Marine Policy 42 (2013) 68–73

Contents lists available at SciVerse ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Elicited preferences for components of ocean health in the California Current

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ARTICLE INFO

Article history:
Received 7 December 2012
Received in revised form
13 January 2013
Accepted 27 January 2013
Available online 1 March 2013

Keywords:
Expert judgment
Probabilistic inversion
Deliberative analytical
Marine spatial planning
Ecosystem-based management

ABSTRACT

As resource management efforts move towards more comprehensive approaches that span multiple sectors and stakeholder groups, decision makers are faced with the challenge of deciding how important each group is, and how much weight their concerns should have, when making decisions. These decisions must be made transparently if they are to have credibility. This paper describes a systematic approach to eliciting such preferences, illustrated through a regional application of the Ocean Health Index in the California Current. The Index provides an ideal case study as it includes a comprehensive set of goals designed to assess the benefits people derive from coasts and oceans. The approach leverages the strengths of two different methods for eliciting preferences, one based on random utility theory and the other on analytical deliberative methodologies. Results showed that the methods were accessible to individuals with diverse backgrounds and, in this case, revealed surprising consensus about fundamental values that may have been missed in deliberations around a specific action, rather than evaluating a spectrum of management priorities. Specifically, individuals, even extractive users, assigned higher weights to cultural and conservation goals compared to extractive ones. The approach offers a general procedure for eliciting explicit preferences through constructive deliberations among diverse stakeholders.

1. Introduction

Resource management and conservation decisions are increasingly being made at broad scales across multiple stakeholder groups with diverse interests. In the marine realm, such deliberations have focused on ecosystem-based management and marine spatial planning, in contrast with traditional sectoral management that focuses on, for example, solely fisheries or water quality. Accommodating diverse interests requires addressing many outcomes with the scientific sophistication that sectoral management applies to just a few. Presented here is a general approach, described below, that transparently elicits these preferences in a systematic way that captures how human actions impact ecosystems and addresses the goals of decision makers.

The approach is grounded in multi-criteria decision making (MCDM), which offers systematic ways to elicit individuals' utility functions over multiple outcomes such that they can be combined into an overall preference ordering among decision options [1,2]. Unlike statistical procedures, such as Principal Component Analysis (PCA) and Nonmetric Multidimensional Scaling (NMDS), MCDM relies on disciplined judgment, allowing for incorporation of expert opinion of a more comprehensive set of issues and values in a quantitative and transparent way [3–5].

There are many situations in which managers and policy makers would benefit from an understanding of the relative values of different attributes, or criteria, related to decisions they face. For instance, in fisheries, managers must negotiate multiple objectives related to food production, generation of economic wealth, and viability of fishing communities, among others [6]. How should these different attributes be weighted in order to accurately represent the desires of stakeholders? In the realm of tourism, stakeholders seek economic wealth and livelihoods, preservation of the aesthetic value of destination sites, clean

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http://dx.doi.org/10.1016/j.marpol.2013.01.019

beaches, and conservation of iconic species. Structured elicitation and MCDM offer a way forward for informing such deliberations.

To anticipate one frequent concern, it is noted that there is no escape from the influence of weighting on outcomes of a decision. Even equal weighting reflects a strong position, namely that all outcomes (e.g., biodiversity, cultural preservation and economic growth) are just as important across the range of possible outcomes. Although one might reach that conclusion, assuming it from the outset is inconsistent with informed, reflective decision making. Moreover, when no explicit choice is made in defining weights, and equal weighting is adopted, the result ultimately is determined by how, and how many, criteria are defined. Eliciting weights has the advantage of transparency and avoids gaming outcomes through the lumping or splitting of criteria.

Rather than broadly describe the approach, here these methods are illustrated with a regional application in the California Current of the recently developed Ocean Health Index [7]. The Ocean Health Index assesses the condition of coupled human-natural ecosystems along ten publicly held goals (described below). Producing an overall index requires combining scores for each of the ten goals, where the weights assigned to those goals by stakeholders within the region are expected to be unequal.

2. Methods

2.1. Case study region

The California Current spans the west coast of the United States, encompassing three States and four marine ecoregions [8] as well as the federal waters that extend out to 200 nautical miles (Fig. 1). The region spans densely populated and heavily used coastal areas, such as Los Angeles, San Francisco Bay and southern Puget Sound, as well as remote, sparsely populated coastlines such as the Olympic Peninsula, Washington and the Lost Coast, California. The coastline includes small fishing communities, regions of suburban sprawl, large areas of coastal agriculture, increasing numbers of aquaculture facilities, world-class surf and scuba diving sites, coastal military bases, and Native American reservations and land rights. It is also one of the most scientifically studied marine regions of the world, and has active and strong conservation communities.

2.2. Ocean Health Index

The Index measures the sustainable delivery now and in the future of ten publicly-held goals for coupled human-natural systems. It consists of extractive goals (food provision, natural products and artisanal fishing opportunities), supporting goals (coastal protection and carbon storage), cultural goals (tourism and recreation and sense of place), economic goals (livelihoods and economies), and conservation goals (clean water and biodiversity). Each goal is assessed by its current status relative to an established reference value intended to represent a societal objective and its likely future state, which is indicated through the recent trend in each goal and the cumulative pressures from human activities and existing governance, social and ecological factors that build resilience. In the initial global calculation of the index, it was assumed each goal contributed equally, but it was acknowledged that this assumption rarely holds true. The goal of the work presented here was to try to get an initial sense of how the importance (i.e., weight) of goals varies across stakeholder groups. Establishing the goal weights for any particular region would require a much more elaborate stakeholder process, and suggest that the approach here might be used as a template.

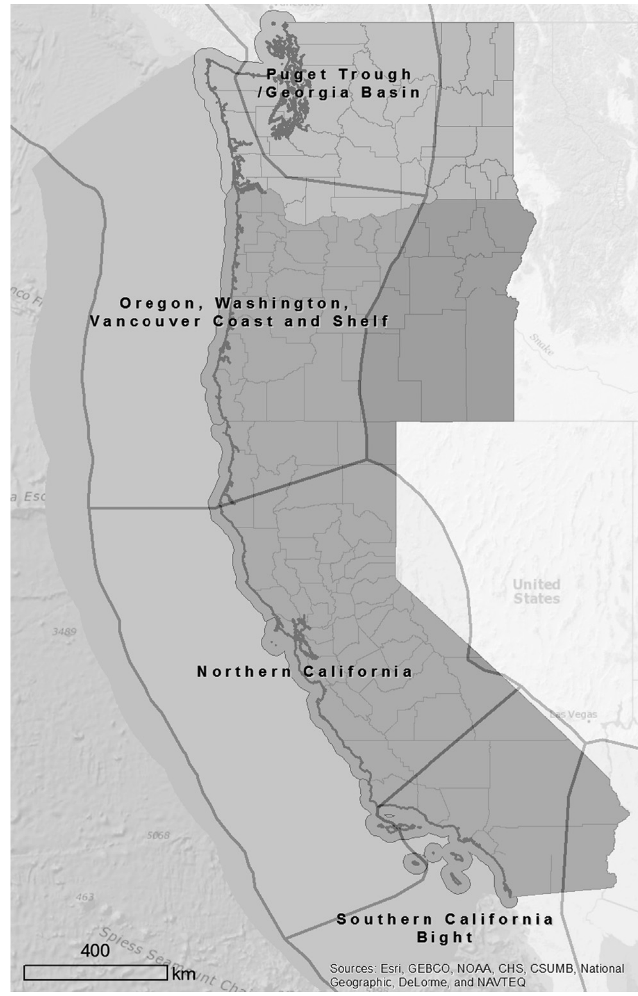

Fig. 1. A map of the California Current and jurisdictional and ecoregion boundaries.

2.3. Eliciting expert judgment

Two methods were used to elicit preferences based on the tradeoffs that would likely emerge from management decisions within the California Current. The first, based on random utility theory, asked people to rank 7 scenarios representing possible states of the California Current, characterized in terms of the 10 goals with hypothetical but realistic values spanning the range of possibilities (see Table 1 for a sample survey). The ranking was done in private and meant to reflect their personal view regarding the "health" of the ocean.

The second method, based on analytical deliberation, involved convening these experts in a workshop where they could discuss their views – and possibly change them, based on what they learned from others and additional reflection. The workshop was moderated based on principles from psychology and decision science, with the goal of deliberation, rather than consensus [9–12]. Readers familiar with the Delphi method would see common features. After the deliberations, experts ranked the scenarios again.

Probabilistic inversion was used to determine the implicit weights underlying those rankings [1,13]. This approach assumes that weights for the ten goals of the Ocean Health Index combine to create a single overall value of ocean health as a simple linear model. The weights are derived so as to most closely reproduce the proportion of experts ranking each scenario as first, second, third, etc. in the sets of scenarios they were given (see Table 1 and

Table 1
Sample section from the expert survey. Experts were presented with a series of ranking tasks in which they were asked to rank their top three choices from seven potential scenarios, with each of the 10 goals within the Index assessed as high (H), medium (M), or low (L).

Scenario	Seafood provisiqon	Artisanal fishing opportunities	Natural products	Carbon storage	Coastal protection	Livelihoods and economies	Tourism and recreaction	Sense of place	Clean waters	Biodiversity
1	H	H	H	M	L	L	M	L	M	L
2	L	L	L	L	L	M	M	M	H	H
3	M	H	L	H	L	M	H	M	L	H
4	L	H	L	M	H	M	H	M	H	L
5	H	H	M	L	M	H	H	L	L	M
6	M	H	H	L	L	M	M	L	H	H
7	M	L	L	H	H	H	H	M	L	M

supplemental material). Based on random utility theory, probabilistic inversion is a minimum information method, similar to a likelihood maximization procedure. However, it does not assume an explicit likelihood in finding a solution that ensures that no other set of goal weights would better recover the expert rankings. Instead, it relies on Kullback-Leibler information to guide the fitting algorithm.

The method uses an iterative proportional fitting algorithm to find a distribution over the set of weights implied by the experts, with the following two properties: (1) if each expert sampled his/her set of weights from this distribution, and used it to determine his/her preferences according to the model, then the pattern of responses (i.e., which scenarios were ranked highest, next highest, and so on) would resemble that found in the expert ranking data, and (2) this distribution over the set of weights implied by the experts was ‘‘as smooth as possible,’’ that is, it was minimally informative with respect to a uniform distribution of those weights. Once the distribution over the set of weights implied by the experts was obtained, 90% confidence intervals were assigned for each weight individually. The 90% confidence interval for the weight for each Ocean Health Index goal means that if one drew an expert at random from the expert pool, there would be a 90% chance that his/her weight for that goal is within these bounds—assuming of course that the MCDM model holds for the experts. Note that the marginal distributions on weights were not independent, since the weights must sum to unity. Analyses were contracted to R. Neslo but can be carried out using UNIVERSE (〈http://risk2.ewi.tudelft.nl/oursoftware/35-universe〉), a software program written by R. Neslo and R. Cooke for such purposes.

Similar applications of probabilistic inversion have been done for other environmental science contexts [14–17]. Key advantages of the method are that it allows for consistency checks through out-of-sample validation (although this was not done here) and that one can robustly calculate confidence intervals around estimates for the weights. A further advantage is that one can identify the factors affecting the weights. Currently probabilistic inversion does not allow one to test for potential interactions among criteria (goal weights); such interactions seem likely and would influence in particular our understanding of value sets (i.e., how preferences for goals cluster under different world views). Strengths and weaknesses of each method are summarized in Table 2.

2.4. Selecting experts

Experts represented many, although not all, of the sectors in the region, including: commercial fishing, recreational fishing, aquaculture, environmental NGOs (N=3), aquarium, education, philanthropic foundation, science, fishing community interests, first nations, offshore energy, military, coastal commission, park service, and the National Sanctuaries. Within that constraint, individuals were recruited with a broad understanding of their sector, such that they could reflect the views of their ‘‘constituency’’ in addition to their personal perspectives. Often this meant that experts had been involved in previous regional, multi-stakeholder planning processes, through which they had been exposed to a range of issues and perspectives. Given limited time and resources, it was not possible to fully represent all sectors, and so the results that follow are not interpreted as a comprehensive picture of stakeholder preferences in the California Current region.

3. Results

3.1. Quantitative outcomes from random utility model

The most striking features of the weights derived from the final ranking of the Ocean Health Index goals (after the group discussion) are their similarities (Fig. 2). The mean weights derived from probabilistic inversion were relatively equal across goals, and the standard deviations around these means were relatively small for every goal. Although the experts do not represent all populations in the California Current region, they were a highly diverse group whose values might have been expected to vary more.

The top weighted goals were clean waters and sense of place, comprising over a third of the total weight for the ten goals. Some of the lowest weighted goals were ones that often dominate discussions, such as livelihoods and economies, tourism and recreation, and food provision.

3.2. Qualitative outcomes from the analytical deliberative process

The deliberative analytical approach produced a rich discussion to accompany the computed weights. Six themes relevant to interpreting their weights and the value articulation process that produced them are discussed below.

3.2.1. Definitions matter

The 10 goals were defined precisely enough to have guided scientists in characterizing their scores for the global application of the Index [7], yet experts at the workshop asked for more details of those definitions in order to apply their values to the ranking task. For example, in discussing the Index’s biodiversity goal, experts asked whether it included only native species. In addition, when told that the target for the biodiversity goal was ‘species at no risk of extinction,’ they asked for clarification about what that meant with respect to the abundance and trends of different species. For the goal of carbon storage, they asked whether it included just long-term sequestration or also short-term storage and whether open-ocean areas were included. The goal of sense of place elicited a vigorous discussion of possible interpretations. Perhaps the most intense discussion focused on

Table 2
Strengths and weakness of the two methods employed to determine weights for each of the 10 goals in the Ocean Health Index. 'Equal weighting' is included as an additional method for comparative purposes.

	Equal weighting	Analytical deliberation	Random utility theory
Strengths	Easily done	Buy-in by the people who are represented by the group	Can be validated using out-of-sample validation, and confidence intervals can be calculated
	Easily explained	Can be moderated	Valuations based on discrete choice data
		Creates 'ambassadors'	Scientifically transparent
		Can reveal limitations to the approach in how criteria were defined	Easily replicable, allowing large sample size
Weaknesses	No group process	Not transparent	No assistance from a moderator
	No statistical assessment	Not easily repeatable: difficult to reconvene experts or new experts	Challenging to explain in a simple way
	Fake transparency: hidden assumptions, hidden weighting	Time-intensive for participants	Complex computation: need an expert to perform the calculations
	Unlikely to be realistic	Results depend on who is invited to participate	New method: need to explain it for experts to buy into it

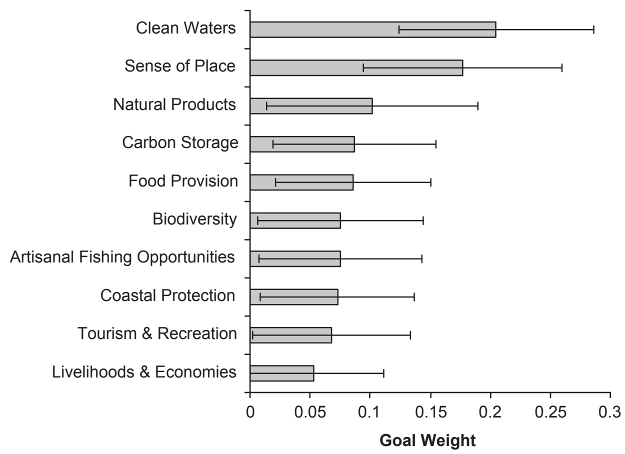

Fig. 2. Weights and their variance for each of the 10 goals (range 0–1) in the Ocean Health Index, as derived from probabilistic inversion of scenarios ranked by experts. Variance around each goal weight was nearly identical (average SD=7.1%; range=5.8–8.8%).

the meaning of sustainability, including focus on the exact definition of sustainability, relevant time scale for constraining it, and the role of precautionary buffers in modifying sustainability targets. In each case of ambiguity, definitions of the term in question were clarified while recording other views.

3.2.2. Fitting into the framework

Most participants had a set of issues that they expect to be addressed when assessing ocean health, yet those issues often were not easily apparent or did not map naturally into the 10 goals of the Index. This often arose because people approach this issue of ocean health from a lens of stressors to oceans rather than benefits to people, as is done in the Index. As a result, a primary task of the moderator was to clarify how to express those key concerns within the Index framework. Challenging topics included recreational fishing, fisheries enhancement (stocking), national defense, ocean acidification, invasive species, and land-based sediment input. Accommodating these concerns allowed for refinement of definitions of the Index components for future uses while also clarifying to participants how the framework connects to their understanding of ocean health.

3.2.3. Experience matters

Workshop participants identified and discussed four issues that help define their expertise. (a) Many had been deeply involved with the large-scale planning processes that led to the California Marine Life Protection Act and established a network of marine protection area in state waters [18], and the knowledge, insight, and frame of reference developed through engagement in that process set them apart from the more general public. (b) Each knew about some, but not all, of the substantive issues associated with the goals. (c) Each knew enough to know when opportunities to learn arose, leading to collaborative, rather than contentious discussions, even among experts who disagreed about some (or many) issues. Establishing the legitimacy of these kinds of expertise clarifies the standing afforded to different kinds of belief. (d) Preferences are not static, changing in response to new information or different decision contexts. That some participants' preferences changed based on discussions within the workshop was particularly illustrative of this point.

3.2.4. Connections among goals

Although the ten goals represent different aspects of ocean health, factors affecting one goal often affect another. For example, loss of coastal habitat often means reduced coastal protection, carbon storage, and biodiversity, and most people noted that changes in biodiversity and clean waters are important, including participants representing resource extractors, because they knew that these supporting services are important for the things they care about. As such, workshop participants had a hard time treating goals as independent. Such interactions, real or perceived, led people to assign ranks to scenarios that would not align with their actual preferences if these interactions were not real or did not happen as expected. The consequences of such biases would be different for interactions that led to tradeoffs versus synergies, i.e., negative versus positive interactions, respectively.

An underlying challenge to understanding these potential connections is that very little is currently known about the nature and consequence of interactions among human activities [19]. It may be relatively straightforward to know that, for example, destroying coastal habitat will negatively affect both coastal protection and carbon storage. It is much more difficult to know how harvest from wild-caught fisheries interacts with nutrient runoff from aquaculture and coastal farming, and how those interact with changes in ocean temperature. Human uses and their associated benefits to people may negatively or positively affect other uses, depending on a variety of contextual variables.

3.2.5. Cognitive challenges

Several problems recurred in the ranking process. One was the sheer cognitive load of dealing with many hypothetical scenarios characterized on 10 diverse goals. When this difficulty arose, participants were encouraged to focus on a few key goals, then see whether the resulting ranking would changes whether the other goals were considered. A second problem arose when participants could not imagine the scenario – even though the experts who created it believed it to be possible. In this case an example of such a scenario was provided and experts were encouraged to consider others. A third problem arose when people could not make the tradeoff posed by a scenario that realized one important goal while failing on another. In other words, they were only willing to rank highly those scenarios that scored well on everything they cared about (or conversely, rank low those scenarios that scored poorly on everything they cared about). Scenarios that presented a mix of scores were difficult to deal with and rank; the transparent display of potential trade-offs made the ranking exercise more difficult for people that had clear preferences in mind. Here, too, they were advised to do the best that they could, lest a simplification was suggested that would fail to capture that conflict. A fourth problem was participants' gradual realization, through the discussions, that they were undervaluing cultural values, because their sense of place was so strong that they could not imagine a world where it was compromised. In this case they were reminded that they needed to account for all their preferences when ranking scenarios.

4. Discussion

All management actions require decisions about the relative value of the different attributes that they will affect. Here a general approach to elicit such values was demonstrated. The approach integrates qualitative and quantitative thinking about both science and values. It engages diverse groups in ways that diffuse conflict, while encouraging them to learn from one another. That approach was applied in a case study, the California Current region, developing weights for the ten goals of the Ocean Health Index. However, it should be relevant to any management process that must reflect diverse impacts on people and ecosystems.

These preliminary results for the California Current suggest relatively equal weights across the ten goals within the Ocean Health Index, with the notably higher values for the clean waters and sense of place goals. As a result, equal weighting, the default value for many approaches, might work reasonably well in this regional application of the Index. The emphasis here is on using these weights to then combine goal scores into a single Index, but policy makers could also use the weights as indicators of issues that most need attention within a planning context or have high consensus across different stake-holders. As such, the methods extend well beyond the application to the Ocean Health Index. The case study shows that structured elicitation and multicriteria decision making techniques can be adapted to the needs of diverse users. Additional work is needed to capture and characterize the full set of perspectives and values within the region's population.

One benefit of structured elicitation procedures is their transparency. Individuals produce the weights themselves rather than having to trust the calculations produced on their behalf by experts. A second benefit is that the method treats preference formation as a "constructive" process, whereby individuals articulate the implications of their basic values for specific choices, rather than assuming that they immediately know what they want in all possible settings. A third benefit is allowing public deliberation of basic issues, whereby individuals can explain their reasoning to one another, showing respect for different positions and perhaps learning in the process.

One risk with such procedures is that the elicitation process will somehow pressure individuals, biasing rather than deepening their thinking. A second risk is that cognitive overload will lead to ill-considered judgments from individuals overwhelmed by the complexity of the issues, especially for multicriteria tasks such as the one presented here. A third risk is that the science will be lost in the process as individuals focus on what they want rather than what is actually possible given the constraints of physical and socio-economic systems. A final risk is that individuals will state idealized preferences rather than what would emerge if presented with real-life choices.

The approach here sought to maximize the benefits and minimize the risks in three ways: (a) structured moderation keeps issues from being brushed aside and stronger personalities from having undue influence; (b) consistency checks allow participants to triangulate on their evaluations and for moderators to encourage participants to reevaluate their choices when they notice inconsistencies, and (c) authoritative, accessible summaries of the relevant science allow informed judgments [15,17]. The approach sits squarely within the tradition of the analytical-deliberative process advocated by the National Research Council's influential *Understanding Risk* [20].

Participants raised three compelling issues for future efforts. First, they asked how the evolution in their values over the course of the day could be incorporated into planning processes, recognizing that other people would come to see things differently as they understood them better. Second, they wanted a better way to accommodate the uncertainty surrounding even the best science, so that they would not ignore an ecosystem's as yet unknown benefits or risks. Third, they wanted to be able to repeat the exercise with different time horizons, recognizing that things might look different when policies are set for 10 years or 25 years or generations out. Resolving these issues will provide important additional context to help guide expert judgment.

There is a vast literature on the many methods for eliciting expert judgment and the corollary process of stakeholder engagement. It is beyond the scope of this paper to compare and contrast those methods to what was done here, but it is worth noting that the combination of two diverse methods, one narrative and deliberative and the other quantitative and individual, provided a means to leverage the strengths and overcome the weaknesses of each. By the end of the workshop, all participants expressed gratitude for the opportunity to discuss the issues in a structured way, reflecting on the views that they heard – and their own. They generally felt that the deliberations made the relevant science more valuable because they knew better where it fit into their decision-making process. They seemed to welcome the chance to revise their ranking, in order to take advantage of that insight. In a similar vein, producing quantitative estimates of weights for each goal allowed for direct and statistical comparison of the relative importance of different values across the many participants, and easy incorporation of the weights into the broader Index framework. Application of similar approaches in new regions and with a broader set of stakeholders will allow for direct comparisons of how preferences vary over space and among communities, allowing for a test of the generality of the results obtained here.

Acknowledgments

Thanks to Steve Gaines, Jim Boyd, Marla Ranelletti, and Rashid Sumaila who offered guidance during the initial scoping of this project and to Ole Shelton for fruitful discussions about methodologies. We thank all of the workshop participants for their time and energy contributing to the elicitation workshop. Thanks to Rabin Neslo for assistance with probabilistic inversion analyses. Beau and

Heather Wrigley generously provided the founding grant. Additional financial and in-kind support was provided by the Pacific Life Foundation, Thomas W. Haas Fund of the New Hampshire Charitable Foundation, the Oak Foundation, Akiko Shiraki Dynner Fund for Ocean Exploration and Conservation, Darden Restaurants Inc. Foundation, Conservation International, New England Aquarium, National Geographic, and the National Center for Ecological Analysis and Synthesis, which supported the Ecosystem Health Working Group as part of the Science of Ecosystem-Based Management project funded by the David and Lucile Packard Foundation.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.marpol.2013.01.019.

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