Social multi-criteria evaluation as a decision support tool for integrated coastal zone management

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A B S T R A C T

Traditional top-down and technocratic approaches seem to be insufficient to tackle the many conflicts related to the sustainable use of natural resources. At the same time, reductionist and mono-disciplinary approaches lack the capacity to capture the complex interactions within evolving socio-ecological systems. Coastal zone management is an area that provides a clear example of such difficulties. In this paper we explore the scope of a participatory integrated assessment process, known as Social Multi-Criteria Evaluation (SMCE), in the context of Integrated Coastal Zone Management (ICZM). Through a two-year collaborative research process, between an interdisciplinary group of researchers and a diverse group of stakeholders in the Urdaibai Estuary (a Biosphere Reserve in the Basque Country, Northern Spain), we show that improving the integration of diverse expertise and values can lead, through a mutual learning process, to the definition of relevant policy options and sound decisions in the face of complexity, value conflict and unavoidable uncertainty.

1. Introduction

In the past, the failure of research to account for the full spectrum of natural system functions and human system complexity has often hindered its ability to produce realistic results that lead to informed policies [1]. In coastal areas this situation has been exacerbated by inappropriate managerial interventions [2]. Hard engineering solutions and command and control approaches, which neglected the diversity of social actors and the multiple scales of complex socio-ecological issues, have been shown to be insufficient for solving many contemporary issues related to coastal zone management. Global trends show a decline in the quality of these regions due to habitat loss, decline in water quality, collapse of fisheries or loss of biodiversity [3,4].

In recent years, increasing attention has been given to the inclusion of participatory approaches in natural resource management and policy making [5–14] and ICZM has also shifted to a more deliberate role worldwide [15–19]. Claims for the active and sustained involvement of different stakeholders and citizens in how coastal resources are allocated and conflicts mediated come from different strands [2,3,9,20–27]. Nevertheless, efforts in this direction still need further attention. In this paper we will try to address the following key questions:

(i) How do we make operational the claim for more inclusive approaches in ICZM?

(ii) Aiming to provide better management options for our coastal systems, how could we enhance participatory approaches capable of integrating a wide range of scientists, coming from different disciplines, with a broader public and stakeholders, with different values and interests, in a collaborative and inclusive partnership?

(iii) How could we deal with fuzzy, uncertain and often incomplete information about the complex socio-ecological systems (SES) that surround us [28]?

Our understanding of how natural and social systems interact, over long time periods and along the spatial scale, needs to be substantiated by democratic mechanisms that can deal with the inherent problems of continuous change, irreversibility, uncertainty and multiple legitimate standpoints of the systems [5]. In this context it is difficult to find
any alternative to what has been defined by Funtowicz and Ravetz [29–31] as an extended community of peers. When facts are uncertain, values in dispute, stakes high and decisions urgent, scientists cannot provide any useful input without interacting with the rest of society, and the rest of society can hardly make any sound decision without considering the best scientific knowledge (see also [32–35]).

From this it seems obvious that in addition to the inclusion of various scientific disciplines, collaboration should be enhanced between all relevant stakeholders representing the diversity of values in society [36]. Local actors, citizens and other collectives traditionally excluded from decision-making can contribute substantially in this sense [37,38], as “non-experts” may see problems, issues and solutions that experts miss [39]. In other words, the process of policy design requires a more collaborative interplay between decision-makers, scientists and other actors [40–44], and participatory approaches constitute a promising framework for pursuing this collective effort [45–47].

Among other holistic approaches, Multi-Criteria Evaluation (MCE) techniques have been shown to be particularly appropriate for integration with participatory approaches in the search for new strategies that foster sustainability in many issues characterized by deep complexities and unavoidable conflicts [10,48–55]. This approach allows one to take into account controversial, multidimensional and uncertain effects of decisions [56], in a systematic and structured way [57]. In the end, management plans are above all hypotheses that require “reflection before action” [44], and public and stakeholder participation supported by integrated assessment tools, like the one presented in this paper, can initiate social learning processes that enrich this reflexive process in the light of complexity and unavoidable uncertainty [47,58,59].

With this study we explore the potential of a participatory integrated assessment process developed under the Social Multi-Criteria Evaluation framework (SMCE), in the context of coastal zone management, through a real case study carried out in the Biosphere Reserve of Urdaibai (Basque Country, Northern Spain). The rest of the paper is organized as follows. Section 2 presents briefly the methodological framework. Section 3 introduces the case study. Section 4 describes the whole participatory integrated assessment process that has been developed to analyse different management options for the study area. Section 5 shows the results obtained from this process. Finally, Section 6 discusses the potential of this methodology in the context of ICZM and gives some general conclusions.


MCE is a means of simplifying and structuring complex decision-making problems that can involve many stakeholders, a diversity of possible outcomes and many, sometimes intangible, criteria by which to assess the outcomes [53]. The origins of MCE lie in the fields of mathematics and operational research but in recent years it has been increasingly applied in the context of natural resource management and other sustainability related issues.

When first developed, MCE was characterized by the methodological principle of multi-criteria decision-making (MCDM). The objective was to elicit clear preferences from a (mythical) decision maker and then to solve a well-structured problem by means of a mathematical algorithm. Progressively, ideas about procedural rationality [60] and the constructive or creative approach developed by Roy [61] have lead to the development of the methodological framework of Multi-criteria Decision Aid (MCDA). With time, more and more authors emphasize the need to include, public participation in MCDA [48,51,53] fostering the emergence of Participatory Multi-criteria Evaluation (PMCE). Social multi-criteria evaluation (SMCE) was born in this context and emphasizes transparency. The main idea is that results of an evaluation exercise depends on the way a given policy problem is structured; thus, the assumptions, ethical positions, interests and values have to be made clear. Within this framework SMCE public participation is a necessary condition, but not a sufficient one, mathematical aggregation conventions play an important role, i.e. to assure that the ranking of alternatives are consistent with the information and the assumptions used [51]. SMCE also includes:

- Consideration of the socio-cultural context in which the relationship decision-makers/analysts is embedded;
- Combination of participatory methods (qualitative and quantitative);
- The use of a cyclic and dynamic evaluation procedure, in which the research team and the involved social actors experiment with a learning process (that may lead to a change in preferences).

Within this framework the application of participatory approaches must account for the:

- Potential influence of powerful stakeholders in discussion groups;
- Lack of representation of qualitative participatory approaches (focus groups and in-depth interviews, among others);
- Inclusion of non-organized groups as part of the social actors;
- Ethics — public participation and scientific outcomes do not entail de-responsibility of decision-makers.

People transform their positions and opinions with regard to an issue by interacting with other agents, exchanging information and reflecting on their underlying values and assumptions. In this regard, authentic deliberation would require non-coercive communication so as to induce reflection upon preferences [62].

There are hundreds of mathematical algorithms to solve multi-criteria analysis problems [63] and each of them has advantages and disadvantages depending on the context in which we want to use them [64]. The mathematical algorithm must yield outcomes consistent with the information and assumptions used: their axiomatization should be complete and clear. Also, they should be as simple as possible in order to assure transparency in a social context [51].

In this case, given the complexity of coastal ecosystems, the surrounding uncertainty and the presence of high degrees of conflict among the stakeholders involved we have chosen the so-called SMCE framework. As we have seen above, this novel approach combines multi-criteria algorithmic (mathematical) methods with participatory approaches in its various stages and was explicitly designed for dealing with complex and uncertain issues in the context of sustainability [65]. The theoretical foundation of this framework can be found in Post-Normal Science and Complex System Theory and rests on the idea of weak comparability of values, which states that irreducible value conflict is unavoidable but can be made compatible with rational choice by

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1 According to Simon, one can distinguish between substantive and procedural rationality. The former is independent of the way a decision is made and refers exclusively to the results of the choice. The last refers to the process in which a decision is made.

2 According to Roy, finding a final solution in a decision problem is less a discovery than a creation, in which the actors taking part in the decision process either shape, argue and/or transform their preferences, arriving at a decision that meets their goals.
employing practical judgments [51,56,66]. Renewable energy policies [67], regional planning [68], risk assessment [69] or water management [70] are but some areas to which this particular framework has been applied. The main characteristics that make SMCE suitable for ICZM in general and this case study in particular, can be summarized as follows:

- inter/multi-disciplinary (with respect to the research team);
- participatory (with respect to all stakeholders involved);
- transparent (since all criteria are presented in their original form and avoid reductionist assumptions);
- allows the inclusion of qualitative information in fuzzy or uncertain evaluation problems;
- adaptive and dynamic in a way that allows a continuous learning process while capturing the emergent properties of the coevolving socio-ecological system.

3. Study area: Urdaibai estuary

Urdaibai is located in the south-eastern corner of the Bay of Biscay, in the Basque Country (Fig. 1). It covers an area of 220 km² with around 45,000 inhabitants, most of them concentrated in the towns of Gernika and Bermeo. It has 22 municipalities, 11 of which lie wholly within its borders. To the north its border is the coast, where capes Matxitxako and Ogoño protect the entrance to the estuary and the island of Izaro stands guard. The rest of its borders follow the watershed of the River Oka which is 12 km in width and 20 in length. The territory is characterized by a hydrographic basin of small creeks that merge in a great salt marsh surrounded by high sheer cliffs. The surrounding countryside is occupied by meadow land, oak groves, leafy woods and, especially, by plantations of fast-growing conifers (mainly Pinus radiata).

The central area of this region is the Urdaibai Estuary (UE), which is also referred to as the Oka, Mundaka or Gernika Estuary. It is 12 km long and around 1 km at its maximum width [71]. This area represents in all its complexity a clear example of the multiple interests that coexist in the coastal zones and the difficulties we face in managing them. The estuary was used for food provision by its prehistoric inhabitants and nowadays we can still find various remnants of the prehistoric, Roman and Middle Ages eras. Since then this area has been in a constant co-evolution with the human activities that modify it. Despite the major industrial development of the district throughout the 20th century, the estuary has maintained its rural character and nowadays it encompasses the largest coastal wetlands and the best preserved estuary in the Basque Country.

3.1. Environmental characteristics and main morphological elements

Like many other estuaries on the Cantabrian Coast, the Urdaibai Estuary and its surroundings include a great variety of habitats and environments: cliffs, rocky shores, sand dunes and sand beaches in the outermost area; intertidal sand banks, muddy banks and low and intermediate marshes in the middle reaches; and high marshes, freshwater habitats and riverine woods in the inner areas. This estuary also hosts several habitats and species of European importance according to the Birds and Habitats Directive. Of special relevance is that the area represents an important refuge for birds, mainly during the migration and winter seasons and both as a resting and feeding area. Many bird species included in the Birds Directive are regular visitors to this estuary, like the Eurasian Spoonbill (Platalea leucorodia), the Osprey (Pandion haliaetus) and many waders.

The estuary can be seen to function as a tidal inlet, in terms of its sediment dynamics. The effect of river flow is relatively low, compared with the tidal prism volume, which represents almost all of the water flow in the estuary mouth [72]. Tidal inlets are one of the most dynamic elements of the littoral sediment budget. Some studies have shown that the characteristics of the main morphological elements of a tidal inlet depend upon the tidal prism, inlet geometry, shoreline configuration, offshore bathymetry, wave climate, littoral drift, sediment characteristics and freshwater runoff [73–77].

The main morphological elements of the UE and their dynamics are described below, in order to create a conceptual model of the evolution of the system and facilitate the construction and valuation of different management options for the area.

According to the dominancy of different dynamics in the morphology and sediment transport we can describe three different parts of the estuary, with different morphological elements in each one.

(i) The offshore sand reservoir: this is the lower part of the beach profile and in the UE is laterally confined by rocky contours (Izaro Island to the east and Matxitxako Cape to the west). Completely wave dominated and without contact with other offshore sand banks or inputs due to coastal sediment drift.

(ii) The estuary mouth: this is the most dynamic area and wave dynamics and tide-dynamics are balanced. In this zone we can identify the following morphological elements:
- Ebb tidal delta. Known locally as the “Mundaka Sandbar” it is formed as the result of equilibrium between the tidal action (tidal outflow) and wave activity. The morphology of the Mundaka Sandbar, in turn, is in response to the shoreline configuration (high-angle half-delta) [72].
- Main channel: tidal action dominates and its cross-sectional area is directly related to the tidal prism. The channel is also conditioned by wave action that tends to accumulate sand, constricting its section.
- Dynamic beach profile: this includes the breaking zone and the intertidal beach. It is almost completely wave dominated and its evolution is related to mean wave climate.
- Supratidal beach: this is a reservoir of sand modelled by wind action creating sand dunes. Its form is also conditioned by extreme storms on its north face and the meandering erosion of the main channel on the southern part.

(iii) The inner part of the estuary: tidal action and river flow are the main dynamics in this area. Wave action can have some impact (especially infragravity waves in extreme storms) but it decreases rapidly towards the inner part. In this part also different morphological elements can be described:
- Flood deltas: these are created by the diffraction of the flux during the flood and modelled by the meandering erosive action of the main channel. Wave activity still has some effect making the sand banks (flood deltas) migrate inland.
- Main channel: tidal action on each point is proportional to the tidal flow. Thus the dominance of the river outflow increases as we move from the estuary mouth to the inside of the estuary. There is still some wave activity, especially in relation to the displacement of the sand banks and morphology of the channel.
- Secondary channels: the dynamics are very similar to these described in the main channel but with no influence of wave dynamics.
- Mud flats: dynamics are really slow in this part. Freshwater runoff and some tidal action are the main factors.
3.2. A turning point: the creation of the Biosphere Reserve and the new legal framework

In 1984, considering its natural and cultural values, this area was accepted as part of the World Network of Biosphere Reserves by UNESCO (Man and Biosphere Programme) and later, the Basque Country Parliament adopted the Urdaibai Biosphere Reserve Protection and Planning Act, Law 5/1989, 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 socio-economic interest” (article 1).

In 1992 this area was also 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, which entailed automatic inclusion in the Natura 2000 network of European protected natural areas; finally in 2006, the Urdaibai littoral zones and marshes were declared a Site of Community Importance (Natura 2000 Network).

3.3. Management problems and related conflicts

Nowadays within this area, like in many other Cantabrian and Mediterranean coastal zones, a wide range of interests coexist, e.g. tourism, agriculture, fishing, industry, recreational activities or conservation. Nevertheless this coexistence is not always an easy task and managing the system in a sustainable manner entails a great challenge.

The estuary encompasses a highly dynamic and complex system, and the human activities within this system are closely interconnected. Due to this complexity, compatibility among various interests is not always possible. Managers have to make trade-offs to appease the diverse interests and competing values. In the case of Urdaibai, fishers claim access to selfish and consider any restriction in favour of conservation measures an infringement on their rights, which are previous to the creation of the Biosphere Reserve. Bird-watchers, environmental guides and others dependent on the ecological values of the estuary underscore the legal status of the estuary as a special protected area and report illegal fishing and navigation as a great threat to these habitats. Surfers depend on the configuration of the Mundaka sandbar to guarantee proper waves.
They reject any conservation measures, like the creation of the dune in the mouth of the estuary, that could alter the dynamics of the channel and modify the configuration of the bar. Tourism also depends on recreational activities, e.g., kayaking or kite surfing, in the inner part of the estuary, which also creates tension between sport practitioners and conservation measures. These are just some examples, but in the last decades many other conflicts have arisen in the area due to the presence of confronted interest and perspectives.

The last serious episode took place in 2003 when a shipyard located in the middle of the estuary dredged over 300,000 m$^3$ of sand and mud to facilitate the launching of its boats. The disposal of the dredged material in the outer estuary modified its hydrodynamics and subsequently the morphological features of the system, affecting a number of activities like surfing, fishing and bird watching, and causing social alarm. The intervention in the bottom of the channel was not a new issue, and has been the focus of many controversies. In the 1970s for instance, under Franco’s dictatorship, the pressures suffered by the estuary led to the creation of some of the pioneering conservation and ecologist associations in the Basque Country. Nevertheless, this time, due to a combination of several factors, especially the impact on Mundaka’s wave (the longest left in Europe and host of the World Cup) and the role of the mass media, the concern about the future of the estuary reached unprecedented levels. Many local, regional and also international collectives showed their concern about the future of the area, leading to a turning point in the current management regime (Fig. 2).

In summary, the emergence of new social values and needs has shifted the management system in the estuary. Between the 16th century and the beginning of the 20th century, a large channel and railway along the estuary were built to serve the local economy, shifting management and greatly influencing the dynamics of the estuary. Between the 1960s and the late 1990s, abandoned agricultural land reverted to marshland, and dredging activities shaped the estuary. Finally, the creation of the Biosphere Reserve in 1989 and the subsequent legal protection of the estuary as a conservation zone have conditioned the future of the area. The law now requires the sustainable management of the estuary (see Section 3.2).

In this context, in 2007 a diverse group of researchers together with local, regional and national stakeholders concerned about the situation in the area, created a collaborative research process with the aim of analysing sustainable management options for the Urdaibai Estuary from a holistic perspective and considering the active involvement of a diverse group of stakeholders. In the following section we describe in more detail the whole participatory integrated process that has been developed with this purpose under the SMCE framework.

4. The participatory integrated assessment process under the SMCE framework

In operational terms, the application of a social multi-criteria framework, in a participatory context, involves the following main steps [51]:

3 Composed of: marine scientists, biologists, sociologists, economists, engineers, lawyers, chemists, ecologists and geologists.

4 Among others this group included representatives from: the Basque government, Spanish environmental ministry, industry and labour unions, mayors, citizens, NGOs, birdwatchers, fishers and surfers.
390

1. Identification of relevant social actors by means of institutional analysis, individual interviews with key agents, focus groups, etc.;
2. Problem definition, which follows a similar procedure as that outlined above;
3. Creation of alternatives — policy options — and the definition of evaluation criteria. This process must be a collective creation resulting from a dialogue between the scientists and the social actors. Criteria are indicators that assess to what extent the different social actors’ objectives are achieved by each alternative;
4. Valuation of criteria in a multi-criteria impact matrix. The matrix synthesizes the scores of all criteria for all alternatives. Each criterion score represents the performance of each alternative according to each criterion;
5. Assessment of social actors’ preferences and values, mainly through in-depth interviews and focus groups;
6. Selection of the multi-criteria evaluation method and application of the model through a mathematical aggregation procedure. In order to obtain a final ranking of the available alternatives, the criterion scores must be aggregated by means of a mathematical algorithm. Many multi-criteria models have been formulated since the 1960s, each one with advantages and disadvantages. In each case, the most appropriate model must be chosen by weighing the pros and cons of each;
7. 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. This step is very important due to the unavoidable degree of uncertainty that characterizes most real-world decision-making processes (Fig. 3).

In summary, the above mentioned steps can be divided into three general phases:

(i) approach to the situation under study, in order to identify the social actors involved, understand the socio-environmental dynamics of the system and define the problem;
(ii) representation of the problem at hand: that is, the definition of the decision space and the evaluation criteria;
(iii) evaluation, in which the set of alternatives forming the decision space are assessed in social and technical terms.

In the following sections each phase as it was carried out in this study is described in more detail.

4.1. First phase: approaching

In this case, this phase included the following steps for developing a wider understanding of the issue at hand and identifying the relevant actors and their stakes:

(i) Institutional analysis by means of:
- A detailed review of the historical uses of the river basin [78–81]
- Mapping the multiple uses/interests in the area and the plausible conflicts among them
- Identifying the relevant stakeholders and their positions with regard to the current situation in the estuary
- A detailed revision of the existing legislation, and other historical documents such as newspaper articles and minutes of the city council sessions to better understand past conflict (Section 3.3).

(ii) Interviews with the relevant stakeholders to complement the broad picture obtained from the institutional analysis, and improve our understanding of the main socio-ecological aspects of the area. With this aim, starting with a few contacts in the local administration, social and ecological movements and the regional government, through a “snowball” technique, during the spring of 2007 we performed more than 20 semi-structured in-depth interviews with a diverse group of stakeholders.

It is worth noting that key informants are not meant to be “representative” of members of an organization or community, in the way that statistical sampling is. Instead, key informants are people who are privy to the events being studied and able to provide the researcher with reliable information about the organization or community to which they pertain and the knowledge that comes from their experience in these settings [8].

(iii) An open meeting (>20 participants) with a diverse group of stakeholders (identified by means of the institutional analysis and the interviews) and the research team. This workshop served to define the issue at hand and complete the full list of relevant stakeholders. In this meeting the research team gave an exception. Many participants showed scepticism about the knowledge that comes from their experience in these settings [8].

During this phase, all parties acknowledged the need for urgent responses to get out of the current "trap", and walk in the direction of sustainability as recognized in the foundation of the Biosphere Reserve. Nevertheless, it was remarkable that the interpretation of sustainability entails a great diversity, and no consensus or common understanding exists with regard to the possible management options for the area. Conflict of interest, diversity of perspectives and mistrust among participants is often a common feature at the beginning of this type of process and this case was not an exception. Many participants showed scepticism about the scope of working together with groups whose interests conflicted with their own.
4.2. Second phase: representing

4.2.1. Creation of alternatives

Once the problem had been defined and the relevant stakeholders identified, the second phase of the SMCE consists in the definition of alternatives or policy options to confront these with a set of criteria. In our case 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 external group of experts, following Massam’s suggestion [82] which includes: (a) the status quo or business as usual situation, (b) an ideal best plan, (c) a hypothetical worst plan and (d) a compromise solution or minimum satisfaction.

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 redefine a preliminary proposal. Table 1 summarizes the resulting set of alternatives and sub-alternatives emerged from this interactive process (Table 1).

4.2.2. Definition of evaluation criteria

Together with the construction of alternatives, in a multi-criteria framework we need to define the diversity of interests and relevant issues in a set of criteria that will constitute the basis for our assessment. These 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. There is no consensus in determining the number of criteria that should be considered in this type of evaluation, but usually this is limited to a maximum of 7–12 [83,84]. In this sense, Bouyssou [83] states that for reasons related to the cognitive limitations of the human mind and to the necessity of gathering inter-criteria information, it is not advisable to include more than a dozen of criteria when implementing aggregation procedures.

The identification and selection of criteria starts with personal interviews, but a joint discussion among participants with different perspectives makes possible the emergence of new ideas, while allowing participants to reflect on their own underlying values and assumptions. In this sense public participation, which includes deliberation and inclusion [85], has been demonstrated to be appropriate to initiating social learning processes that reflect collective needs and understanding [47,86–88].

The second workshop, organized after the approaching phase, had the aim of defining the relevant set of criteria. The 15 participants were organized into several groups in order to facilitate their participation and involvement. They were asked to discuss and define the main criteria needed to guide the UE in the future.

The workshop was structured as follows:

(i) Brief presentation of the objectives of the workshop
(ii) Joint reflection about the future of the region
(iii) Discussion in focus groups of around eight people, about the relevant aspects to be considered for the sustainable management of the estuary
(iv) A final joint discussion among all the working groups

In this type of workshop it is desirable to combine big settings with small groups in order to offer everybody the chance to participate, and

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Table 1

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Alternatives</th>
<th>Sub-alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>A1 Do nothing: leave the system on its own but without any type of intervention.</td>
<td>B1. Both sides of the main channel</td>
</tr>
<tr>
<td></td>
<td>No active conservation measures, no dredging activities, no compensation measures.</td>
<td>B2. Intertidal zone</td>
</tr>
<tr>
<td></td>
<td>A2 Compensation: do not allow dredging and compensate the affected parties (mainly shipyard workers) due to constraints on their activities.</td>
<td>B3. Emerged area</td>
</tr>
<tr>
<td></td>
<td>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...</td>
<td>B4. Submerged area</td>
</tr>
<tr>
<td>Max</td>
<td>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...</td>
<td>C1. Both sides of the main channel</td>
</tr>
<tr>
<td>Min</td>
<td>C Compromise: minimum dredging according to the “systems limit” (20,000—30,000 m$^3$ to guarantee navigability for small boats) and conservation measures. Disposal of dredged material in...</td>
<td>C2. Intertidal zone</td>
</tr>
</tbody>
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Table 2

<table>
<thead>
<tr>
<th>Working groups</th>
<th>Environment and biodiversity</th>
<th>Economic dynamism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Society and welfare</td>
<td>Environmental guide</td>
<td>Citizen</td>
</tr>
<tr>
<td></td>
<td>Shipyard worker</td>
<td>Zain Dezagun Urdaibai (Environmental NGO)</td>
</tr>
<tr>
<td></td>
<td>Trade union representative</td>
<td>Representative of recreational boats</td>
</tr>
<tr>
<td></td>
<td>Fishers association representative</td>
<td>Head of dune recovery program</td>
</tr>
<tr>
<td></td>
<td>Ekologia tailerra (NGO)</td>
<td>Chemist expert in marine pollution working in the area</td>
</tr>
<tr>
<td></td>
<td>Assistance from the research team</td>
<td>Mayor of Mundaka</td>
</tr>
<tr>
<td></td>
<td>Engineer and Sociologist</td>
<td>Biologist and Marine Scientist</td>
</tr>
</tbody>
</table>

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*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.*
avoid potential lobbying strategies (i.e., some interests, like those of fishers or surfers, were over-represented compared to others). On the other hand, often power relations can intimidate the free intervention of some participants (e.g., between the owner of a business and his employees, politicians and civil servants, etc.) which also makes it desirable splitting them in different settings. It is worth noticing that the groups should be homogeneous with regard to their participants and that heterogeneity can be reached by a diversity of groups. In this case, participants were distributed in three groups and discussed the current and future situation of the estuary from the following perspectives: (1) society and welfare; (2) environment and biodiversity; (3) economic dynamism. Table 2 summarizes the composition of each working group.

With a similar rationale, collecting different points of view through anonymous questionnaires and personal interviews is also essential within the participatory process [33, 68, 70, 89], and a second round of personal interviews was carried out with relevant actors that did not have the opportunity to participate in the workshops (Head of the Biosphere Reserve, Basque Environmental Ministry, Head of Coastal Affairs, Head of Harbours and Ministry of Transport, Mayor of Busturia, among others). In this case, interviewees were also asked to express their needs, preferences and that heterogeneity can be reached by a diversity of groups. In this case, participants were distributed in three groups and discussed the current and future situation of the estuary from the following perspectives: (1) society and welfare; (2) environment and biodiversity; (3) economic dynamism. Table 2 summarizes the composition of each working group.

With a similar rationale, collecting different points of view through anonymous questionnaires and personal interviews is also essential within the participatory process [33, 68, 70, 89], and a second round of personal interviews was carried out with relevant actors that did not have the opportunity to participate in the workshops (Head of the Biosphere Reserve, Basque Environmental Ministry, Head of Coastal Affairs, Head of Harbours and Ministry of Transport, Mayor of Busturia, among others). In this case, interviewees were also asked to express their needs, preferences and desires with regard to the UE, and to define relevant criteria for the evaluation phase.

These qualitative [participatory] techniques can be criticized for their lack of statistical meaning, but they give the participant and the analyst the time to deliberate, i.e., to think and create relevant knowledge for policy making, which is necessary when facing situations with multiple and uncertain outcomes [68].

From this interactive process we identified the list of criteria that is summarized below. (Table 3)

### Table 3: Evaluation criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Needs and expectations</th>
<th>Criteria scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Socio-economical dimension</td>
<td>Employment</td>
<td>- Enhance local employment and avoid people's displacement to other areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Support local economic activities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Improve the quality of life</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Guarantee job stability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Coherence with local reality – local identity maintenance</td>
</tr>
<tr>
<td></td>
<td>Local incomes</td>
<td>- Increase municipality's income</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Avoid becoming a residential area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Promote local business</td>
</tr>
<tr>
<td></td>
<td>Compatibility between socio-ecological activities</td>
<td>- Equitable development among municipalities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Avoid collapsing activities</td>
</tr>
<tr>
<td></td>
<td>Cost of implementation</td>
<td>- Minimize impact on fishing, surfing, industry, conservation, tourism, navigation</td>
</tr>
<tr>
<td></td>
<td>Environmental disturbance</td>
<td>Impact on habitat and fauna</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Avoid impact on fauna: birds, shellfish, benthonic communities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Diminish the impact of toxic sediments, in ground and water.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Avoid invasive species proliferation in abandoned agricultural land</td>
</tr>
<tr>
<td></td>
<td>Reversibility</td>
<td>- Not jeopardize the potential of the area for the future</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Respect the dynamics of the river</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Recover the original channel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Consider the long term and the time to get back to equilibrium</td>
</tr>
<tr>
<td></td>
<td>Uncertainty</td>
<td>- Reduce the degree of uncertainty of management options</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Acknowledge the uncertain and complex response of the system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Adopt a precautionary approach</td>
</tr>
</tbody>
</table>

#### 4.2.3. Valuation of criteria: feeding the impact matrix

Having defined the relevant criteria and constructed the alternatives, the next step in an SMCE process consists of feeding the impact matrix in which each alternative is confronted with each criterion. This serves to assess the performance of each alternative according to its impact on the selected criteria (see Table 3).

The construction of the criteria (indicators) in the framework of the decision aid depends more on the art and the experience of the analyst than on “science” [83]. In the case of a SMCE process (in which the participation of divers' disciplines play an active role) each discipline has its job, although an interdisciplinary discussion about methodologies and assumptions — a space in which constructive critique is possible — is an essential part of the valuation process.

Briefly the valuation process to feed the impact matrix entails:

1. Selection of the indicators to assess the performance of the alternatives. Criteria represent certain objectives or relevant issues present in society and the indicators measure the degree of fulfilment of these;
2. Choice of the temporal and spatial scale in which the indicators are valued;  
3. Collection of information and data needed for the valuation of the criteria; There can be several indicators to measure the performance of one criterion;
4. Evaluation of criterion scores.

The valuation process is not an easy task. When measuring the impact of a given policy, the interpretation of indicators might be controversial. What may be beneficial for some, may be harmful for others, and vice versa. For example, an increase in the number of cars sold might be good for the economy but bad for the quality of
the air. Similarly, the presence of endemic species might be seen as a treasure for environmentalists, but a menace for others who see their activity threatened by the presence of such species. For these reasons, it is important to recall that before fulfilling the impact matrix and obtaining the values of indicators to assess criteria, the narrative that guides the evaluation (discourses, objectives, values, etc.) must first be defined. Neglecting this preliminary work can create ambivalence and confusion in the valuation process, undermining the legitimacy of the result.

In addition, data are often sparse, knowledge of processes limited, and management actions change the being managed, making inevitable the presence of surprise and change [90]. In these cases, the ability to incorporate and manage different data sources in a modelling process becomes essential. It is impossible to be certain about the consequences of any environmental management decision [91] and qualitative approaches become essential for including the best available information [32,93]. This avoids excessive assumptions and forecasting of data, increasing the transparency of the decision-making process [68].

The information yielded in this process is represented in a multi-criteria impact matrix (Table 4) which allows:

1. Structuring of all the information in a simplified way;
2. Reflection of the diversity of impacts according to different type of information, i.e. fuzzy, crisp, ordinal or qualitative;
3. Comparison of each alternative according to their strengths and weaknesses in an illustrative manner;
4. Analysis of criteria (objectives, values) supporting choices.

In the following lines we present briefly the scoring procedure we follow to fulfil this impact matrix.

4.2.3.1. Employment. This criterion assesses the number of jobs created (or eliminated) in the area under each management option. In order to take into consideration the duration of the jobs (i.e. their seasonality and/or temporality) we have decided to use people per year as the unit of measurement. Among others we have assessed potential impacts on the workers of the shipyard; environmental guides; staff at the bird watching centre and at hostels (Table 5).

4.2.3.2. Local income. This criterion evaluates the income derived for each management proposal and its distribution. The evaluations are in qualitative terms due to the lack of reliable quantitative data and the uncertainty involved in this sort of calculation. To obtain the scores of these criteria we take into account the following considerations:

A1: this does not include any initiative to promote economic activity and in contrast the lack of conservation measures to mediate the present environmental problems, mainly propa- gation of invasive species, would affect current economic activities such as providing environmental guides or benefitting from tourism. Therefore it gets the worst score in both sub-criteria.
A2: the difference with respect to option A1 is that this management option considers compensation mechanisms for the shipyard, due to a ban on dredging, which increases the possibility of gradually adapting its current. This would avoid higher losses for the shipyard activities but would only benefit the municipality of Murueta.
A3: in this case all the municipalities would benefit from the fit out works to restore the area. In addition other municipalities would obtain incomes coming from the regulated moors. Moderate incomes and high distribution were assigned to this option.
Table 6
Impact on employment (unit: people per year).*

<table>
<thead>
<tr>
<th>Jobs</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>B1</th>
<th>B2</th>
<th>B3</th>
<th>B4</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefitted</td>
<td>0</td>
<td>0</td>
<td>26.3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>19.3</td>
<td>19.3</td>
<td>19.3</td>
<td>19.3</td>
</tr>
<tr>
<td>Damaged</td>
<td>127.5</td>
<td>96</td>
<td>112</td>
<td>28.7</td>
<td>28.72</td>
<td>29.72</td>
<td>29.72</td>
<td>19.3</td>
<td>19.3</td>
<td>19.3</td>
<td>19.3</td>
</tr>
<tr>
<td>Rescaled</td>
<td>31.5</td>
<td>41.8</td>
<td>97.77</td>
<td>97.77</td>
<td>97.77</td>
<td>97.77</td>
<td>97.77</td>
<td>79.11</td>
<td>83.11</td>
<td>76.86</td>
<td>83.11</td>
</tr>
</tbody>
</table>

* The results have been rescaled, to facilitate the interpretation, comparing all alternatives with the non-intervention scenario, A1.

B1, B2, B3, B4 are equal in terms of income and include incomes coming from motor vehicle taxes, business taxes and property taxes derived from the shipyard which would account for 8,000 € to 10,000 € per year (moderate). The distribution is low as the only council to benefit would be Murueta and other councils would suffer decline in their incomes due to the impact of dredging activities on surfing, fishing or tourism.

C1, C2, C3, C4 are also equal in these terms. These management options are similar to A3 but in addition to the conservation measures included in A3 they consider a “minimum dredging” that would make possible the navigation of small boats and certain activities of the shipyard within the limits of the surrounding system. That means that the industrial activity would have to readjust to the construction of boats that required less depth in the channel. All in all these alternatives obtain high incomes and moderate distribution.

To aggregate the scores of both sub-criteria, we use the NAIAD (Novel Approach to Imprecise Decision Environment) method (see Section 4.3.1.), which gives us an ordinal ranking of alternatives by means of fuzzy set comparison among the sub-criteria (Table 6).

4.2.3.3. Compatibility between socio-ecological activities. To estimate the score of these criteria, first we identified the main uses in the UE (first column) and then based on the existing information and a consultation process, we defined the degree of compatibility for each activity within each scenario as the set of sub-criteria. The degree of compatibility goes from Very Low (VL) to Low (L), Moderate (M), High (H) or Very High (VH).

In this way, we carry out a multi-criteria evaluation of the management options based on the following set of sub-criteria:

(a) Compatibility with shell fishing
(b) Compatibility with industry
(c) Compatibility with conservation
(d) Compatibility with surfing,
(e) Compatibility with tourism
(f) Compatibility with navigation.

In order to assign values to these sub-criteria we consider the following factors:

- An intensification of dredging would increase the hydraulic potential of the channel and could be responsible for the silting up of secondary channels, altering oxygen supply and nutrient fluxes, and affecting the flora, fauna and habitats and, consequently, economic activities such as fishing and shell fishing [94,95]. The deposition of the sediments would also affect the configuration of Mundaka’s sandbar and thus the surfing and tourism associated with this [96,97].

Table 7
Compatibility among socio-economic activities.

<table>
<thead>
<tr>
<th>Activities</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>B1; B2; B3; B4</th>
<th>C1; C2; C3; C4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell fishing</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>VL</td>
<td>VL</td>
</tr>
<tr>
<td>Industry</td>
<td>N</td>
<td>L</td>
<td>M</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Conservation</td>
<td>VL</td>
<td>VL</td>
<td>VI</td>
<td>VI</td>
<td>VI</td>
</tr>
<tr>
<td>Surfing</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>VI</td>
<td>VI</td>
</tr>
<tr>
<td>Tourism</td>
<td>VL</td>
<td>VL</td>
<td>H</td>
<td>VL</td>
<td>VL</td>
</tr>
<tr>
<td>Navigation</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>VL</td>
<td>VL</td>
</tr>
<tr>
<td>Ordinal ranking</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>8</td>
<td>7</td>
</tr>
</tbody>
</table>

- Massive dredging activities would also affect safety in navigation due to sudden changes of currents.
- Conservation interests would be affected by dredging and benefited by habitat recovery plans, the creation of guard services or eradication of invasive species.
- Industrial activity in the UE depends on the shipyard and whether or not to dredge is the determining factor in this sense.

Aggregating the impacts on these sub-criteria by means of NAIAD, we obtain the ranking presented in Table 7.

4.2.3.4. Cost of implementation. The costs are estimated in euros and include the cost of all the interventions considered in each alternative for the following 10 years (Table 8).

A1 does not include any intervention and therefore does not imply any cost.

A2 considers compensations for the shipyard workers due to restriction of their activities and according to the current labour legislation the compensation framework that has been considered would cost around 2,442,330 €.

A3 includes: (a) conservation and recovery plans for around 160 ha of the estuary and transferring the cost of similar plans in the area the cost of this actuation would be around 1,961,624 €; eradication of invasive species (78 ha completely affected and 100 ha partially), 2,560,000 €; maintenance service to conserve the environmental value of the estuary, 990,000 € and guard service, 675,000 €.

B1, B2, B3 and B4 include the cost of maximum dredging, 3,500,000 € and the removal of polluted material derived from the dredging activity, 1,425,819 €. This cost has been reached taking into account the cost of similar actucaations in the past. C1, C2, C3 and C4 include: conservation measures in 138 ha, 1,657,024 €; eradication of invasive species in 78 ha completely affected, 1,560,000 €; maintenance service, 990,000 € and guard service 675,000 €.

4.2.3.5. Environmental disturbance. Several studies show that given the limited human resources available in the Reserve to fulfil the existing legal restrictions, the estuary is the focus of many undesirable practices that disturb the environment of the area [98]. We understand as a perturbation those incidents that alter the calm environment of the area, like the noise or the inflow of people in areas of high sensitivity that negatively affect the presence of many species.
4.2.3.6. Impact on habitat and fauna. This criterion is evaluated according to the following index:

$$\text{IHF}_j = \sum \left( [W_{ij} \times \text{VHH} + W_{ij} \times \text{VHB} + W_{ij} \times \text{VHR}]_j \times \text{AHB}_j \right)$$

where $\text{IHF}_j$ is the Impact on Habitat and Fauna index of the management option $j$, and $i$ represents the different habitats within the estuary (i.e. cliff, sub-tidal rock, intertidal rock, intertidal sand and mud, beach, supra littoral rock, intertidal sand, intertidal mud, dune vegetation, estuarine water, marsh, freshwater habitats, riverine wood, artificial habitats and areas for future restoration). Each habitat type is evaluated based on three components:

- **VHB** is the value of the habitat as a breeding, resting or feeding area both for passing and for sedentary birds [99];
- **VHH** is general habitat value, keeping in mind the presence of species or areas of high value, the biodiversity and the singularity and rarity in the area [100];
- **VHR** is the potential of the habitat regarding exploitable resources, mainly fishing and shell fishing [101].

For each scenario and habitat, each sub-criterion was scored from 0 to 2 (0 for low value; 1 for intermediate value; 2 for high value).

In this case, each sub-criterion is also weighted according to its relative importance. To attach these values we take into account the Urdabaï Estuary is especially important for its variety of estuarine habitats, holding species of high ecological value. The area is also of relevance for wintering and migratory birds. Finally, some exploitable resources (e.g. shellfish) have considerable social importance, although in economic terms their contribution is not so significant. Along these lines we considered that VHH is more important than the value of the habitat as a breeding, resting or feeding area, and VHR is considered more relevant than VHR taking into account its international importance for migratory birds. With this in mind we consider the following weights: $W_{ij} > W_{ij} > W_{ij}$, where $W_{ij} = 3$, $W_{ij} = 2$ and $W_{ij} = 1$. Finally, each habitat $i$ is also weighted according its side, multiplying the sum of weighted sub-criteria by the corresponding area in each scenario.

This global sum provides us with a qualitative hierarchy, ordering the scenarios from more valuable to less valuable in terms of impact on habitat and fauna. The results are presented in Table 10.

In this assessment, it is generally observed that the magnitude of the impact will depend mainly on the dredged volume, the location of the disposal area of dredged sediments and the restoration works that would be undertaken.

4.2.3.7. Stability. We approach the issue of stability by assessing in qualitative terms the time that the system would require to get back to a stable situation. In order to do so we have integrated two variables: morphodynamic and ecological stability. This criterion has been widely ignored in the past although it encompasses a standard element of sustainability [102].

In morphodynamic terms, there is no impact in the first two alternatives (A1, A2) and assuming that currently the estuary is in natural equilibrium we assign them the optimum value. The third alternative (A3) includes a modification that could affect the dynamics of the system, with an increase in the intertidal area of the estuary and therefore in the tidal prism. However as: (a) the expected increase in the tidal prism does not exceed 10% (within the range of natural variability); (b) the intervention will take place progressively over a range of 10 years, giving enough time for the system to adapt; and (c) in any case the proposed modifications would enhance the stability of the main morphologic elements and therefore the equilibrium of the system, this alternative is also considered as optimal.

B1, B2, B3, and B4 get the worst scores. All of them implicate important sediment movements (similar to the volume of the main morphological elements) over a very short period of time.

Despite the fact that alternatives C1–C4 represent an instantaneous and important movement of sediment within the estuary, they can be compared with the natural oscillation (in volume) of the main morphological elements due to cyclic natural variability in the hydrodynamics (tides and wave climate). Therefore, these alternatives obtain intermediate values.

The final score of each alternative also takes into account the intensity of the main dynamics in the affected area. Very intense dynamics would implicate a higher probability of reaching an important disequilibrium state over a very short period of time, while slow dynamics let the system to absorb the changes. On the other hand, if the dynamics are too low the changes can become irreversible.

In ecological stability terms the best option is A3, because it does not touch any of the sensitive areas and it proposes actions to
restore the equilibrium in those areas covered by invasive species or sequestrated to the marsh. Then, in alternatives C the amount of material removed is small enough to let the system recover quite rapidly, and it also has the recovery plan to eradicate invasive species. A1 and A2 get medium scores due to propagation of invasive species. The rest obtain the worst scores, due to the amount of the removed and deposited materials and for the lack of measures to deal with exotic species.

Finally the (ordinal) criterion score for each alternative is obtained by aggregating those sub-criteria by means of NAIADE (Table 11).

Table 11

<table>
<thead>
<tr>
<th>Impact on stability.</th>
<th>Stability</th>
<th>Morphodynamic</th>
<th>Ecological</th>
<th>Ordinal Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A1</td>
<td>A2</td>
<td>A3</td>
<td>B1</td>
</tr>
<tr>
<td>Stability</td>
<td>VH</td>
<td>VH</td>
<td>VH</td>
<td>M</td>
</tr>
</tbody>
</table>

4.2.3.8. Uncertainty. The corresponding qualitative scores have been obtained as a result of an intense dialogue among the local stakeholders (fishers, surfers, etc.) and an interdisciplinary group of researchers that addressed the following sources of uncertainty with regard to the different management options:

(a) Although in recent years there has been a considerable progress in monitoring the dynamics of this system [96], the response of the estuary in the presence of major alterations is still enigmatic. We do not know with certainty the morphological response of the system due to changes in the sediment distribution or changes in the tidal prism.

(b) In ecological terms, material removal might pollute the environment due to the presence of polluted sediments but its impact is uncertain [103]. In our study area these factors have not been studied consistently but the presence of heavy metals is recognized by many studies [104–107].

(c) The presence and potential propagation of invasive species constitutes another source of uncertainty in our study, as it depends on many uncontrollable factors (changes in temperature, sea level rises, etc.).

According to all these factors those scenarios that imply more sediment removal obtain the worst scores and among those alternatives that do not consider any dredging activity, discrimination is done considering the presence or not of measures to deal with invasive species (Table 12).

Table 12

<table>
<thead>
<tr>
<th>Degree of uncertainty.</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>B1; B2; B3; B4</th>
<th>C1; C2; C3; C4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncertainty ordinal ranking</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Low</td>
<td>Very high</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

We want to remark that other sources of uncertainty associated with the rest of the criteria have been addressed using qualitative and ordinal evaluations, combining the scientific knowledge of the research team and the knowledge of those participants involved in the evaluation process.

4.3. Third phase: evaluating

4.3.1. Selection of the multi-criteria method and application of the mathematical aggregation algorithm.

Once the impact matrix has been completed (i.e., information structured in a multi-criteria way), one can analyze the information contained in it and/or aggregate the criterion scores by means of a mathematical algorithm in order to yield a set of orderings of alternatives (i.e., rankings). As mentioned above, there are hundreds of mathematical algorithms to solve multi-criteria analysis problems and the desirable properties in the context of sustainability issues have been already discussed elsewhere.

According to Munda [51,65,108] the multi-criteria aggregation method should:

- Be as simple as possible to guarantee transparency among the counterparts.
- Be non-compensatory. Very good performances in some criteria can offset bad performances in other criteria and a non-compensatory method doesn’t allow such a counterbalance between very good and bad performances;
- Use methods that include indifference and preference thresholds, which imply considering the intensity of preferences [5];
- Use of weights as importance coefficients. Note that the mix of intensity of preference and weights leads to compensation and trade-off between criteria, and therefore in these cases to avoid compensation we have to consider weights with ordinal criterion scores.

In this study, we applied the NAIADE method, developed in the Joint Research Centre of the European Commission by Giuseppe Munda [109], to aggregate the evaluation criteria and to obtain a ranking of alternatives. The main advantage of NAIADE is its ability to deal with mixed information (i.e., qualitative and quantitative simultaneously). Another advantage is that it also considers intensity of preferences in the aggregation procedure and allows the analyst to manage the degree of compensation between criteria (from non-compensatory to completely compensatory). Unfortunately, NAIADE does not use weights and, therefore, the prioritization of dimensions (socio-economic, socio-ecological, etc.) depends on the number of criteria within each dimension. In our case, to reach a balance between dimensions, we use the same number of criteria in each dimension.

In operational terms, NAIADE is an outranking method and consequently its aggregation procedure works as follows:

1. Pair-wise comparison of alternatives by means of preference relationships. Indifference and preference thresholds have to be defined for this task;
2. Calculation of preference intensity indexes, which indicate how much better or worse one alternative is in respect to another. NAIADE calculates the number of criteria in favour of one

---

5. Note that other sources of uncertainty are already addressed in the way that has been adopted to estimate the impact of each criterion.

6. The indifference threshold is the maximum difference between the criterion scores of two alternatives that makes no difference between them (under that criterion). The preference threshold is the minimum difference between the performances of two alternatives in one criterion that makes one option preferable to another.

7. On the one hand, weights as importance coefficients reflect the relative importance — given by the decision-maker, the analyst or the social actor — of one criterion in relation to the others. On the other hand, weights as trade-off reflect the substitution rate among criteria.

8. For a detailed review of other methods able to deal with this type of information see Gomiero and Giampietro [90].
alternative with respect to another and the intensity of preference;

(3) Aggregation of preference intensity indexes and calculation of two indexes. One index indicates how one alternative is better than all other alternatives, and the other indicates how the alternative is worse than all other alternatives;

(4) Obtaining the ranking of alternatives, based on the comparison of the two indexes calculated in the previous step.

It is important to highlight that several factors influence the rankings of alternatives, e.g., the quality of the information and data used, and the criteria or indicators chosen for the evaluation or the criteria aggregation method (mathematical model). In other words, the result of the multi-criteria analysis will depend on the structure of the problem. Public participation plays a key role in quality control for: (i) the definition of the problem; (ii) the information used in the assessment; and (iii) the calculation of criterion scores.

5. Results

5.1. Ranking of alternatives

In this case, by applying the NAIADE method we obtain the following results according to the different degrees of preference (first column) and the degree of rejection (second column) of each alternative. That is, the ranking in the first column (left) is based upon the number of criteria in favour of an alternative. The second ranking from left to right is based upon the number of criteria against the alternatives. The third ranking from left corresponds to the intersections of the previous ones.

Alternative A3, which involves the biggest number of conservation measures and different mechanisms for the complementation of the existing law, gets the best score together with alternative C4 (minimum dredging, deposition of the sediments in the subtidal north part of the estuary accompanied by conservation measures). The former obtains the first position among all alternatives with regard to compatibility, impact on habitat and fauna, reversibility and disturbance, and second in terms of income and employment. It gets the worst scores in terms of cost and employment. The latter, although it does not get the first position, shows a good average performance in most criteria and is not punished with a bad score in any particular one.

In second place are options A2 and C2. C3, A1 and C1 obtain middle values and in the worst position are all the alternatives that consider the maximum dredging: B4 and B2 followed by B1 and B3 respectively. The bad performance of these alternatives is due to the impact they have on habitat and fauna, as well as socio-economic activities, and the great uncertainty and disequilibrium that they imply for the system. Their positive aspect is confined to job creation. A low amount of income and a high cost of implementation are other common characteristics of these latter alternatives.

One characteristic of outranking methods like NAIADE (based on pair-wise comparison) is the possibility of rank reversal, meaning that despite the fact that one alternative is better than another according to most of the criteria; their position in the final ranking could be reversed or equal. Therefore, it is sometimes necessary to review the results of the pair-wise comparisons (e.g., when two or more alternatives are sociably acceptable and obtain a similar position in the ranking).

To clarify this point, in Fig. 5 we illustrate the pair-wise comparison of alternatives A3 and C4, which obtain both the first position in the ranking. The (brown) bar graphs on the right show the degree of credibility that one alternative (in this case A3) is much better (>) than the other alternative (in this case C4). The horizontal red line in the graph indicates the degree of credibility determined by the preference thresholds (see Section 4.3.1).

As we can see in Fig. 5, A3 is much better than C4 under criteria C6 and C8 (brown bars in the upper-right graphic of Fig. 4). Also, A3 is better than C4 under the same criteria (second bar graph from above). Both alternatives are almost equal under criteria C3 and C7, and are equal under criterion C3. A3 is much worse (and worse) than C4 in criterion C1.

These are the results obtained from a more technical perspective, but as we have already remarked, considering different stakeholders' perspectives and potential conflicts is an essential part of public policies related to complex socio-ecological systems. For this reason, in addition to integrated assessment processes that can capture the complexity of the issue at hand from multiple perspectives, it is useful to perform a conflict analysis.

5.2. Conflict analysis: searching compromise solutions

This analysis highlights plausible conflicts among the different stakeholders. By mapping winners and losers and making explicit the trade-off between different interests, this analysis provides rich information in the search for compromise solutions. In sustainability policy related issues, distributional issues are a key question when it comes to reaching a sound decision. In this sense, for the sustainable management of natural resources in general and coastal zones in particular, participatory approaches appear to be of key importance. These processes can help to address conflicting areas, build bridges between confronted interests and achieve the co-evolution of stakeholder preferences. In this case to structure the dialogue between the affected parties and help in the search for shared goals and compromise solutions, we developed an ad hoc analysis of potential coalitions by means of an eclectic approach that uses concepts coming from land use planning, fuzzy cluster analysis and social choice [65,110,111].

The first step to performing this analysis consists of the construction of the equity matrix (Table 13). In this table we map the preferences of each interest group with regard to each alternative.

---

9 Outranking methods works as a soccer league, in which each team play with the rest of the participants. The final position of a team depends on the results of the games between this team with the rest of the teams and the results of all other games.
Table 13
Social impact matrix.

<table>
<thead>
<tr>
<th>Social actors</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>B1</th>
<th>B2</th>
<th>B3</th>
<th>B4</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bird watchers</td>
<td>Good</td>
<td>Good</td>
<td>Very good</td>
<td>Extremely bad</td>
<td>Extremely bad</td>
<td>Extremely bad</td>
<td>Extremely bad</td>
<td>Bad</td>
<td>Moderate</td>
<td>Bad</td>
<td>More less bad</td>
</tr>
<tr>
<td>Fishers</td>
<td>Good</td>
<td>Good</td>
<td>Very good</td>
<td>Extremely bad</td>
<td>Extremely bad</td>
<td>Extremely bad</td>
<td>Extremely bad</td>
<td>Very bad</td>
<td>Extremely bad</td>
<td>Very bad</td>
<td>More less bad</td>
</tr>
<tr>
<td>Surfers</td>
<td>Good</td>
<td>Good</td>
<td>Very good</td>
<td>Extremely bad</td>
<td>Extremely bad</td>
<td>Extremely bad</td>
<td>Very bad</td>
<td>Extremely bad</td>
<td>Good</td>
<td>Extremely bad</td>
<td>More Less bad</td>
</tr>
<tr>
<td>Busturia Council</td>
<td>Very bad</td>
<td>Very bad</td>
<td>Perfect</td>
<td>Good</td>
<td>Very good</td>
<td>Perfect</td>
<td>Bad</td>
<td>Good</td>
<td>Perfect</td>
<td>Bad</td>
<td>Good</td>
</tr>
<tr>
<td>Mursueta Council</td>
<td>Extremely bad</td>
<td>Extremely bad</td>
<td>More less good</td>
<td>More less good</td>
<td>More less good</td>
<td>Good</td>
<td>Very good</td>
<td>Perfect</td>
<td>Bad</td>
<td>Bad</td>
<td>Bad</td>
</tr>
<tr>
<td>Recreational boats</td>
<td>More less good</td>
<td>More less good</td>
<td>Very bad</td>
<td>Very bad</td>
<td>More less good</td>
<td>More less good</td>
<td>More less good</td>
<td>Very bad</td>
<td>Very good</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Shipyard workers</td>
<td>Very bad</td>
<td>Good</td>
<td>Very good</td>
<td>Extremely bad</td>
<td>Extremely bad</td>
<td>More less good</td>
<td>More less good</td>
<td>Very bad</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Head Coastal Management</td>
<td>Good</td>
<td>Very good</td>
<td>Perfect</td>
<td>Good</td>
<td>Very good</td>
<td>Perfect</td>
<td>Bad</td>
<td>Bad</td>
<td>Bad</td>
<td>Bad</td>
<td>Bad</td>
</tr>
<tr>
<td>Env. Ministry (Reserve Director)</td>
<td>More less good</td>
<td>Good</td>
<td>Very good</td>
<td>Extremely bad</td>
<td>Extremely bad</td>
<td>More less good</td>
<td>More less good</td>
<td>Very bad</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Dune Recovery</td>
<td>Good</td>
<td>Good</td>
<td>Perfect</td>
<td>Extremely bad</td>
<td>Extremely bad</td>
<td>Extremely bad</td>
<td>Very bad</td>
<td>Bad</td>
<td>Bad</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Environmental Guides</td>
<td>More less good</td>
<td>Very good</td>
<td>Perfect</td>
<td>Extremely bad</td>
<td>Extremely bad</td>
<td>Extremely bad</td>
<td>Very bad</td>
<td>Bad</td>
<td>Very Bad</td>
<td>More less bad</td>
<td></td>
</tr>
<tr>
<td>Arteaga Council</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Very good</td>
<td>Extremely bad</td>
<td>Extremely bad</td>
<td>Extremely bad</td>
<td>Very bad</td>
<td>Bad</td>
<td>Moderate</td>
<td>Bad</td>
<td>Moderate</td>
</tr>
<tr>
<td>Ekologia Tailerra (NGO)</td>
<td>Bad</td>
<td>Very good</td>
<td>Perfect</td>
<td>Extremely bad</td>
<td>Extremely bad</td>
<td>Extremely bad</td>
<td>Very bad</td>
<td>Bad</td>
<td>Moderate</td>
<td>Bad</td>
<td>Moderate</td>
</tr>
<tr>
<td>Shipyard Owners</td>
<td>Extremely bad</td>
<td>Moderate</td>
<td>Extremely bad</td>
<td>More less good</td>
<td>More less good</td>
<td>More less good</td>
<td>More less good</td>
<td>Good</td>
<td>Perfect</td>
<td>Bad</td>
<td>Bad</td>
</tr>
<tr>
<td>Head Harbors</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Extremely bad</td>
<td>Extremely bad</td>
<td>Extremely bad</td>
<td>Extremely bad</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
</tbody>
</table>
In order to do so, we asked each of the identified interest groups about their preferences regarding each management option, based on qualitative terms: extremely good, very good, good, more or less good, moderate, more or less bad, bad, very bad to extremely bad.\[^{10}\]

Then, through a sequence of mathematical reductions, we used NAIADE to build a dendrogram of coalition formation. Fig. 6 shows the potential coalitions and the degree of credibility of their occurrence (the number on the left in Fig. 6).

For instance, there is a quite high degree of credibility (0.775) that surfers (G3), environmentalists (G11) and Head of Coastal Management (G8) will form a coalition, given the fact that a stable system serves the interest of each of these groups. Environmentalists would view as negative any destabilization of the system that could affect habitats and damage the environmental properties of the estuary; surfers desire stability because any changes to the Mundaka sandbar could alter surfing possibilities; and managers prefer to avoid the potential conflicts and social tensions that disruption could cause (as has happened in the past). Surprisingly, the diverse interest groups that were in opposition at the beginning of the participatory process had acknowledged their common interests by the end. An interactive process that allowed better understanding of the complex dynamics in the estuary helped to create a common space and possibilities for compromise solutions. Comments like the following, by a Mundaka surfer, are one example of those we heard several times during the last phase of the process:

“We saw fishermen and birdwatchers as enemies, and now we know that we share a lot of interest. We should row in the same direction” (Personal communication with surfer).

In the other hand, other coalitions have less degree of credibility and are unlikely to form, according to the results of our study. For example, there is a very low probability (0.360) that shipyard workers (G7), shipyard owners (G14) and Murueta Council (G5) will form a coalition with other stakeholders. These three interest groups depend on industrial activity in the estuary to satisfy their needs: industry provides employment for shipyard workers; it guarantees the viability of the enterprise; and it provides income through taxes for the Murueta Council. However other social actors see their interests threatened by the shipyard. The rejection of industrial activity by the other interest groups was remarkable during the participatory process. The assessments also elucidated the incompatibility between current shipyard activity and other user group interests. Adapting the shipyard to work with smaller boats, which do not require as deep canals as do the current ships, is the only foreseeable way to make multiple interests compatible. However, this seems rather improbable due to the high competition in international markets, where European shipyards face serious difficulties to compete with Asian constructors. Reducing the shipyards’ potential market to small boats could threaten its economic viability.

In any case, it is worth noting that to reach this type of conclusions it is relevant to validate the information gathered in this questionnaire with the information that is collected in the previous interviews in the institutional analysis and during the whole process. A quality check control confronting different sources of information can help to identify and minimize the presence of strategic behaviour and draw a more realistic picture.

From here, we can also obtain the ranking of alternatives according to the different coalitions, and look for possible conflicts of interest and their sources. The image below shows the ranking of the coalitions derived from the coalition dendrogram with a coincidence degree of 0.696 (quite high). (Table 14)

In overall from these results (Fig. 6 and Table 14) it is observed that the coalition formed by Environmental NGO (G13), Head of Biosphere Reserve-Basque Environmental Ministry (G9), guides (G11), surfers (G3), Head of Coastal Affairs – Spanish Environmental Ministry (G8), birdwatchers (G1), dune recovery supporters (G10) and the Fisheries Association (G2), prefers management option A3, which was also the best option according to the technical analysis (see section 5.1). This is also the best option for the Head of Harbours – Basque Ministry of Transport (G15), Arteaga (G12) and Busturia Council (G4), which have a different ranking of alternatives but agree on the first option. This option would be rejected by the owners of the shipyard (G14), its employees (G7) and Murueta Council (G5), because it implies restrictions on their activities and losses in the employment and income derived from it. For representatives of recreational boats alternative A3 is the second-best option after a minimum dredging option. In any case from this analysis we could state that all management options that consider maximum dredging would be vetoed by the vast majority of stakeholders, regardless of the deposition site. In the middle we find alternatives A2 and C4 followed by C2 and C3. These alternatives, although not among the preferred ones for the majority of the

\[^{10}\] NAIADE uses this scale by default.
identified groups, are not rejected by anyone and might encompass a compromise solution or a second-best option.

5.3. Sensitivity analysis

Sensitivity analysis is an important feature of this type of evaluation to check the robustness of the results [112].

The objectives of sensitivity analysis are (at least) threefold:

- To deal with uncertainties in data, assumptions and calculations, among other things, and check their influence on the results.
- To check the influence of changing model’s parameters in the results;
- To check the influence of different prioritizations of criteria (i.e., weights) in the results.

In this case, we have dealt with uncertainties in the evaluation process (data, assumptions and calculations) by using qualitative, ordinal and fuzzy evaluations. Since NAIADE does not use weights, we have carried out the sensitivity analysis by changing parameters of the model: in this case, we have changed the degree of compensation between criteria.

Our results show that the ranking is quite stable when changing the degree of compensation in the evaluation. Alternative A3 remains in the first position, followed by C4, A2 and C2. The worst positions are for those alternatives that contemplate a maximum dredging to satisfy the needs of industry B1, B2, B3 and B4 respectively.

6. Discussion and conclusions

This paper explores the potential of Social Multi-Criteria Evaluation, in the context of Integrated Coastal Zone Management. Starting from a real conflict in a coastal zone that pertains to a Biosphere Reserve, this paper shows how to structure, in a systematic way, complex and uncertain issues characterized by high degrees of conflict, by means of a well grounded analytical framework such as MCE. This analytical method has been applied with the support of participatory approaches that integrate a diverse group of scientists with different knowledge and a diverse group of stakeholders that represent the multiple interests and values in the society. The Biosphere Reserve of the Urdaibai Estuary in northern Spain has been used as a pilot case study to validate this approach in the context of ICZM.

Like in many other coastal systems, in this case, most of the previous research has been focused on mono-disciplinary and top-down approaches that neglected the multidimensional and dynamic nature of this complex socio-ecological system. As a consequence, despite the huge amount of financial and human resources invested in the past, policy makers and natural resources managers have not been able to tackle the continuous deterioration of the area. In these areas the institutional aspects, environmental dynamics, socio-economic processes and cultural values are coevolving over time and their management faces conflicts, uncertainty and surprises, making it necessary to abandon the expectation to find a global steady state. Decision-making in coastal systems requires a shift to an adaptive and evolutionary approach, trying to capture the complexity of the system from multiple perspectives.

According to GESAMP (Group of Experts on the Scientific Aspects of Marine Environmental Protection), ICZM is: “a continuous and dynamic process that unites government and the community, science and management, sectoral and public interests in preparing and implementing an integrated plan for the protection and development of coastal ecosystems and resources” [3]. As such this process requires flexible approaches capable of integrating the best knowledge in an inclusive manner, and SMCE encompasses a promising framework to foster this shift.

Any adaptation which enhances a specific optimization process of an individual subsystem could fail to enhance the resilience — the capacity to buffer perturbations — of the whole system [57] and policies for sustainable development cannot rely on the notion of optimal solutions based on a single measurement; the most likely being of course economic efficiency [102]. Instead collaborative learning processes that consider the multiple aspects of the issue at hand appear to be of central importance for social-ecological
systems to build resilience [113]. From this perspective, an adaptive management approach treats policies as hypotheses, and management as an experiment from which managers can learn, accepting uncertainty and expecting surprises [114]. Under this view it is also acknowledged that flexible social networks and organizations that proceed through learning-by-doing are better adapted for long-term survival than are rigid social systems that have set prescriptions for resource use [115].

Following these statements and foreseeing practical application to a real case, in this paper, we hypothesize that for a shift toward an integrated coastal zone management, efforts should draw on a broader set of knowledge domains that are represented in a single discipline and guarantee the inclusion of a wider public in a decision-making process. With this case study we have shown how to make operational this claim in the real world. Through a two-year collaborative research process, between an interdisciplinary group of researchers and a diverse group of stakeholders, we show that improving the integration of diverse expertise and values can lead, through a mutual learning process, to the definition of relevant policy options and sound decisions in the face of great complexities, value conflict and unavoidable uncertainty.

In this sense the scope of the SMCE process presented here goes beyond the search for an optimum solution and it follows the idea of procedural rationality which is emphasized in the quality of the decision-making process itself [60,116,117]. It encompasses a mutual learning routine among scientists and non-scientists that besides improving the knowledge of the system, open up the possibility to reframe the issue at hand in an adaptive manner while creating opportunities for a shared understanding, joint action and the search for compromise solutions. Note that here the emphasis is on compromise and not on forcing consensus, since ignoring the negotiation dimension of participatory approaches might erode their legitimacy and effectiveness as a learning process to solve complex socio-ecological issues [118].

Summarizing, the whole participatory integrated assessment framework developed within this case study was shown to be

- **dynamic** in a way that included continuous feedback loops among all the counterparts and was open to a continuous process of reframing the issue at hand
- able to allow inclusion and deliberation among different actors with different states in the assessment of alternative management options
- integrated with respect to disciplinary sciences but also with diverse types of knowledge that were neglected to date

Notwithstanding, this pathway is not safe from difficulties. Building trust among different stakeholders, reframing our monodisciplinary perspectives, becoming aware of the continuous changes in our complex and interconnected socio-ecological systems or the search for a common language among a diverse group of social actors (including the scientific team) are only a few of the main challenges we have faced in this process.

Other difficulties may emerge in the future if our choice is to shift ICZM towards a more holistic and inclusive partnership. Time for reflection, open dialogue among all the counterparts and huge doses of creativity are some necessary ingredients for this promising scientific and socio-political journey.

Acknowledgements

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