A note on communicating environmental change for non-market valuation

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Highlight

- We explore options for formulating environmental change for valuation studies.
- All formulations have limitations depending on context.
- The choice of formulation reflects philosophical stance.
- The assumptions associated with the formulation must be clearly defined.
- A graphical method is proposed to reduce limitations of formulations.

Abstract

Communicating change in environmental condition is a critical component of non-market valuation studies. However, the underlying assumptions and implications associated with alternative ways of expressing change in environmental condition for surveys are rarely discussed in the literature. Our review found no cases where alternative formulations were both discussed and tested. In this note we report on our multi-disciplinary analysis of how best to express such change. We interrogate the meaning of, and inferences from, four formulations for quantitative expressions, or metrics, of environmental indicators that are used in the field of ecology and we then evaluate their usefulness in non-market valuation.

The assumptions and limitations of each formulation are discussed using seven hypothetical cases of change in environmental condition. We show that formulations for expressing change can be grouped based on two inherent philosophies potentially held by people when they consider their preferences for environmental changes: 'more is better philosophy' and 'restoration philosophy'. We contend that, without careful consideration of which philosophy people may apply, it is possible to inadvertently bias respondent choices when a particular formulation is used in a valuation study. If this happens, resulting value estimates will be a poor reflection of what researchers seek. An alternative approach that does not presuppose a philosophy but instead helps reveal a respondent's philosophy, is proposed.

Keywords

Environmental indicators; environmental metric; formulation; non-market valuation; environmental valuation; ecological change.

1 Introduction

Understanding change in environmental condition is pivotal to the development of policy and the management of environmental systems; poor understanding of change is often the cause of misguided or inappropriate policy or management actions (Golembiewski et al., 1976). Central to usefully representing change is the capacity to measure and communicate the type, magnitude and implications of change. The challenge is how best to represent change for monitoring and research purposes. Specifically, our particular interest is how to do so in order to elicit preferences in non-market valuation surveys aimed at ranking alternative levels of environmental condition on the basis of people's preferences.

When representing change, indicator metrics are widely used to succinctly represent the states of a system. Such metrics are particularly useful for providing information about complex systems especially where measuring all attributes is impractical or impossible (Heink and Kowarik, 2010). Indicators can be used to represent a change in state through repeated measures demonstrating trends (Butchart et al., 2010; Kubiszewski et al., 2013; Wolseley et al., 1994), or through formulations, to represent the state relative to some reference point (Bouleau and Pont, 2015; Norris et al., 2007). The latter approach is frequently used within environmental planning and management to establish goals or define limits on activities (Walker and Reuter, 1996). It is also widely used in environmental 'report cards' to communicate condition to the general public (Harwell et al., 1999). Typically, those designing these metrics are natural scientists and more specifically ecologists.

Approaches to estimating economic values held by people for environmental resources are often based on surveys administered by economists to representative samples of the underlying population (Laurila-Pant et al., 2015). Responses are used to estimate the willingness-to-pay (WTP) for environmental resources and changes in their condition. There is an extensive literature and many textbooks on how to estimate WTP (e.g. Haab and McConnell, 2002). Much advice exists on the various sources of bias afflicting the various non-market valuation methods (Venkatachalam, 2004). Lack of prior knowledge about the environmental goods and services is commonly a problem in environmental valuation and a potential cause of information bias. It is dealt with typically by using information sheets provided to respondents (Ajzen et al., 1996). However, vagueness in descriptions of the object of valuation may produce meaningless results (Hanemann, 1994) and insensitivity to scope has often been highlighted as a potentially serious issue that can compromise validity of a survey (Carson, 1997). In a classic example, Kahneman (1986) found little difference in respondents' WTP for cleaning up lakes of different sizes. Similarly, Desvousges et al. (1992) found very small difference between respondents' WTP estimates to save 2000, 20,000 or 200,000 birds. Hence, it has been argued that respondents' stated WTP derived from non-market valuation surveys reflects more of a general support for the environmental causes underlying the survey than a preference for particular degrees of improvement. Carson (1997), however, argues that in many cases what is seen as insensitivity to scope is actually the result of poorly conveyed description of environmental goods, highlighting the need for careful formulation.

Some researchers have resorted to using photographs to convey a difference between scenarios (Ruto et al., 2008; Scarpa et al., 2007; Willis and Garrod, 1993). However, such approaches rely on respondents being able to contextualise those images sufficiently to articulate preferences. Insufficient understanding or knowledge on behalf of the respondents may yield results that lack robustness. Examining this issue while studying respondents' preference of wilding conifers (an invasive species) in New Zealand, Greenaway et al. (2015) asked survey respondents to pick a preferred scene from two pictures (Figure 1). The photos were of the same location taken 30 years apart – before and after the spread of invasive wilding conifers. For the next question, the respondents were then shown a close-up of the trees in the photos and asked if they could identify them. As expected, those who correctly identified the trees chose option 'A' – an equivalent of 'natural condition' discussed later; whereas the majority that did not correctly identify the trees, and did not understand that the trees were an invasive species, preferred option 'B'. This illustrates that without a scenario specification that most respondents can interpret in an identical manner, photos can result in biased estimates.

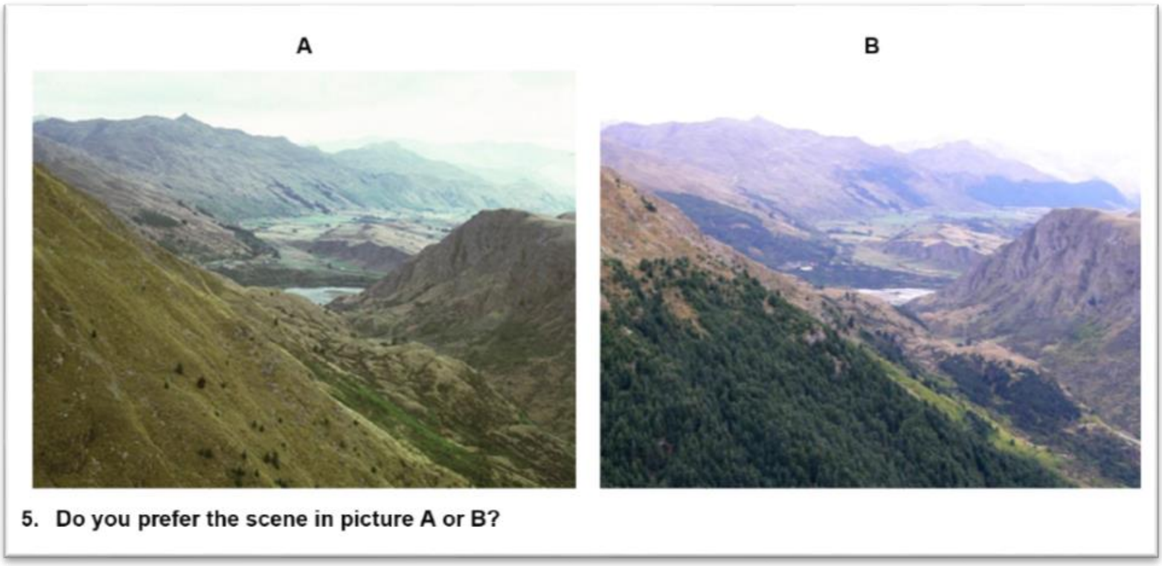

Figure 1. A simple choice task yielding potentially biased results (Greenaway et al., 2015)

The challenge of how best to formulate environmental change has motivated us in our interdisciplinary research. However, in the literature we found little discussion and even less testing of what constitutes the best way to communicate environmental change. What we found in the literature is that non-market valuation surveys broadly express environmental conditions using a variety of different indicators that represent change in quantity or extent of the environmental conditions (Freeman III et al., 2014). Indicators that represent condition relative to a reference point have been developed to help understand the significance of changes. For example, Bennett et al. (2008) estimated values for a certain percentage improvement in fish population or river length with healthy vegetation; Hatton Macdonald and Morrison (2010) investigated values for change in habitat area; Loomis et al. (2000) measured change through increase in ecosystem services. The reference point for each of these is implicitly the current condition. On the other hand, in ecology or conservation literature, the selection of reference points to assess change is often based on a ‘natural’ condition – the condition that we consider to be healthy or acceptable in an ecosystem. This gave rise to the reference condition approach in bioassessment (Bailey et al., 2004). Note that in the ecological literature, the term ‘reference condition’ generally refers to natural or best available condition, whereas we use the term ‘reference condition’ to mean any condition that is selected as a point of comparison. Our concern is that there are different ways to represent or express change and yet these are rarely discussed in the existing literature and there is no guidance on ‘best practice’.

In this paper we explore how to formulate environmental indicators for use in valuation studies where people are asked to value policy or management actions that change the ecology of a system. We contend that the selection and formulation of indicator metrics has significant bearing on how people understand and interpret the often unfamiliar changes in the environment. To ensure that valuations are ‘meaningful’, we examine a range of metric formulation options using a hypothetical case study. The intention is to raise awareness of the underlying implications of alternative formulations and promote debate about the way we communicate environmental change in the context of non-market valuation to ensure we generate meaningful valuation results.

2 Hypothetical case study

Let us assume one wants to elicit people’s preferences for changes in environmental flow outcomes obtained from policy options regulating the flow regimes in a large wetland ecosystem. The environmental outcomes are predicted from a model that quantifies the number of suitable flooding events (events that meet pre-defined water requirements of species) in a given time period from various flow scenarios (Fu et al., 2015). These *suitable* flooding events are defined on the basis of existing knowledge about what a species requires to persist within an environment, rather than more complex concepts of the provision of an ecosystem service by the species. For example, a suitable event for waterbird breeding or survival of riparian vegetation in a landscape is an event of a certain magnitude and duration at a particular time of year. There will be a physical limit to the number of suitable events achievable in a given time period, depending on the species of interest. The number of suitable flooding events is then used to construct indicators for a survey designed to elicit people's preferences for the environmental outcomes. The challenge is to find an unambiguous formulation for an indicator of change that people find useful and is not too complex so as to ease cognitive processing.

We surmise that there are two reference points that people would find helpful in their interpretation of the number of suitable flooding events under each scenario. The first reference point is a 'Current' value, which indicates the number of suitable flooding events under the current policy (e.g. for our research this is the currently legislated *Water Sharing Plan* in New South Wales, Australia). The second reference point is a 'Natural' value, which indicates the number of events under natural conditions (e.g. prior to river regulation upstream of the wetland). Changes in environmental condition can then be measured relative to a reference point for a range of possible scenarios of interventions.

We have defined seven different sets of possible combinations of scenario, current and natural conditions that could occur in this hypothetical wetland. These are called 'cases' in Figure 2. The number of suitable flood events under 'Current', 'Natural' and 'Scenario' conditions is given for each case. Cases A, B and C are common, showing reduced or increased number of suitable flood events under a specific scenarios (e.g. due to less or more environmental watering for the right time, duration and dry period). Cases D, F and G are less common, showing situations where more suitable flood events under the scenario condition than what would have naturally occurred (e.g. due to policy intervention where more water is diverted to and/or retained in a focused area for the right time, duration and dry period). Cases E and F are characterised by currently more suitable flood events than what would have naturally occurred due to current policy intervention. We assume that all three conditions (current, natural and scenario) are within the maximum possible number of suitable events that can be physically achieved.

We want to identify the most informative and intuitive formulation of an environmental indicator that can be used to elicit people's preference for different scenarios in as unbiased a manner as possible. Four potential formulations of change were explored (Figure 2):

1. S-C: Scenario – Current
2. S/N: Scenario/Natural
3. |S-N|/N: |Scenario – Natural| /Natural
4. (S-C)/(N-C): (Scenario – Current)/(Natural-Current)

All formulations have been used in environmental science and management; some have been used for economic survey. Our goal is to evaluate each of the options with a view to identifying the best formulation of change that is meaningful enough for survey respondents to reveal their preferences to researchers in as an informative and unbiased way as possible.

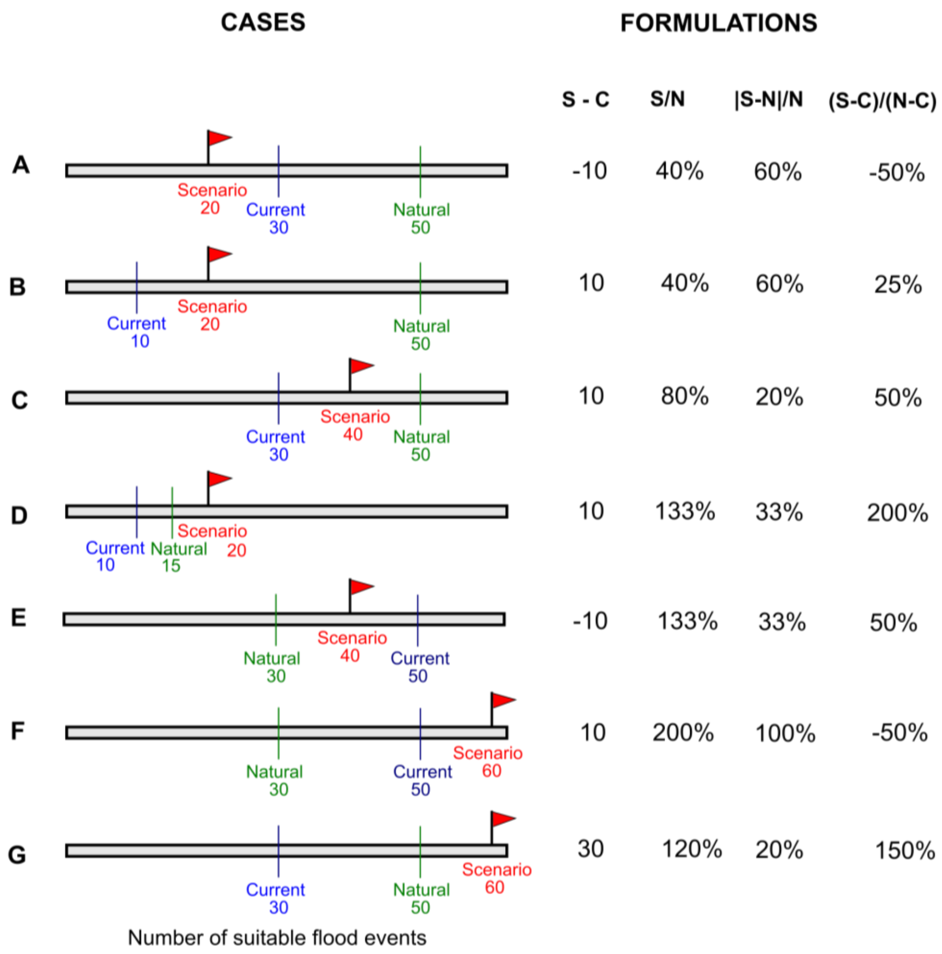

Figure 2: Seven hypothetical cases used to show the number of suitable flood events under current, natural and scenario conditions. The metric outputs under each of the formulations considered in this paper are shown on the right (proportions are expressed as percentages). S: Scenario, C: Current, N: Natural.

3 Formulating indicators of change

3.1 Scenario – Current

This formulation uses the current condition as the only reference point and measures an absolute change. A higher positive value indicates that the scenario provides more suitable events compared with current conditions and a negative number indicates fewer suitable events. When using this formulation we make the following assumptions about respondents' preferences:

- respondents are only interested in the absolute change from current and that other reference points are not important;
- more of a ‘good thing’ (e.g. suitable flood events) is preferred to less.

In our hypothetical examples, Cases B, C, D, F result in the same score using this formulation (10 in Figure 2) despite these cases having vastly different context. In Case B, under natural conditions we would have 50 suitable flooding events, but currently the system is severely modified and there are only 10 suitable events. The proposed policy intervention (the scenario) doubles the number of suitable events to 20. Case C also has 50 suitable events under natural conditions, but is moderately modified and currently we have 30 events. With policy intervention we can increase the number of suitable events to 40. In Case D, the system naturally has a low number of suitable events (15); with intervention the number of events increase from 10 (current) to 20 (scenario), which exceeds the natural conditions. In Case F, there are currently more suitable events than those expected to naturally occur and proposed policy intervention would increase the number of events well beyond the expected number that would occur naturally. While the number of suitable events increases by 10 from the current level in all four cases, they have different contexts defined by the relative position of the current, natural and scenario levels. However, people would not know this when assigning preferences according to a metric value of ‘10 additional events’. It is quite likely that people would value these four cases differently if they had the extra information about the natural conditions. By using this formulation as the environmental indicator, we would be assuming that there would be no difference in valuations for these cases (i.e. people are asked to value an increase of 10 suitable events, without knowing there might be different contexts). Although this assumption is potentially flawed, it has been used in research that has attempted to integrate valuation with hydro-ecological modelling (Akter et al., 2014). Many non-market valuation studies that use a metric of percentage increase or quantity increase from the current level expose themselves to similar flaws if they do not provide greater context as shown by the cases in Figure 2.

3.2 Scenario/Natural

Contrasting with the previous formulation, the S/N formulation considers the natural condition as the reference point in a ratio, so that the numerator is given as a proportion of the natural state. The outcomes of this formulation are proportions of the natural condition. An outcome of 1 is equal to natural condition; above 1 means more suitable events than under natural conditions and below 1 means fewer. This formulation is the classic reference condition approach that has been used in many parts of the world (Bailey et al., 2004; Pardo et al., 2012; Stoddard et al., 2006). In this case, the use of natural as the reference point could imply that natural conditions are the ultimate target. This has been a criticism of the reference condition approach because the environmental system can be sufficiently modified that the natural condition may not be an achievable target (Acreman et al., 2014). In Figure 2 we express this formulation in percentage terms. When using this formulation, we assume that:

- natural condition is the reference state of interest to respondents;
- the starting point (i.e. current situation) is irrelevant to respondents.

In our case study, Cases A and B have the same output when using this formulation (S/N = 40%) because both cases have the same number of suitable flood events under natural and scenario conditions. However, in Case A, the Current level (30 events) is closer to Natural than the Scenario, whereas in Case B, the Current level (10 events) indicates greater current degradation. Using this formulation as the ecological indicator in a valuation questionnaire implies that the degree of current degradation does not enter into the preference set of respondents. This holds for D and E as well – these cases both have the same output (S/N=133%) – but are quite different in relation to the number of suitable events under current conditions. These are fundamentally different situations that we feel could be valued quite differently if people had information about the degree of degradation in the current situation. Missing information about arguments in the preference function can bias results because some may consider that intervention in highly degraded systems is valuable while others may feel that it is not.

3.3 |Scenario – Natural|/Natural

Similar to formulation 2, this formulation also uses the natural condition as the only reference point and thus implies that natural condition is the target state. Any deviation from natural, positive or negative, is to be measured with the same yardstick. It represents the proportional departure in absolute terms from the natural condition. This is similar to the hydrologic deviation measure used in the Index of Stream Condition (ISC) (Ladson et al., 1999). The outcomes of this formulation are always zero or positive. An outcome of zero occurs when the proposed policy scenario equals the natural condition. A positive outcome indicates some degree of departure from the natural condition; the higher the positive value, the further the departure. When using this formulation, we make the same assumptions as formulation 2. In addition, this formulation assumes that:

- the proportional departure from natural is important for people's choices;
- the direction of change from natural condition is not important.

These new assumptions are demonstrated by comparing Cases C and G. Both cases have the same outputs when using this formulation (|S-N|/N = 20%), indicating the same level of departure from natural conditions. In Case G, the scenario produces a greater number of suitable events than Case C. These different contexts will be concealed when using this formulation for economic valuation. Perhaps the biggest drawback in this case is the absence of directional change.

3.4 (Scenario – Current)/(Natural – Current)

We have established from the previous three formulations that the use of only one reference point (either Current or Natural) fails to reflect different contexts behind the scenario outputs that may influence how people allocate preferences. The use of two reference points within a formulation can be used to include more information about relative changes.

One possible formulation is the (S-C)/(N-C) ratio. This formulation, termed as the percentage change in anthropogenic baseline, is used for setting water quality targets and reporting progress for the Great Barrier Reef catchments in Australia (Waters et al., 2013). Here, the numerator denotes the scenario change from current conditions and the denominator represents the current number of suitable events in relation to those occurring under Natural conditions. Hence, a value described by this environmental indicator provides information relative to the scale of the difference between Natural and Current. A value of 1 (or 100%) indicates that the proposed Scenario is equivalent to Natural conditions, while a value of zero means the Scenario is no different from the Current condition (no change). The key assumptions underlying this formulation are:

- the Natural condition is the reference state;
- information about both Current and Natural states is important for determining preferences.

Cases A and F illustrate the first assumption; using this formulation produces identical outputs (-50%) in the two cases. In Case A, there are 30 and 50 suitable flood events with current and natural conditions, respectively. In Case F, the figures are reversed with 50 and 30 suitable events under current and natural conditions, respectively. In Case A, the scenario has 10 fewer events than current; while in Case F, the scenario has 10 more suitable events than current. In both cases the scenario is equally far away from the number of suitable events that would occur naturally, albeit in Case F we get more events and Case A we get fewer. This output may be challenging to interpret for some people for Case F when we have a negative value even though the proposed scenario produces more suitable flood events. However, this is because the scenario is further away from the naturally occurring number of suitable events. It may be argued that this formulation implies that the natural situation is what we want to achieve. Additionally, we must also assume that the situation under Case F is identical to that under Case A, in the sense that people will value them equally.

Using this formulation, if the numbers of suitable events under natural and current conditions are numerically close, the proposed scenario will be associated with a high percentage value (demonstrated in Case D). For example, say there is small increase in the number of suitable events in the scenario (5 more suitable events) and the difference between the natural and current levels is very small (10 events) then the output of the formulation is 200%, which is much higher than might be obtained for other cases with much higher value changes. This could be a problem where respondents are comparing alternative scenarios and a 'big number' gives the impression of a much better environmental outcome when this is not necessarily the case.

4 Discussion

Our main challenge in environmental valuation is in understanding what information is relevant for eliciting preferences over a proposed change in environmental conditions. If policy makers and managers wish to prioritise interventions in a way that is consistent with people's preferences then ecologists and economists must work together to reveal unbiased preferences. It is paramount to understand the potential unintended bias that may arise from the use of a selected metric of environmental change. This demands that we understand what might affect preferences and how information can be presented in an informative and unbiased way. The alternative formulations discussed above provided some insight into what is required in communicating environmental change with respect to current and natural conditions. Here we used suitable flood events as examples, but the idea applies to any type of quantitative indicators.

In our own deliberations and trans-disciplinary discussions, we found that all formulations have limitations, and there is no ‘global’ metric formulation that will satisfy the need to inform people adequately in all situations where they are required to reveal preferences for environmental outcomes. In practice, the choice of formulation will reflect a philosophical stance, and thus the assumptions associated with the formulation must be clearly understood when WTP results are interpreted.

Consider two philosophies: a ‘more of a good thing is better philosophy’ where an individual wants to produce an increase in certain attributes in a system (within a physical limit) and a ‘restoration philosophy’ whereby a person wants to restore a modified system to its natural condition. The S-C formulation reflects the ‘more is better philosophy’ while the S/N and |S-N|/N formulations are consistent with the ‘restoration philosophy’ (Figure 3). The S/N formulation is concerned with proportional change whilst the S-C formulation focuses on the absolute change between the scenario and the reference. The (S-C)/(N-C) formulation reflects an intermediate perspective that emphasises that we need to consider both where we are now (e.g. Current) and where we came from (e.g. Natural). In both of these formulations, the magnitude of change from the current is important although an additional factor of importance for the (S-C)/(N-C) formulation is that a positive value indicates the change puts the system closer to the ‘Natural’ state.

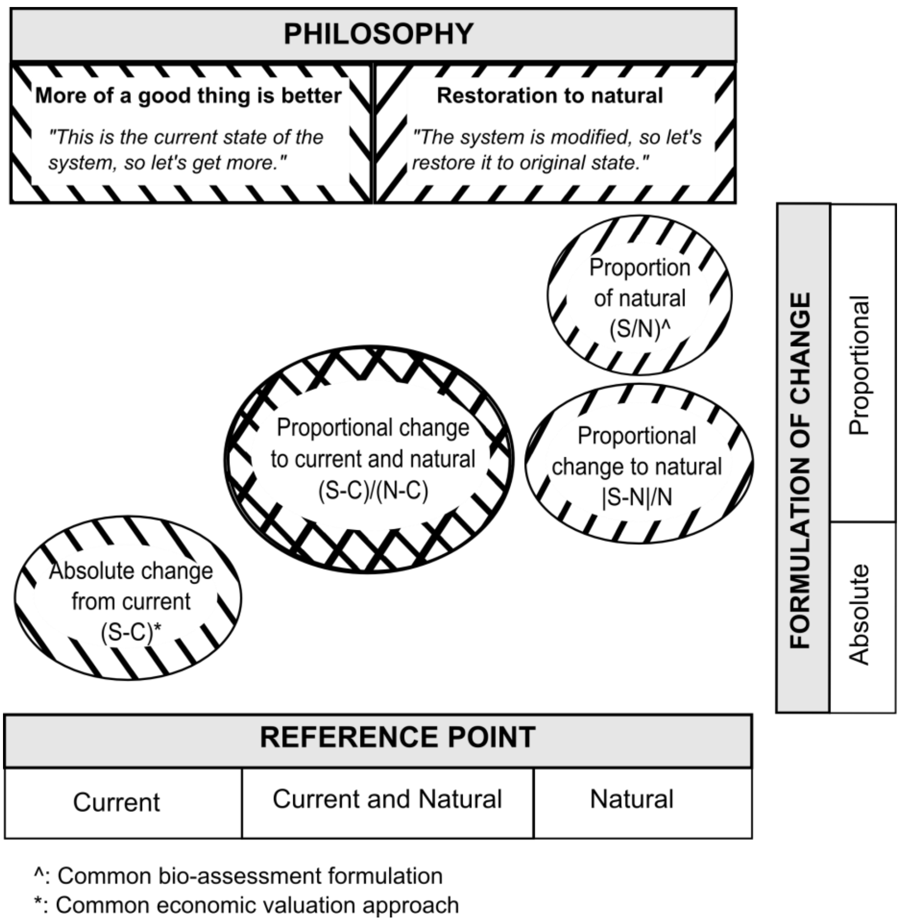

Figure 3: Conceptualising the philosophical basis of the formulations

There are potential risks for economic valuation studies associated with each of the formulations. Considering only one reference point raises the possibility that a person does not have enough context and so their preferences become inadvertently biased by a lack of information about variables that are included in their personal preference function. It may also be the case that certain informational variables should be represented in their personal preference function but currently are not. This is a common problem with information asymmetries between what scientists understand and what decision makers, or in this case respondents, understand. For example, people may not be informed about natural conditions and whether they are attainable. Hence, if the current condition is the only reference point, people may not appreciate the extent to which a system has been modified. Furthermore, their preference may differ considerably if they feel that a system is beyond repair or, alternatively, is in pristine condition. In contrast, using the natural condition as the only reference point in a study could signal to respondents that it is being asserted that the natural condition is the desired outcome. This may sometimes be the case although restoration to an historically defined natural state is unattainable in many systems and may also be undesirable if, for example, future climate conditions are very different from those experienced historically (Acreman et al., 2014). In such circumstances, using the natural condition as the only reference point puts the environmental valuation study at risk of not being considered legitimate and also suffering from the vagueness that Hanemann (1994) says renders valuations meaningless.

While the (S-C)/(N-C) formulation considers both reference points, it is conceptually more difficult for people to interpret, which has implications for the design of valuation surveys and targeted respondents. An additional risk of the (S-C)/(N-C) formulation for environmental valuation is that the perceived change in ecosystem response can be overinflated, which in turn might lead to stronger preference statements than may otherwise be elicited.

Given the challenges described with each of the formulations, we sought a more meaningful way to indicate environmental change. In our research, photographs were not a solution given the aforementioned difficulties in representing condition (good or otherwise). Alternatively, a graphical tool with indicative locations of the reference points (e.g. current and natural conditions) was developed, and the respondents' preferences are elicited by drawing WTP curves in the graph (Figure 4).

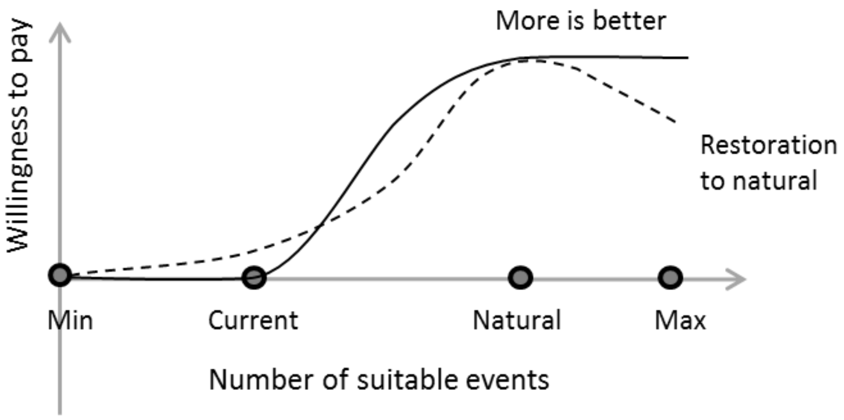

Figure 4: Willingness to pay preference based on the current and natural condition. The respondents are given a blank graph with the locations of the four reference points: minimum, current, natural and max. They are asked to draw their preference curves based on the four reference points. Two hypothetical preference curves provided by respondents are shown, the solid line reflects a 'more is better philosophy', while the dashed line indicates a 'restoration philosophy' with a lower preference given to condition with some departure to natural condition.

With this method, people are asked to draw their preferences (WTP) based on the relative position of both reference points: Current and Natural. The minimum and maximum points, which indicate the physical limits of the object of valuation, are also identified to set the boundary of the preference curve. In this way, we can bypass the need to quantify the object of valuation in a single metric while still providing adequate contextual information. This enables the respondent to contribute their own preference function without it being influenced by the particular formulation of the metric used to describe change. Such an approach allows researchers to add more reference points if they provide crucial context for understanding the environmental change and are important to the respondent in their preference function. There may be several preference curves depending on the illustrated circumstance (e.g. for each of the seven cases – see Figure 2).

The graphical method allows respondents to consider their own preference rankings explicitly based on relative positions of the multiple reference conditions. This is illustrated in Figure 4, where the shapes of the preference curves elicited from the respondents reflect the two different philosophies discussed earlier. The S-shaped solid line reflects a 'more is better philosophy', with a quicker increase in WTP when the scenario is much lower than natural, and a slower increase in WTP when the scenario is closer to natural. The parabolic shape with unimodal peak (dashed line) indicates a 'restoration philosophy' with a drop in preference given to condition that differs from natural condition. In this way, the research design does not pre-empt the sort of preferences or philosophical stance that researchers may think is not sensible but that may legitimately be seen as desirable by participants. It is in this way that this design is intended to be 'unbiased'.

The two most common stated preference non-market valuation methods are Contingent Valuation and Stated Choice. Our proposed graphical method could feasibly be included as part of either method. Contingent Valuation typically asks respondent to explicitly state how much they are willing to pay for the improvement of a particular environmental service. Traditional Contingent Valuation implementation estimates single WTP values per respondent and assumes linearity between minimum and maximum values. This may not be the case as it has been suggested that once a certain amount of an environmental resource has been provided, the respondents may have a steeply declining marginal utility (Bateman, 2011; Rollins and Lyke, 1998). This is supported by economic theory that suggests a diminishing rate of increase of WTP as the improvement increases. Together with capturing such nonlinearities, our proposed graphical method would allow researchers to identify preference heterogeneity within respondents' preferences for each attribute – usually something that only a very involved choice modelling exercise can achieve.

Stated Choice method consists of presenting respondents with a set of alternative scenarios and asking them to choose their preferred alternative at a monetary cost. In our case, as part of a Stated Choice exercise, attribute levels[1] could be defined as 'current', 'natural', 'min' or 'max' or somewhere in between those spaces. However, to depict meaningful scenario differences, one would need to somehow resort to indexation of levels (e.g. to differentiate cases where 'current' and 'natural' are either far or close to each other). Hence, the proposed graphical method would keep the parsimony of the reference definitions as well as depict the distance between scenarios.

A further advantage of the proposed graphical method is that it could be extended to consider issues of asymmetrical preferences. Asymmetries in preferences occur when respondents exhibit a behaviour difference depending on whether they are asked to accept a payment or have to pay for an essentially the same outcome. In a classical study to examine the WTP/WTA (Willingness To Accept) gap (or gain/loss asymmetry), Kahneman et al. (1991) found a significant gap between what buyers were willing to pay and what sellers were willing to accept and attributed this phenomena to an 'endowment effect' whereby already owning an object added value and a 'loss' of it was relatively more painful to the sellers than the 'gain' to those who could buy it. This gap has been frequently identified in environmental valuation literature and could lead to biased environmental policies (Knetsch, 1994). In the scope of the proposed graphical method, this effect is a testable hypothesis. One could extend our work by inverting Figure 4, with the scenarios on the x-axis and WTA on the y-scale. This could be particular useful if examining projects that could negatively affect the environment and respondents would be expected to receive compensation for any environmental degradation suffered.

Finally, the restriction deliberately imposed by the graphical tool would ensure strict conformity to economic theory. An often contested part of Contingent Valuation results is the

[1] An attribute is a one of, potentially, many fields that are used to differentiate between alternatives in a choice experiment. For instance, if one was to decide between two cars in a choice exercise, engine size could be one of the attributes, and the two choices may have varying attribute levels, (1.5 litres and 2.2 litres).

seeming insensitivity of respondents' WTP with respect to the quantity of an environmental good (Carson et al., 2001). By restricting the minimum and the maximum to within physical limits of the object of valuation (e.g. number of suitable events for a species), yet allowing respondents to change the shape of WTP curve, the tool would provide respondents' WTP at each number of suitable events that were empirically possible.

5 Conclusion

The intent of this note was to evaluate the metrics in use in environmental science to determine if they could be adapted for valuation studies. We explored four formulations for use in studies where people are asked to value policy and management options that are expected to have future environmental outcomes. Through seven hypothetical cases we identified the underlying assumptions made in each of the formulations and discussed their limitations. Although these formulations are commonly in use in environmental science applications, we showed that the different formulations can inadvertently bias respondent choices if information is missing and respondents need that information to form their preferences. Ultimately, preferences depend on their philosophy. Ideally it is this dependency that researchers need to unpack but the quantitative approaches currently in use do not always allow this. For this reason we conclude that these quantitative formulations may not always be the best choices for valuation studies. The value of our work is in providing increased awareness of the assumptions and risks associated with the way we communicate environmental change and the metrics currently in use. These issues need to be addressed to reduce the vagueness in the object being valued, and ensure more meaningful, robust and useful valuation results. A qualitative graphical method was proposed that could address the limitations of the various formulations of the quantitative methods we examined. This method could feasibly be included as part of non-market valuation methods such as Contingent Valuation and Stated Choice.

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