope, the diversity of the group was assessed according to three attributes: power, legitimacy, and urgency (Mitchell et al., 1997). Taking into account the various combinations of these three attributes, we were able to distinguish among different types/classes of social actors (e.g. dominant, definitive, dependent, demanding, and discretionary). For instance, in our case study (see second column in Table 1), the Spanish Environmental Ministry and the Director of Harbours and Maritime affairs have been classified as "dominant", taking into account that they have the power and legitimacy to take decisions, but lack the urgency to do it. The Basque Environmental Ministry and the Head of Biosphere Reserve also share these attributes, but had the urgency to take a decision and, therefore, were catalogued as "definitive" social actors. In contrast fishermen, environmental guides, and labour unions have the legitimacy and urgency, but do not have the power to impose their will and consequently were considered as "dependent".

These classifications provided useful information for understanding the dynamics of the social conflict and deciding upon the social group composition of the workshops (to avoid an excessive number of dominant actors in the same discussion group or to ensure a balance among actors with highest influence on a decision and those most affected by it).[1] Table 1 summarises the list of the involved social actors, their profiles, and the interest they represent.

3.1.2. Criteria

Criteria are a technical translation of social actors´ needs and expectations operated by the research team and, should cover the multiple dimensions of the issue at hand. Although there is no consensus in determining the number of criteria in this type of evaluation this is limited to 7–12 (Bouyssou, 1990; Yoon and Hwang, 1995).

[1] Note that this typification was not considered in the weighting procedure. For instance, we did not calculate average weight for the different types of actors, and each actor was considered separately.

Table 1
Stakeholders and their profiles.

Actor	Type	Scale	Summary of position
Spanish Environmental Ministry (Head Coastal zones)	Dominant	National	Will finance restoration of estuary and other coastal zones. Against dredging activities.
Basque Environmental Ministry	Definitive	National	Want environmental criteria to prevail.
Director of Harbors and Maritime Affairs	Dominant	National	Consider that management of the estuary is not their business but believe continued operation of the shipyard in the estuary will be difficult.
Head of the Biosphere reserve	Definitive	Regional	Want to recover degraded habitats. Against dredging; want more restrictive measures to protect the estuary.
Fishers	Dependent	Local,	Against any human intervention that may alter the ecosystems (whether dredging or dune recovery).
Environmental guides	Dependent	Regional, international	Concerned about continuous deterioration of the estuary; against dredging. Want ecology of area improved.
Surfers	Definitive	Local	Threatened by dredging and suspicious of conservation measures that might alter the dynamics of the estuary.
Labor union	Dependent	Local, regional	Want to conciliate industrial activity with the environment. Priority is to keep local jobs.
Bird watchers	Dependent	Local, regional, international	Concerned with the decline in bird due to fishing, or uncontrolled navigation. Against dredging; want more restrictive measured to protect the area.
Recreational Boaters	Demanding	Local	Support human intervention that would recover the old shape and depth of the channel. Oppose dune recovery program.
Shipyard workers	Definitive	Local, regional, international	Claim the right to continue their activities and financial support to keep the channel depth. Would leave the estuary if compensated.
Ekologia Tailerra (volunteers)	Dependent	Regional	Want stricter law enforcement and socio-economic activities compatible with conservation. Want integrated plan for the area.
Zain Dezagun Udaibai (NGO)	Dependent	Local	Support natural value of area to foster local development avoiding major tourism. Habitat recovery is a priority.
Dune recovery group	Discretionary	Regional	Want to limit human activity to within ecological constraints (e.g., dredging should not undermine the natural evolution of the dunes). Want more research to monitor the evolution of the estuary.
Murueta Council	Demanding	Local	In favour of keeping shipyard and promoting agropecuary activities in the estuary. Claim economic compensation for those whose lands were converted to public use.
Sukarrieta Council	Discretionary	Local	Want sand for their beaches and to build a harbor in the estuary for recreational boats. In favour of dredging the channel for recreational purposes.
Mundaka Council.	Dependent	Local	Against major dredging that might affect shell-fishing and surfing. Want to conserve environment as a tourism attractor.
Busturia Council	Discretionary	Local	In favour of promoting local development and employment compatible with conservation. Against massive dredging. Involved in habitat recovery plans
Arteaga Council	Discretionary	Local	Against massive dredging; are developing conservation initiatives, want more autonomy for local authorities.

The identification and selection of criteria started with personal interviews and was complemented with a workshop. In this type of participatory workshop it is not always easy to ensure the free participation of everybody and to avoid the lobbying capacity of those interests that might be overrepresented and power inequalities we combined big setting with small groups. Participants were distributed around three topics to discuss about the present and future situation of the estuary in the workshops: (1) society and welfare; (2) environment and biodiversity, (3) economics dynamism. With a similar rationality in participatory processes becomes essential to collect different point of views through anonymous questionnaires and interviews (De Marchi, et al., 2000; Gimarães-Pereira et al., 2006) and after the workshop a new round of interviews was carried out to validate the results.

A diversity of perspectives coexists in the Basque society, many of which were represented in the participatory workshops. As expected, meetings were characterised by intense debates among the counterparts. Taking into account the contrasting views regarding the principles that should guide the future management of the estuary, the set of criteria shown in Table 2 was finally adopted. A more detailed description of the procedure used for identifying, defining, and measuring the selected set of criteria can be found in Garmendia et al. (2010a).

3.1.3. Alternatives

In this case study alternatives represent management options for the Urdaibai Estuary (UE). Dredging activities, disposal sites and the ecological threats to the estuary arose during the participatory process as the key factors to define different philosophies of action together with compensation mechanism for those affected by the management plan. On this basis a preliminary proposal was constructed by the research team and an external group of experts. Following Massam's (1988) suggestion, a set of alternatives was defined to include (a) the status quo or business as usual scenario, (b) an ideal best plan, (c) a hypothetical worst plan, and (d) a compromise solution or minimum satisfaction. Alternative A1, the business-as-usual scenario, represents the current management regime. To represent an ideal best plan, we consider that the overarching goal in the management of the Urdaibai Biosphere is the achievement of a sustainable future.[2] Accordingly, this scenario includes those alternatives that concurrently do not harm the environment and create socio-ecological benefits for the local inhabitants (A2 and A3). In contrast, those alternatives that harm the environment and the diverse socio-economic interests that coexist in the area (B2 and B3) represent the worst scenario. Alternatives between these two extreme scenarios (C2 and C3) encompass the compromise options. The alternatives covered a wide range of options, enabling all social actors to identify with at least one option. The external experts provided preliminary feedback and, after calculating the criteria scores for all alternatives, those that resulted dominated were omitted. In addition, to avoid biases from the research team and the selected group of consulted experts this set of management options was exposed to the revision of the wider public, in a second participatory workshop (>25 participants) that served to validate the preliminary proposal. The remaining alternatives are summarised in Table 3.

[2] Urdaibai Biosphere Reserve Protection and Planning Act, Law 5/1989, approved by the Basque Parliament with the aim of: "*…protecting the integrity and promoting the recovery of the land, flora, fauna, landscape, water and atmosphere, and in short, of the whole ecosystem on the basis of its natural, scientific, educational, cultural, recreational and socioeconomic interest*" (article, 1).

Table 2
Evaluation criteria.

Criteria	Needs and expectations
Employment	– Enhance local employment and avoid displacing residents – Support local economic activities – Improve the quality of life – Guarantee job stability – Coherence with local reality
Local incomes	– Increase municipality's income – Increase municipality's income – Avoid becoming a "bedroom community" – Promote local business – Support equitable development among municipalities
Compatibility between socio-ecological activities	– Avoid severe impacts to activities – Minimise impact on fishing, surfing, industry, conservation, tourism, navigation – Foster a balance between development, education, and conservation
Cost of implementation	– Maintain industrial competitiveness and warranty, economic viability – Consider administrative budget constraints – Take opportunity costs into account
Environmental disturbance	– Keep noise pollution to a minimum – Avoid massive affluence and foster quality tourism – Limit navigation – Enhance non invasive cultural and economic activities – Conserve the environmental quality of the area
Impact on habitat and fauna	– Reduce impact over ecosystems: marshes, reed beds, sandbanks, etc. – Avoid impact on fauna: birds, shellfish, etc. – Diminish the impact of toxic sediments. – Avoid invasive species proliferation
Reversibility	– Maintain the potential of the area for the future – Respect the dynamics of the river – Encourage a long-term orientation for reaching an equilibrium
Uncertainty	– Reduce uncertainty of management options – Acknowledge the uncertain and complex response of the system – Adopt a precautionary approach

Table 3
Summary of alternatives/management options.

Alternatives	Sub-alternatives
A1 Do nothing: leave the system on its own without any type of intervention. No active conservation measures, no dredging activities, no compensation measures.	
A2 Compensation: do not allow dredging and compensate the affected parties (mainly shipyard workers) for the constraints on their activities.	
A3 Conservation: do not allow dredging and direct all the public resources into conservation measures for the estuary. Eradication of invasive species, recovery plans for damaged areas, creation of guard and maintenance services in the estuary and removing the illegal boats…	
B Satisfy demands from industry (shipyard) with a maximum dredging along the channel (200,000–300,000 m^3) and disposal of dredged material in…	B2… intertidal zone B4… submerged area
C Compromise: minimum dredging according to the "systems limit" (20,000–30,000 m^3 to guarantee navigability for small boats) and conservation measures.[a] Disposal of dredged material in…	C2… intertidal zone C4…submerged area

[a] In this case the conservation measures will be less than in scenario A3 considering that part of the public budget would be assigned for a minimum dredging.

3.1.4. Prioritisation of Criteria

The fourth step in the evaluation process involved the prioritisation of criteria. The fact that a group of diverse social actors can agree on a set of criteria do not mean that they attach the same relevance to each of them. When deciding about our surrounding socio-ecological system there is a need for some form of deliberative institutions within which the relevance of different reasons can be considered (Holland et al., 1996).

3.1.4.1. Individual Weighting. At the individual level, the social actors were first requested to rank criteria with regard to their own interest. This was done using Simos' revised method, which provides individual quantitative and ordinal weights (Figueira and Roy, 2002; Maystre et al., 1994). The result of this prioritisation exercise is illustrated in Table 4, which shows the different priorities assigned to the various criteria by the social actors. The weights obtained by this method should be applied as importance coefficients.

The dispersion of individual weights is illustrated in Fig. 2, with each point representing the weight given to a criterion by one social actor.

Descriptive statistics of the weights attached to each criterion are provided in Table 5. The coefficient of variation[3] shown in this table reflects the degree of conflict regarding the prioritization of a given criterion done by the social actors. The greatest differences in individual weights were related to the importance associated to the implementation cost criteria.[4] In this those actors that would hypothetically afford the cost of some of the measures included in the set of alternatives (i.e. Shipyard and the Spanish Environmental Ministry) were the ones that attach more relevance to this criterion.

3.1.4.2. Social or Group Weighting. The determination of group priorities (group weighting) is based upon a hierarchical clustering process, in which each social actor is represented by a point in an *l*-dimensional weight space (where *l* is the number of criteria). The clustering process considers each point (i.e., social actor) as an individual cluster and calculates the squared Euclidean distance between these points. Then, clusters are merged according to Ward's criterion, implying a minimum increase in the total within-cluster variance.

The dendrogram in Fig. 3 shows the sequence by which social actors and groups are merged according to the similarities of their priorities. At each step, the number of clusters decreases and the within-cluster variance (the difference of opinions within the cluster) increases. Therefore, it becomes necessary to determine an adequate number of clusters for the further multi-criteria analysis.

Several statistical tests and methods can be used to determine the "optimal" or adequate number of clusters. However, the grouping should be checked to make sure they are conceptually valid and not imposed by the classification method (Aldenderfer and Blashfield, 1984, quoted in Köbrich et al., 2003). "The most meaningful way of testing the conceptual validity of the classifications is determining if they serve the purpose of the analysis" (Köbrich et al., 2003: 146).

Therefore, the decision about the number of relevant clusters for the analysis should be based on the researcher's experience and the knowledge acquired through empirical observations (e.g., in interviews and workshops in which it is possible to contrast the perception of credible groups with the results of the cluster analysis, and through subsequent feedback with a reduced group of relevant social actors). For this case study, after we discussed the potential similarities and discrepancies of the individual priorities, we clustered the individual weights into five groups; these are represented by the "cutting line" C–C′. The cutting lines A–A′ and B–B′ yielded more groups that were operating in reality. For instance, the Head of Maritime Affairs and the Basque Environmental Ministry would fall in different groups according to this clustering, while they actually expressed similar priorities during the evaluation process. On the other hand, the cutting line D–D′ yields too few clusters and combines some of the group social actors who

[3] The *coefficient of variation* (σ/μ) is a normalized measure of dispersion of a probability distribution. It shows the extent of variability in relation to mean of the sample.

[4] We also found significant statistical differences (Kruskal–Wallis test, $\chi^2 = 45.2$, d.f. = 7, p<0.0001) when comparing the prioritization of the criterion *implementation costs* across social actors with the prioritizations of the rest of criteria.

Table 4
Weights of criteria according to social actors' priorities.

Social actors	Criteria							
	Employment	Local incomes	Socio-ecological compatibility	Implementation costs	Environmental disturbance	Impact on habitat and fauna	Reversibility	Uncertainty
Shipyard Labour Union	21.9	9.4	3.1	15.6	15.6	1.9	9.4	3.1
Ekologia Tailerra (boluntiers)	13.8	10.3	17.2	3.4	17.2	17.2	0.0	207
Duna Recovery	13.5	3.5	13.5	2.7	13.5	13.5	10.8	18.9
Shipyard	20.0	20.0	16.7	3.3	13.3	13.3	6.7	6.7
Murueta Council	15.0	15.0	20.0	5.0	10.0	10.0	15.0	10.0
Mundaka Council	19.2	15.4	19.2	3.8	7.7	7.7	15.4	11.5
Spanish Env. Ministry	11.8	5.9	17.6	17.6	11.8	11.8	17.6	5.9
Recreational Boats (Sukarrieta Co.)	8.3	8.3	16.7	8.3	8.3	16.7	25.0	8.3
Head Marine Affairs	5.0	10.0	20.0	5.0	10.0	15.0	20.0	15.0
Surfers	4.7	7.0	18.6	2.3	14.0	16.3	18.6	18.6
Arteaga Coucil	5.9	5.9	23.5	5.9	11.8	23.5	11.8	11.8
Basque Env. Ministry (Head of Biosphere)	8.3	8.3	10.4	2.1	18.8	20.8	14.6	16.7
Env. Guides	7.3	7.3	9.8	2.4	22.0	19.5	14.6	17.1
Birth Watchers	7.0	9.3	11.6	2.3	16.3	20.9	18.6	14.0
Zain Dezagun (NGO)	9.1	9.1	12.1	3.0	18.2	18.2	15.2	15.2
Fishers	15.4	2.6	17.9	5.1	12.8	17.9	17.9	10.3
Busturia Council	11.1	5.6	16.7	2.8	22.2	19.4	13.9	8.3

actually had quite different views, e.g., volunteers of an environmental NGO and representatives of the shipyard. Table 6 provides descriptive statistics regarding the weights of each criterion derived by cluster.

The standard deviations shown in this table indicate the polarisation of opinions within each group; these are smaller than the standard deviations associated with the whole array of social actors (Table 5).

Once validated, the results of the clustering process with the social actors enabled us to assess the influence of weights in the multi-criteria aggregation process in an explicit manner. This complements the standard sensitivity analysis used in MCEs, reinforcing the robustness of the analysis from a social perspective. After the impact of each alternative is obtained in accordance with the selected set of criteria (see Garmendia et al., 2010a), and group weights are identified, a multi-criteria aggregation procedure must be run to account for these diverse priorities, as discussed in Section 3.2.

It is important to note that social preferences expressed as part of a group may be different from those held by the individual group members (Sagoff, 1988). Therefore, discussion among social actors on the results of the cluster analysis is critical for encouraging the emergence of different opinions.

3.2. Multi-criteria Aggregation Procedure under Diverse Social Preferences

Numerous mathematical algorithms have been devised to solve multi-criteria problems (Ananda and Heralth, 2009; Figueira et al., 2005), each with its own advantages and disadvantages, depending on the application context (Montis et al., 2004).

In accordance with our earlier statement that partially or non-compensatory multi-criteria models are the most suitable for use with sustainability related issues, we adopted the C–K–Y–L ranking procedure presented in Munda (2005).

We began the procedure by carrying out $N\cdot(N-1)$ pair-wise comparisons, where N is the number of alternatives. This step results in the construction of the outranking matrix (Table 7), in which each element e_{jk} of the matrix is equal to the sum of both the weights of criteria under which alternative j is better than alternative k and

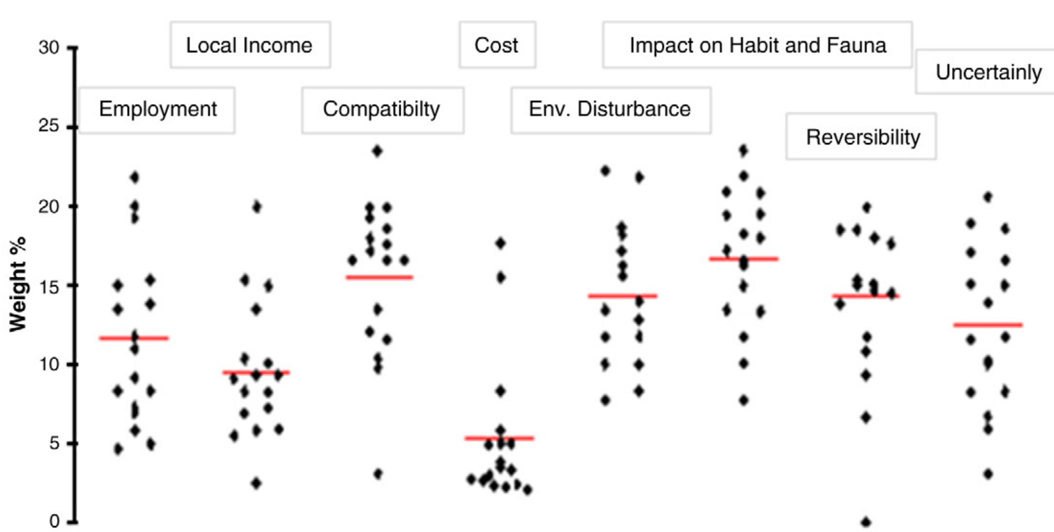

Fig. 2. Diagram of dispersion of individual weights.

Table 5
Descriptive statistics according to individual weights with 95% coefficient interval.

Criterion	Min	Max	Mean μ	Std. deviation σ	Coefficient of variation
Employment	4.7	21.9	11.6	5.37	0.46
Local incomes	2.6	20.0	9.6	4.30	0.45
Socio-ecological compatibility	3.1	23.5	15.6	4.93	0.32
Implementation costs	2.1	17.6	5.3	4.56	0.85
Environmental disturbance	7.7	22.2	14.3	4.36	0.30
Impact on habitat and fauna	7.7	23.5	16.7	4.35	0.26
Reversibility	0.0	25.0	14.4	5.68	0.39
Uncertainty	3.1	20.7	12.5	5.08	0.41

half of the weight of the criterion under which alternatives *j* and *k* are indifferent. More formally, $e_{jk}+e_{kj}=1$, with $j\neq k$.

If *R* is the set of all *N!* possible complete rankings of alternatives (i.e., all the possible permutations of the set of N alternatives: $R=\{r_s\}$, $s=1,2,\ldots, N!$), the procedure computes the corresponding score, Φ_s, for each r_s as the summation of e_{jk} where $j\neq k$, $s=1,2,\ldots N!$ and $e_{jk}\in r_s$ (Eq. (1)).

$$\phi_s=\sum e_{jk} \tag{1}$$

For instance, if we have the following ranking, r_s:

r_1 : A2→A3→A1 (A2 better than A3 better than A1)

Then $\Phi_1=e_{\mathbf{23}}+e_{\mathbf{21}}+e_{\mathbf{31}}$

The final ranking (r^*) is the one that maximises the summation of e_{jk}

3.3. Ranking of Alternatives Resulting from Multi-Criteria Aggregation

Table 8 presents the rankings of alternatives with best Φ_s scores according to the priorities of each social group. As shown, Groups 2, 3, 4, and 5, would prefer to constrain dredging activities and develop conservation measures through habitat recovery plans or invasive species eradication that enhance local development, while improving the quality of the environment (alternative A3). For these groups, minimum dredging activity accompanied by some conservation measures (alternative C4), or no dredging activities with compensation paid to affected parties (A2) are the second best options. Only Group 1, which represents the shipyard labour union, would prefer that alternatives A2 and C2 prevail over A3.

In addition to revealing that alternatives A3, A2, and C4 were favoured by the majority of the identified social actors, the weighting analysis showed that alternatives B4 and B2 (i.e., maximum dredging in order to satisfy the demand from industry) were ranked lowest according to the preferences of all social actors. Note that beyond the search for optimal solutions, in defining public policies it is also desirable to discard alternatives that are unsupported by the majority of the stakeholders. Interestingly, the evaluation process for this case study revealed a paradox: massive dredging, which has been the prevailing policy in the Urdaibai Estuary during the last decades, is the one option that all involved social actors agreed should be abandoned. This is partially a result of changes in the decision-making authorities due to regional elections. It is also important to note that the preferences of the diverse social actors have changed due to the impacts of the latest dredging event in 2003 and the subsequent social contestation. These results are in coherence with the preliminary results obtained by means of NAIADE (JRC-EC, 1996), a non-compensatory outranking model that does not incorporate the explicit definition of weights (for further details of this analysis see Garmendia et al., 2010a).

The prioritisation process also yielded relevant information with regard to conflicting social preferences and extreme positions (Table 4). In this context, defining the relevance of each criterion explicitly provided a quality assurance mechanism to guarantee that the relevant properties of the issues at hand, which emerged during the participatory evaluation process, were incorporated adequately in the analysis. In other cases, this mechanism also could serve to identify and reconsider the incorporation of irrelevant criteria that could disturb the quality of the analysis.

As discussed below, time for reflection on individual and group preferences also provided an opportunity for a social learning process and the increase of participants' mutual understanding (for further

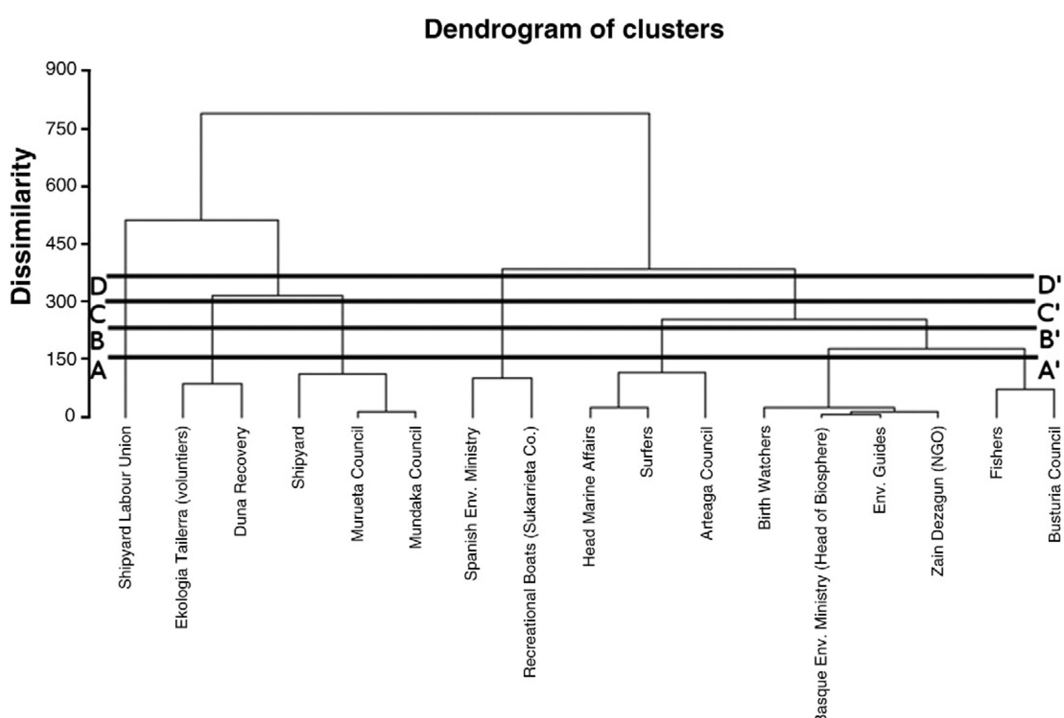

Fig. 3. Dendogram of clusters according to group weights.

Table 6
Descriptive statistics according to group weights with 95% coefficient interval.

Criteria		Weights				
		Group 1	Group 2	Group 3	Group 4	Group 5
Employment	Max		13.8	20.0	11.8	15.4
	Mean ± S.D.	21.9 ± 0	13.7 ± 0.1	18.1 ± 2.2	10.0 ± 1.7	8.2 ± 3.2
	Min		13.5	15.0	8.3	4.7
Local incomes	Max		13.5	20.0	8.3	10.0
	Mean ± S.D.	9.4 ± 0	11.9 ± 1.6	16.8 ± 2.3	7.1 ± 1.2	7.2 ± 2.2
	Min		10.3	15.0	5.9	2.6
Compatibility between socio-ecological activities	Max		17.2	20.0	17.6	23.5
	Mean ± S.D.	3.1 ± 0	15.4 ± 1.9	18.6 ± 1.4	17.2 ± 0.5	15.6 ± 4.6
	Min		13.5	16.7	16.7	9.8
Cost of implementation	Max		3.4	5.0	17.6	5.9
	Mean ± S.D.	15.6 ± 0	3.1 ± 0.4	4.1 ± 0.7	13.0 ± 4.7	3.4 ± 1.4
	Min		2.,7	3.3	8.3	2.1
Environmental disturbance	Max		17.2	13.3	11.8	22.2
	Mean ± S.D.	15.6 ± 0	15.4 ± 1.9	10.3 ± 2.3	10.0 ± 1.7	16.2 ± 4.1
	Min		13.5	7.7	8.3	10,0
Impact on habitat and fauna	Max		17.2	13.3	16.7	23.5
	Mean ± S.D.	21.9 ± 0	15.4 ± 1.9	10.3 ± 2.3	14.2 ± 2.5	19.1 ± 2.4
	Min		13.5	7.7	11.8	15.0
Reversibility	Max		10.8	15.4	25.0	20.0
	Mean ± S.D.	9.4 ± 0	5.4 ± 5.4	12.4 ± 4.0	21.3 ± 3.7	16.1 ± 2.6
	Min		0.0	6.7	17.6	11.8
Uncertainty	Max		20.7	11.5	8.3	18.6
	Mean ± S.D.	3.1 ± 0	19.8 ± 0.9	9.4 ± 2.0	7.1 ± 1.2	14.1 ± 3.2
	Min		18.9	6.7	5.9	8.3

details regarding the social learning process that took place in this participatory process see also Garmendia and Stagl (2010)).

4. Discussion and Conclusions

Because socio-ecological systems are complex and uncertain (Berkes et al., 2003) individuals need to simplify them in order to comprehend the myriad factors and forces that shape the associated problems and social processes (Simon, 1983). In this context the key questions is how to simplify the system. On the one hand, in public policy debate the number of diverse priorities can become so great that both the MCE process and the analysis of the results are intractable. On the other hand, compressing a complex situation into a single scale of priorities (weights) can result in deadlock for the decision-making process because the conditions have become too rigid for compromise (Munda et al., 1995).

The novel approach proposed in this paper seeks a balance between these two extreme situations. With this aim, it manages the diverse and often conflicting individual priorities that are characteristic of public decision-making processes by reducing the set of social preferences through the combination of a cluster analysis and a deliberative appraisal. This aggregation of preferences avoids forcing a consensus or searching for a single aggregated parameter (average set of weights).

Under this perspective, individual priorities are grouped according to their degree of similarity and the clusters are discussed in an open and deliberative process in which new individual and social priorities can emerge. In this way, the involved social actors are able to observe their priorities in the context of the priorities of others, bringing their positions closer. Also, the opinion of individuals may distance from the group they pertain, but it didn't happen in this case.

Preferences are not fixed (Norton et al., 1998; O'Hara, 1996; Slovic, 1995), but can evolve through a social learning process that extends beyond individual, and often predefined, priorities. Moreover, as other valuation studies show, individual preferences of the same subject may differ depending on whether the choice is made in isolation or in a group setting and depending on the criteria (e.g., individual versus collective well-being) (Álvarez-Farizo et al., 2007; Spash, 2007).[5] A questionnaire survey carried out at the beginning and the end of the participatory process to assess the social learning process show that the preferences of participants have evolved over time giving rise to social concerns in detrimental of the initial prevalence that attracted the economic parameter. The survey also shows an increase in mutual understanding and the perception that the capacity for joint action have increased after the participatory process (more details in this regard can be found in Garmendia and Stagl (2010)).

In the context of public deliberation for social preference elicitation, the cluster analysis (Fig. 3) provides a useful interface to facilitate a dialogue among all counterparts in a public decision-making process. The cluster dendogram allows the mapping of the diversity of priorities and making explicit potential coalitions, and works as a communication tool that enables people to understand their position/priorities with respect to other actors.

Within this framework the diverse prioritisations obtained from the clustering process (various set of weights) are used to perform the multi-criteria aggregation procedure, opening the possibility for a new round of deliberation regarding the outcomes of the whole participatory evaluation process (different ranking of alternatives).

The use of different weight combinations in this final aggregation procedure entails a social sensitivity analysis of the evaluation process. That is, it allows the assessment of the robustness of the results according to the diverse social actor's priorities.[6] This is an important feature, not only to elucidate plausible conflict, but also to identify

Table 7
Outranking matrix.

	A_1	A_2	A_k	A_N
A_1	e_{11}	e_{12}	e_{1k}	e_{1N}
A_2	e_{21}	e_{22}	…	…
.				
A_j	…	…	e_{jk}	e_{jN}
.				
A_N	e_{N1}		e_{Nk}	e_{NN}

[5] In this case the elicitation of preferences was done individually in isolation but after having time to deliver in a group setting.

[6] Notice that analysts are also relevant social actors, who can include a set of weights not expressed in the sample. For instance, one can include a set of weights giving priority to ecological values and/or future generations.

Table 8
Raking of alternatives according to group weights.

Rank								
	First	Second	Third	Fourth	Fifth	Sixth	Seventh	φ_s score
Group 1	A2	C2	C4	A3	A1	B4	B2	13.03
	C2	C4	A3	A2	A1	B4	B2	12.97
	C4	A3	A2	A1	C2	B4	B2	12.94
	C4	A3	A2	C2	A1	B4	B2	12.94
	A2	C4	C2	A3	A1	B4	B2	12.94
Group 2	A3	A2	C4	C2	A1	B4	B2	15.09
	A3	A2	C2	C4	A1	B4	B2	15.04
	A3	C4	A2	C2	A1	B4	B2	15.02
	A4	A2	C4	A1	C2	B4	B2	14.97
Group 3	A3	C4	C2	A2	A1	B4	B2	14.75
	C4	A3	C2	A2	A1	B4	B2	14.74
	C4	C2	A3	A2	A1	B4	B2	14.72
	A3	C4	A2	C2	A1	B4	B2	14.68
	C4	A3	A2	C2	A1	B4	B2	14.67
Group 4	A3	C4	A2	A1	C2	B4	B2	15.17
	A3	A2	C4	A1	C2	B4	B2	15.06
	A3	C4	A2	C2	A1	B4	B2	15.06
	C4	A3	A2	A1	C2	B4	B2	14.98
	A3	A2	C4	C2	A1	B4	B2	14.95
Group 5	A3	A2	C4	A1	C2	B4	B2	16.07
	A3	A2	C4	C2	A1	B4	B2	16.02
	A3	C4	A2	A1	C2	B4	B2	16.02
	A3	C4	A2	C2	A1	B4	B2	15.96

the power relations among the stakeholders that may influence in the adoption of any public decision. In this case, the assessment revealed that the alternative of massive dredging that prevailed in the past is now the least suitable option according to the priorities of the majority of social actors. Dredging in the future would be possible only if the shipyard imposes a veto power.

Conversely, performing the assessment under tractable, but diverse social priorities, allows social actors to identify the differences and similarities across the calculated rankings, facilitating the search for compromise decisions (Van den hove, 2006). In this case, the leading alternatives were the same under different weight combinations; thus, allowing people to see that they were closer to other actors than previously perceived.

In this case study the dialogue for the elicitation of weights also allowed social actors to be explicit with regard to their priorities, to address common and conflicting areas, and to participate in a social learning process. Similar to the deliberative appraisal work of Fiorino (1990), Laird (1993), Webler et al. (1995), and Schusler et al. (2003), an ex-post analysis of the project showed that the entire participatory MCE contributed to the acquisition of more factual knowledge and created more opportunities for joint action after the project. Allowing time to reflect on social preferences and providing a wide opportunity for interaction among participants also fostered greater mutual understanding of the preferences of others (for further details regarding the ex-post analysis see Garmendia and Stagl, 2010).

Notwithstanding, the participatory process described above is not free from difficulties. Coping with the influence of powerful social actors and respecting the diversity of perspectives is central to the proposed framework; the adoption of a decision based upon specific social priorities must be as transparent and inclusive as possible. Transparency requires continuous feedback loops among all the counterparts (social actors and external experts) and the ability to reframe the issue at hand with the best available knowledge that emerges during the process. In participatory MCE approaches, inclusivity requires the assistance of professional facilitators, a combination of public sessions and confidential interviews, and the use of participatory dynamics that allow flexible group discussions that support the rights of all participants to express their positions in a non-coercive way (Gamboa, 2006; Kowalski et al., 2009; Munda, 2004).

Based on the lessons learned during this participatory process, we note that the search for a sound decision should not oversimplify complex social realities nor impose an artificial consensus. Individual values and preferences should be aggregated by mutual consent and agreement and not necessarily merged into a single, all-encompassing identity (Howarth and Wilson, 2006). This is crucial to ensure that the subsequent decision-making process is legitimised and socially accepted. Moreover, compression of the option space through open dialogue, with the help of decision support frameworks like the one presented in this study, can provide a robust basis for reaching agreement in the formulation of sustainable public policies.

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References

Aldenderfer, M.F., Blashfield, R.K., 1984. Cluster Analysis. The International Professional Publishers, Beverly Hills, USA.

Al-Kloub, B., Al-Shemmeri, T., Pearman, A., 1997. The role of weights in multi-criteria decision aid, and the ranking of water projects in Jordan. European Journal of Operational Research 99, 278–288.

Álvarez-Farizo, B., Hanley, N., Barberánc, R., Lázarod, A., 2007. Choice modelling at the "market stall": individual versus collective interest in environmental valuation. Ecological Economics 60, 743–751.

Ananda, J., Heralth, G., 2009. A critical review of multi-criteria decision making methods with special reference to forest management and planning. Ecological Economics 68 (10), 2535–2548.

Antunes, P., Kallis, G., Videira, N., Santos, R., 2009. Participation and evaluation for sustainable river basin governance. Ecological Economics 68 (4), 931–939.

Atkinson, R., Flint, J., 2001. Accessing hidden and hard-to-reach populations: snowball research strategies. Social Research Update 33, 1–4.

Banville, C., Landry, M., Martel, J.M., Boulaire, C., 1998. A stakeholder approach to MCDA. Systems Research and Behavioral Science 15 (1), 15–32.

Berkes, F., Colding, J., Folke, C. (Eds.), 2003. Navigating social–ecological systems: building resilience for complexity and change. Cambridge University Press, Cambridge.

Borcherding, K., Eppel, T., Winterfeldt, D., 1991. Comparison of weighting judgments in multiattribute utility measurement. Management Science 37, 1603–1619.

Bouyssou, D., 1990. Building criteria: a prerequisite for MCDA. In: Bana e Costa, C.A. (Ed.), Readings in Multiple Criteria Decision Aid. Springer, Berlin, Heidelberg, New York.

Choo, E.U., Bertram, S., Wedley, W., 1999. Interpretation of criteria weights in multicriteria decision making. Computers and Industrial Engineering 37, 527–541.

Daly, H.E., 1990. Toward some operational principles of sustainable development. Ecological Economics 2 (1), 1–6.

de Marchi, B., Funtowicz, S.O., Lo Cascio, S., Munda, G., 2000. Combining participative and institutional approaches with multicriteria evaluation. An empirical study for water issues in Troina, Sicily. Ecological Economics 34, 267–282.

Dryzek, J.S., 2000. Deliverative democracy and beyond. Liberals, Critics, Contestations. Oxford University Press, U.K.

Figueira, J., Roy, B., 2002. Determining the weights of criteria in the ELECTRE type methods with a revised Simos' procedure. European Journal of Operational Research 139, 317–326.

Figueira, J., Greco, S., Ehrgott, M., 2005. Multiple-criteria decision analysis. State of the Art Surveys. Springer, New York.

Fiorino, D.J., 1990. Citizen Participation and Environmental Risk: A survey of institutional mechanisms. Science Technology and Human Values 15 (2), 226–243.

Funtowicz, S.O., Ravetz, J., 1990. Uncertainty and Quality in Science for Policy. Kluwer, Dordrecht.

Gamboa, G., 2006. Social multi-criteria evaluation of the different development scenarios of the Aysén region, Chile. Ecological Economics 59 (1), 157–170.

Gamboa, G., Munda, G., 2007. The problem of windfarm location: a social multi-criteria evaluation framework. Energy Policy 35, 1564–1583.

Garmendia, E., Stagl, S., 2010. Public participation for sustainability and social learning: concepts and lessons from three case studies in Europe. Ecological Economics 69 (8), 1712–1722.

Garmendia, E., Gamboa, G., Franco, J., Garmendia, J., Liria, P., Olazábal, M., 2010a. Social multi-criteria evaluation as a decision support tool for integrated coastal zone management. Ocean and Coastal Management 53, 385–403.

Garmendia, E., Prellezo, R., Murillas, A., Escapa, M., Gallastegui, M., 2010b. Weak and strong sustainability assessment in fisheries. Ecological Economics 70, 96–106.

Giampietro, M., 2010. Integrated Assessment of Agricultural Sustainability: the Pros and Cons of Reductionism. Reports on Environmental Sciences. Institut de Ciència i Tecnologia Ambientals - Universitat Autònoma de Barcelona. Available at: http://www.recercat.net/bitstream/2072/96137/1/RepEnvSci_2010-01.pdf.

Giampietro, M., Mayumi, K., Munda, G., 2006. Integrated assessment and energy analysis: quality assurance in multi-criteria analysis of sustainability. Energy 31, 59–86.

Gimarães-Pereira, A., Guedes, S., Tognetti, S., 2006. Interfaces between Science and Society. Greenleaf Publishing, Sheffield.

Kangas, J., Kangas, A., 2005. Multiple criteria decision support in forest management-the approach-methods applied, and experiences gained. Forest Ecology and Management 207, 133–143.

Habermas, J., 1996. Between Facts and Norms: Contributions to a Discourse Theory of Law and Democracy. Blackwell Publishing, London.

Hajkowicz, S.A., 2008. Supporting multi-stakeholder environmental decisions. Journal of Environmental Management 88, 607–614.

Hajkowicz, S.A., Collins, K., 2009. Measuring the benefits of environmental stewardship in rural landscapes. Landscape and Urban Planning 93 (2), 93–102.

Hajkowicz, S.A., McDonald, G.T., Smith, P.N., 2000. An evaluation of multiple objective decision support weighting techniques in natural resource management. Journal of Environmental Planning and Management 43, 505–518.

Hämaläneinen, R., Alaja, S., 2008. The threat of weight biases in environmental decision analysis. Ecological Economics 68, 556–569.

Hämaläneinen, R., Salo, A., 1997. The issue is understanding the weights. Journal of Multi-Criteria Decision Analysis 6, 340–343.

Harremoës, P., Gee, D., MacGarvin, M., Stirling, A., Keys, J., Wynne, B., Guedes Vaz, S. (Eds.), 2001. Late lessons from early warnings: the precautionary principle 1896–2000. European Environmental Agency, Copenhagen.

Hermans, C., Erickson, J., Noordewier, T., Sheldon, A., Kline, M., 2007. Collaborative environmental planning in river management: an application of multicriteria decision analysis in the White River Watershed in Vermont. Journal of Environmental Management 84 (4), 534–546.

Holland, A., O'Connor, M., O'Neill, J., 1996. Costing Environmental Damage: A Critical Survey of Current Theory and Practice and Recommendations for Policy Implementation. European Parliament STOA, Luxembourg.

Howarth, R.B., Wilson, M.A., 2006. A theoretical approach to deliberative valuation: aggregation by mutual consent. Land Economics 82 (1), 1–16.

Jacobi, S.K., Hobbs, B.F., 2007. Quantifying and mitigating the splitting bias and other value tree-induced weighting biases. Decision Analysis 4, 194–210.

Janssen, R., Munda, G., 1999. Multi-criteria methods for quantitative, qualitative and fuzzy evaluation problems. In: van den Bergh, J. (Ed.), Handbook of Environmental and Resource Economics. Edward Elgar, Cheltenham.

JRC-EC, 1996. NAIADE Manual & Tutorial—Version 1.0.ENG. Institute for Systems, Informatics and Safety. Joint Research Centre—European Commission, Ispra, Italy.

Kasemir, B., Gardner, M., Jäeger, J., Jaeger, C. (Eds.), 2003. Public Participation in Sustainability Science. Cambridge University Press, Cambridge.

Köbrich, C., Rehman, T., Khan, M., 2003. Typification of farming systems for constructing representative farm models: two illustrations of the application of multi-variate analyses in Chile and Pakistan. Agricultural Systems 76, 141–157.

Kowalski, K., Stagl, S., Madlener, R., Omann, I., 2009. Sustainable energy futures: methodological challenges in combining scenarios and participatory multi-criteria analysis. European Journal of Operational Research 197, 1063–1074.

Laird, F.N., 1993. Participatory analysis, democracy, and technological decision making. Science Technology and Human Values 18 (3), 341–361.

Liu, S., Proctor, W., Cook, D., 2010. Using an integrated fuzzy set and deliberative multi-criteria evaluation approach to facilitate decision-making in invasive species management. Ecological Economics 69, 2374–2382.

Martinez-Alier, J., Munda, G., O'Neill, J., 1998. Weak comparability of values as a foundation for ecological economics. Ecological Economics 26, 277–286.

Massam, B., 1988. Multi-criteria decision-making techniques in planning. In: Diamond, D., McLoughlin, J. (Eds.), Progress in Planning. Pergamon Press, Oxford.

Maystre, L., Pictet, J., Simos, J., 1994. Méthodes multicritères ELECTRE—description, conseils pratiques d'applications à l gestion environmentale. Presses Polytechniques et Universitaires Romandes, Lausanne.

Millennium Ecosystems Assessment (MEA), 2005. Synthesis Report—Ecosystem and Human Well-Being. http://www.maweb.org/documendts/document.356.aspx.pdf.

Mitchell, R.K., Agle, B.R., Wood, S.J., 1997. Toward a theory of stakeholder identification and salience: defining the principle of who and what really counts. Academy of Management Review 22 (4), 853–886.

Monterroso, I., Binimelis, R., Rodríguez-Labajos, B., 2011. New methods for the analysis of invasion processes: multi-criteria evaluation of the invasion of *Hydrilla verticillata* in Guatemala. Journal of Environmental Management 92, 494–507.

Montis, A., De Toro, P., Droste-Franke, B., Omann, I., Stagl, S., 2004. Assessing the quality of different MCDA methods. In: Getzner, M., Spash, C.L., Stagl, S. (Eds.), Alternatives for Environmental Valuation. Routledge, London, pp. 99–133.

Munda, G., 2004. Social Multi-Criteria Evaluation (SMCE): methodological foundations and operational consequences. European Journal of Operational Research 158 (3), 662–677.

Munda, G., 2005. Multiple criteria decision analysis and sustainable development. In: Figueira, J., Salvatore, G., Ehrgott, M. (Eds.), Multiple Criteria Decision Analysis: State of the Art Surveys. Springer, New York.

Munda, G., 2008. Social Multi-criteria Evaluation for Sustainable Economy. Springer, New York.

Munda, G., Nijkamp, P., Rietveld, P., 1995. Qualitative multi-criteria methods for fuzzy evaluation problems. European Journal of Operational Research 82, 79–97.

Neumayer, E., 2010. Weak versus Strong Sustainability: Exploring the Limits of Two Opposing Paradigms. Edward Elgar, Cheltenham, UK. Northampton, MA, USA.

Norton, B., Costanza, R., Bishop, R., 1998. The evolution of preferences: why 'sovereign' preferences may not lead to sustainable policies and what to do about it. Ecological Economics 24, 193–211.

O'Hara, S.U., 1996. Discursive ethics in ecosystems valuation and environmental policy. Ecological Economics 16, 95–107.

O'Neill, J., 2001. Representing people, representing nature, representing the world. Environment and Planning C: Government and Policy 19, 483–500.

Pöyhönen, Hämäläinen, 2001. On the convergence of multiattribute weighting methods. European Journal of Operational Research 129, 569–585.

Proctor, W., 2004. MCDA and stakeholder participation—valuing forest resources. In: Getzner, M., Spash, C.L., Stagl, S. (Eds.), Alternatives for Environmental Valuation. Routledge, London, pp. 134–158.

Proctor, W., Drechsler, M., 2006. Deliberative multicriteria evaluation. Environment and Planning C: Government and Policy 24, 169–190.

Roca, E., Gamboa, G., Tàbara, J.D., 2008. Assessing the multidimensionality of coastal erosion risks. Public participation and Multicriteria Analysis (MCA) in a Mediterranean Coastal system. Risk Analysis 28 (2), 399–412.

Roy, B., 1985. Méthodologie multicritere d' aide à la decision. Economica, Paris.

Roy, B., Mousseau, V., 1996. A theoretical framework for analysing the notion of relative importance of criteria. Journal of Multi-Criteria Decision Analysis 5, 145–149.

Sagoff, M., 1988. The Economy of the Earth: Philosophy, Law and the Environment. Cambridge University Press, New York.

Saltelli, A., Chan, K., Scott, E.M. (Eds.), 2000. Sensitivity Analysis. John Wiley and Sons, Ltd., West Sussex, England.

Santos, R., Antunes, P., Baptista, G., Mateus, P., Madruga, L., 2006. Stakeholder participation in the design of environmental policy mixes. Ecological Economics 60 (1), 100–110.

Schoemaker, P.J., Waid, C.C., 1982. An experimental comparison of different approaches to determining weights in additive value models. Management Science 28, 182–196.

Schusler, T.M., Decker, D.J., Pfeffer, M.J., 2003. Social learning for collaborative natural resource management. Society and Natural Resources 16 (4), 309–326.

Simon, H.E., 1976. From substantive to procedural rationality. In: Latsis, J.S. (Ed.), Methods and Appraisal in Economics. Cambridge University Press, Cambridge.

Simon, H.E., 1983. Reason in human affairs. Stanford University Press, Stanford.

Slovic, P., 1995. The construction of preference. American Psychologist 50, 364–371.

Spash, C.L., 2007. Deliberative monetary valuation (DMV): Issues in combining economic and political processes to value environmental change. Ecological Economics 63, 690–699.

Stagl, S., 2006. Multicriteria evaluation and public participation: the case of UK energy policy. Land Use Policy 23, 53–62.

Stagl, S., 2007. Emerging methods for sustainability valuation and appraisal—SDRN rapid research and evidence review, www.sd-research.org.uk. Sustainable Development Research Network, London.

Stillwell, W.C., von Winterfeldt, D., John, R.S., 1987. Comparing hierarchical and nonhierarchical weighting methods for eliciting multiattribute value models. Management Science 33, 442–450.

Stirling, A., 2006. Analysis, participation and power: justification and closure in participatory multi-criteria analysis. Land Use Policy 23, 95–107.

Strager, M.P., Rosenberg, R.S., 2006. Incorporating stakeholder preferences for land conservation: weights and measures in spatial MCA. Ecological Economics 57, 627–639.

Triantaphyllou, E., Sanchez, A., 1997. A sensitivity analysis approach for some deterministic multicriteria decision making methods. Decision Sciences 28 (1), 151–194.

Tzeng, G., Chen, T., Wang, J., 1998. A weight-assessing method with habitual domains. European Journal of Operational Research 110, 342–367.

van den Hove, S., 2006. Between consensus and compromise: acknowledging the negotiation dimension in participatory approaches. Land Use Policy 23 (1), 10–17.

Vansnick, J.C., 1986. On the problem of weights in multiple criteria decision making (the noncompensatory approach). European Journal of Operational Research 24, 288–294.

Videira, N., Antunes, P., Santos, R., 2009. Scoping river basin management issues with participatory modelling: the Baixo Guadiana experience. Ecological Economics 68, 965–978.

Vogt, W.P., 1999. Dictionary of Statistics and Methodology: A Nontechnical Guide for the Social Sciences. Sage, London.

Weber, M., Borcherding, K., 1993. Behavioral influences on weight judgments in multiattribute decision making. European Journal of Operational Research 67, 1–12.

Webler, T., Kastenholz, H., Renn, O., 1995. Public participation in impact assessment: a social learning perspective. Environmental Impact Assessment Review 15, 443–463.

Wei, Q., Yan, H., Ma, J., Fan, Z., 2000. A compromise weight for multi-criteria group decision making with individual preference. Journal of the Operational Research Society 51 (5), 625–634.

Wynne, B., 1992. Uncertainty and environmental learning—reconceiving science and policy in the preventive paradigm. Global Environmental Change 2 (2), 111–127.

Yoon, K., Hwang, C., 1995. Multiple Attribute Decision Making: An Introduction. Sage.

Zionts, S., 1979. MCDM—if not a Roman numeral, then what? Interfaces 9, 94–101.

Zionts, S., Wallenius, J., 1976. An interactive programming method for solving the multiple criteria problem. Management Science 22, 652–663.

Zografos, C., Howarth, R.B. (Eds.), 2008. Deliberative Ecological Economics. Oxford University Press, New Delhi.