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Research article

Tackling communication and analytical problems in environmental planning: Expert assessment of key definitions and their relationships

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ABSTRACT

Inadequate definition of key terms and their relationships generates significant communication and analytical problems in environmental planning. In this work, we evaluate an ontological framework for environmental planning designed to combat these problems. After outlining the framework and issues addressed, we describe its evaluation by a group of experts representing a range of expertise and institutions. Experts rated their level of agreement with 12 propositions concerning the definitions and models underpinning the framework. These propositions, in turn, were used to assess three assumptions regarding the expected effectiveness of the framework and its contribution to addressing the abovementioned planning problems. In addition to point-based best estimates of their agreement with propositions, expert ratings were also captured on a continuous interval-valued scale. The use of intervals addresses the challenge of measuring and modelling uncertainty associated with complex assessments such as those provided by experts. Combined with written anonymous expert comments, these data provide multiple perspectives on the level of support for the approach. We conclude that the framework can complement existing planning approaches and strengthen key definitions and related models, thus helping avoid communication and analytical problems in environmental planning. Finally, experts highlighted areas that require further development, and we provide recommendations for improving the framework.

1. Introduction

Environmental planning is hampered by a range of issues. Although some, such as how best to manage community planning (Lane and McDonald, 2005; NRC et al., 2008) and 'wicked problems' (Head, 2019), are inherently difficult to resolve, others are more readily addressed. One issue that is seemingly straightforward, but which has received little attention, is the inadequate definition of key terms and their explanatory models. This is especially the case with respect to the concepts of 'values' and 'wellbeing', where inadequate definitions may lead to communication and analytical issues that hinder planning and decision-making. For example, Reser and Bentrupperbäumer (2005) assessed the underlying concepts and application of 'environmental values' and 'World Heritage values' in the Wet Tropics World Heritage Area of North Queensland and found that their varied use and interpretation detrimentally affected every aspect of environmental management. More recently, Tadaki et al. (2017) have described ongoing difficulties with the values concept; Heink and Jax (2019) concluded that there was an urgent need to better integrate 'wellbeing' into ecosystem service frameworks, a point echoed by Rasheed (2020); and Wallace and Jago (2017) described a range of issues arising from poor discrimination among environmental entities including values, properties, and processes.

We propose that these and related problems could be reduced by using an explicit ontology[1] that delineates the key entities in environmental planning and describes their relationships through models – an ontological framework. We describe such a framework here (building on Wallace and Jago, 2017) and then evaluate it using experts. The framework is aimed largely at supporting group deliberation for natural resource and environmental planning, including expert or

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[1] An ontology is "a list of concepts and categories in a subject area that shows the relationships between them" (Oxford Learner's Dictionary, https://www.oxfordlearnersdictionaries.com/definition/english/ontology). The ontological task is to: "say what there is, what exists … [and to] … say what the most general features and relations of these things are" (Hofweber, 2018, p 13).

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community-based deliberative processes (e.g., Gregory et al., 2012; Head, 2019; NRC,2008). If professional planners are unclear concerning their ontological framework, then this is likely to hinder communication and analysis as discussed in Section 2. We view the framework as complementing existing planning approaches whether they involve participant-driven processes, such as that in structured decision making (e.g., Gregory et al., 2012), or more researcher-driven processes (e.g., Smith et al., 2016).

After trialling the framework in application, including peer-reviewed publications as summarised in Wallace et al. (2020), and adaptation through a process of informal strategic review similar to that outlined for framework synthesis by Macura et al. (2019), it was decided that the next step should be to present the framework to experts for critical review. To capture expert uncertainty, the study includes interval-valued[2] questionnaires – an increasingly popular approach specifically designed to capture response uncertainty. The contribution of the paper is to provide an assessment of the relevance and utility of the ontological framework designed to reduce problems of ambiguity and confusion in environmental planning, particularly in relation to values and wellbeing. If assessed favourably, the ontological framework can be utilized by environmental managers and researchers with a clear view to its utility. Otherwise, we aim to identify avenues for improving it.

Specifically, in this paper, we describe a set of issues that commonly lead to communication and analytical problems in environmental planning processes (Section 2). We summarise the models and definitions of the ontological framework that was developed by Wallace and Jago (2017) to reduce those problems (Section 3). Under methodology (Section 4), we describe 12 propositions assessed by experts and how they are used to evaluate the framework.[3] We also describe the criteria used to evaluate propositions, and the steps followed in the workshops and subsequent analysis. In presenting the results (Section 5), we emphasise the usefulness of both interval-based outputs and the three-pronged approach to assessing propositions. This provides the basis for a multi-perspective evaluation of the framework, and recommendations for its further development (Section 6).

2. Communication and analytical issues addressed by the framework

Poor definition of key environmental terms – such as processes, properties, and values – not only leads to communication issues (Newton, 2016; Reser and Bentrupperbäumer, 2005); it may also result in category mistakes (the placing of an entity in a category in which it cannot logically belong, Table 1) and consequent analytical errors, such as double-counting in calculations (Wallace and Jago, 2017). At the same time, it is important that explanatory models underpinning definitions support communication and application. For example, Bercht and Wijermans (2019) describe how unstated and unreconciled mental models among researchers may lead to communication problems that hamper successful collaboration. Each of these two aspects – definitions of key terms and related explanatory models – is considered separately in the remainder of this section.

2.1. Issues with key terms

Ambiguity among key environmental terms, for example, the inconsistent use and blurred boundaries between 'properties' and 'values', creates problems in planning. It confuses meaning, and thus hinders communication and may lead to obfuscation and consequent lack of transparency. As described by Morar (2019, p 2):

> "Scientific concepts are (purportedly) based on a solid foundation since they are supposed to capture (subject-independent) facts and patterns about the world. At the same time, these concepts *have also been invested with normative force and treated as proxies for values*. This class of concepts is especially operative when it comes to values assigned to nature …" [Italics added.]

Such loading of values[4] onto apparently objective terms is common in the environmental literature. Examples include how biodiversity (Morar, 2019; Wallace and Jago, 2017), ecosystem health (Jamieson, 1995; Lackey, 2001), air and water quality (Hull et al., 2003 [5]), sustainability (Newton and Freyfogle, 2005), and profitability and resilience (Newton, 2016; Wallace, 2012) are sometimes applied. These authors describe how problems are generated when these terms – which are properties of a 'thing' such as a system, element (physical entity), or process – are sometimes used as encompassing both an objective property and a normative sense with implied values. This is the case, for example, where 'sustainability' is used as implying a 'good thing' in itself, despite such a property potentially belonging to both desirable and undesirable systems from the perspective of any organisms, including humans. Whether strong sustainability is 'a good thing' will depend on the values at stake. Sometimes value loading even takes the form of using properties as goals in themselves.

For instance, Newton and Freyfogle (2005) have pointed out that 'sustainability' may be a property of a means to achieve a goal but itself is neither a means nor a goal, despite how it is sometimes used. They also point out that the normative aspects of goals are beyond objective science. This highlights that goals reflect values whether or not this is overtly stated. Jamieson (1995) and Lackey (2001) underline that disentangling values from seemingly objective terms, such as properties, is not straightforward.

All the terms described above as causing difficulties are properties of some system or entity. Although both 'health' and 'quality' seem to imply values of some sort, biodiversity (as biological diversity),

Table 1
Definitions of key terms (from Wallace and Jago, 2017). These form the definitions component of the environmental ontology evaluated by experts.

Term	Definition
Category mistake	"the placing of an entity in the wrong category" or the "attribution to an entity of a property which that entity cannot have" (Meiland, 2015, p 147).
Elements	The concrete entities in a system including: water, rocks, mountains, roads, buildings, and organisms.
Processes	The interactions (including actions, reactions, and operations) among and within elements that lead to a state change.
Properties	The ways things are. They are the entities represented by descriptions of elements, processes, systems, or values.
State	A specific way things are, involving one or more element, process, system, or value, plus one or more of their properties.
System	A unit formed by all the elements of a defined space and time, including the processes occurring within and among them.
Values (end-state values)	Enduring beliefs concerning the preferred end states of human existence, including those required for survival and reproductive success, which taken together determine human wellbeing
Values (principles)	Enduring beliefs concerning the preferred ethical properties of human behaviour that instrumentally contribute to human wellbeing.

[2] Unless otherwise explicitly stated, an *interval* in this paper always refers to the range [A,B] on a continuous scale defined by its numeric left endpoint [A] and numeric right endpoint [B].

[3] From this point, 'framework' is used only for the ontological framework for environmental planning.

[4] We use 'value(s)' here in the sense of: "principles or standards of behaviour; one's judgement of what is important in life" (Oxford English Dictionary (OED) online, 4 June 2020) – see Wallace et al. (2020) for how this sense is discriminated from other value definitions, particularly magnitude and worth.

[5] Hull et al. also include health, sustainability, productivity, biodiversity, and ecological integrity in their list.

sustainability, resilience, and profitability contain no inherent or implied value content in the sense of 'value' used here. Thus, to attribute values to properties is to make a category mistake (Wallace and Jago, 2017, Table 1). In the case of 'ecosystem health', Jamieson (1995) suggests this term may sometimes be used to deliberately cloak a normative position with objective respectability. A similar case could be argued for 'ecosystem quality' and similar terms, and their use may lead to distrust of the policy-makers and scientists applying them (Hull et al., 2003). More recently, Newton (2016) has described the misuse of the ambiguous term 'resilience', and Porumbescu and Grimmelikhuijsen (2018) have shown how procedural fairness combined with transparency decreases voiced opposition to government decisions. Whatever the intent, value loading is not helpful where communication aims for transparency, clarity, and public support.

In addition to hindering communication, misuse of terms also causes analytical problems. For example, mixing means (processes) and ends (values) in either the construction of goals or the identification of points for economic analysis in environmental planning may lead to double-counting or attempts to trade-off non-comparable entities (e.g., as described by Boyd and Banzhaf, 2007; Fu et al., 2011; Gregory et al., 2012; Heink and Jax, 2019; Lele et al., 2013; Wallace and Jago, 2017). The problems described in these papers largely relate, either directly or indirectly, to the mixing at the classificatory level of two or more of: elements, processes, values (or some closely related term), and properties. Transparent and accurate communication and analysis require careful definition and consistent application of these terms and their compound derivatives, such as 'state' and 'system'. The framework presented here addresses these issues by providing re-worked definitions of key terms (Table 1) elaborated specifically for environmental management (Wallace and Jago, 2017), together with explanatory models that describe their relationships.

2.2. Issues with models

The issues described above are only partly definitional. There is often also a lack of clarity concerning relationships among different entities such as elements, properties, processes, and values. Just how do they fit together? This issue is exemplified by Heink and Jax's (2019) conclusion that human wellbeing should be better linked into ecosystem service cascade frameworks. Such concern reflects that although the MEA (2003) viewed the ultimate end of managing ecosystems as human wellbeing involving some form of values, elucidation of the terms and their relationships is still needed. Heink and Jax (2019) are implicitly seeking a better explanatory model of the relationships between wellbeing on the one hand; and values, processes, and elements on the other. Well-constructed models support sound analysis, hypothesis generation and testing, and effective communication as variously emphasised by Alexandrova (2012), Bercht and Wijermans (2019), Michie et al. (2011), and Wallace et al. (2020).

In summary, failure to effectively define key terms and describe their relationships can seriously hamper communication and analysis in environmental planning and decision-making. Defining the categories of things that exist within models explaining their relationships through an ontological framework thus provides a basis for: exploring and comparing mental models, generating and testing hypotheses, and establishing a sound basis for communication and analysis. The ontological framework outlined in Section 3 is designed to address these matters. Its success in doing so is assessed by experts in Sections 4-6.

Section 3. Summary of models and definitions presented to experts.

The material outlined in this section, together with additional explanations (Appendices 1, 2 [6]), was presented to the experts as the content of the framework. Here, we describe major components of the approach including the two cornerstone models (Models 1 and 2) and key definitions. This introduces the Wallace and Jago (2017) approach, including signposts to the relevant literature.

Wallace and Jago (2017) reworked existing definitions (Table 1) drawing on the literature, including that in the philosophical domain. Additional information on the classification of values and underlying criteria and assumptions are provided in Wallace et al. (2020). The development of Model 1 (Fig. 1) is also described in Wallace and Jago (2017), and further explained in Wallace et al. (2020, 2021). Model 1 provides a context which, in diagrammatic form, lays out the relationships among environmental elements (including natural capital), processes, wellbeing, and the two core types of values used in the framework. Model 2 (Fig. 2) is explained in Wallace et al. (2021). It describes the factors affecting decision-making, including those that influence ratings by experts. Model 2 also disentangles desires from beliefs and discriminates values from other types of beliefs and 'values' that are important in environmental planning. Arrows in Figs. 1 and 2 describe relationships among entity categories. These models contribute to resolving the issues outlined in Section 2 by emphasising the relationships delineating the different entities described in Table 1. Models 1 and 2 are briefly described below.

Model 1 (Fig. 1): Paraphrasing Wallace et al. (2021), under this model, planning involves one or more of investigating, deciding, or justifying actions towards achieving specified goals. These goals are formulated as desired system states, and include wellbeing detailed in terms of its constituents, i.e., end-state values (see Table 1 and Appendix 2). To achieve goals, actions are planned to shift the structure and composition of system elements to a new state (Time 2 in Fig. 1), with the aim of improving or maintaining the wellbeing of a target community. For example, a nature conservation manager may aim to increase the populations of specific organisms to fulfil a conservation ethic (a spiritual-philosophical value) preferred by a regional community. Thus, planners devise ways to achieve states expressed in terms of the structure and composition of elements that ultimately, as end-state values, contribute directly to wellbeing. Management actions (processes) act directly and shape other system processes to achieve the desired arrangement of elements. It is proposed that when this model is combined with the definitions in Table 1, it helps avoid double-counting, loading of values, and confusion of incomparable items. The expert evaluation assesses these propositions.

Model 2 (Fig. 2): For those involved in group deliberations, including facilitators and researchers, it is important to understand the factors that influence the ratings and opinions of group participants. Model 2, developed in Wallace et al. (2021), outlines the relevant factors and discriminates personality and emotional/intuitive factors on the one hand, from cognitive beliefs such as end-state values and principles. The model also discriminates beliefs concerning values (Bbi, Fig. 2), from other beliefs.

4. Methodology

Expert evaluation is a useful technique, although challenging given the potential fallibility of experts and related risks outlined by Burgman (2016). To the extent practicable, we have followed Burgman's 'advice for decision-makers' (2016, pp 141–142). This included ensuring experts' (un)certainty concerning ratings was systematically captured and that they had an opportunity to share their views in discussion before making their own, anonymous assessments. We also used a set of questions (propositions, see Table 2), generated at the outset of the research process, and rated by the experts in our workshops. These propositions evaluate three core assumptions that would be realised if the framework is, in practice, useful. Namely, that the framework:

a. Promotes clearer communication by using explicit definitions of key terms (Table 1);

[6] All appendices are in the supplementary material.

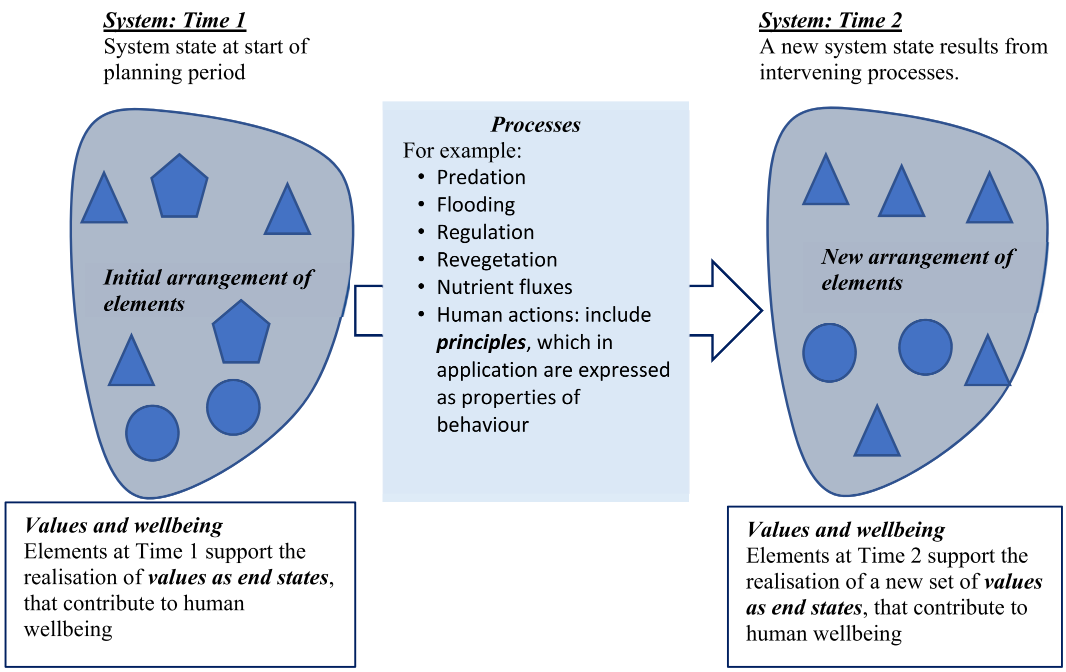

Fig. 1. Model 1, the structure and composition of system elements at Time 1 are transformed by system processes and exchanges with adjoining systems, not shown here, to a new structure and composition at Time 2. Human actions (processes) aim to ensure that the composition and structure of elements at the second point in time better support desired end-state values, and thus wellbeing. Note the points where 'principles' and 'end-state values' are generated. (Based on Wallace and Jago, 2017). Arrows show relationships. The diagram was amended based on expert comments. See Appendix 1 for diagram used with experts.

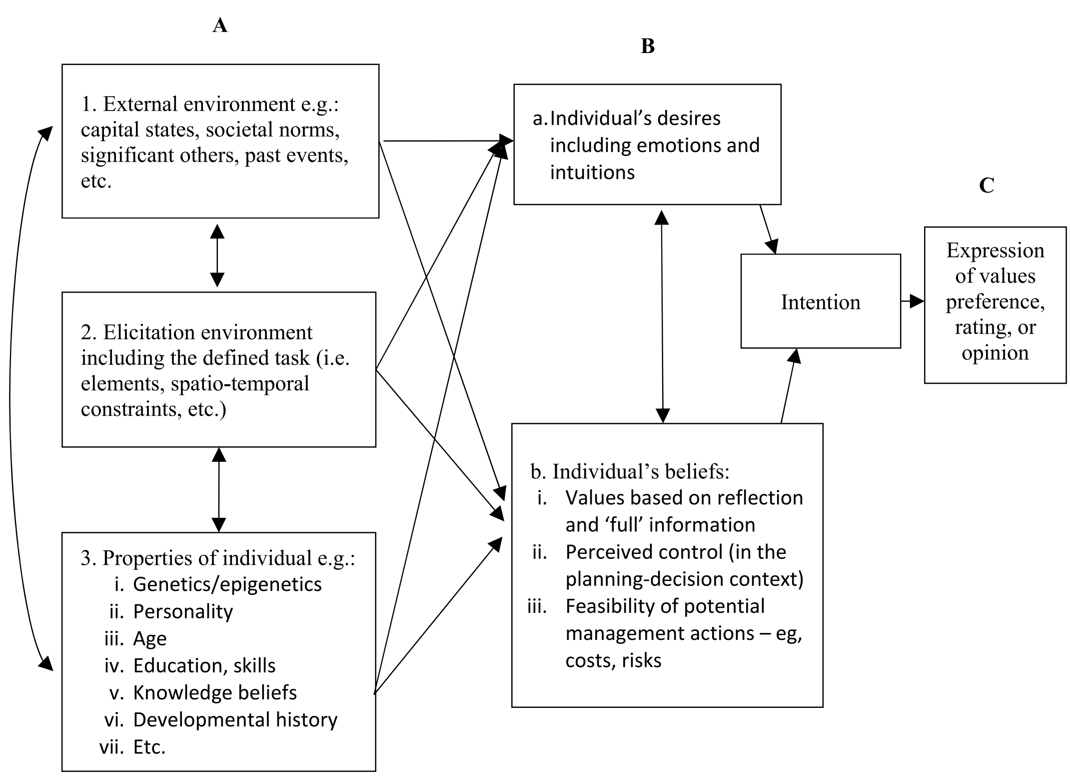

Fig. 2. Model 2, factors affecting the expression of a value preference, rating, or opinion. Factors are: (A) properties of the individual and environmental factors, including past events; (B) factors that are integrated by the individual to form an intention; and then (C) the act of expression, which may be anonymous. For simplicity, feedback arrows are omitted. (Figure from Wallace et al., 2021).

b. Exposes and addresses category mistakes, such as mixing of means and ends, which may lead to errors in analysis such as double-counting; and

c. Encourages integration of values and wellbeing into natural resource planning and decisions.

Table 2
Relationship of 12 propositions assessed by experts to core assumptions concerning the framework. Relationships are, subjectively, strong (✓✓), moderate (✓) and weak (O).

Propositions	Assumption (a), clearer communication	Assumption (b), exposes category mistakes	Assumption (c), encourages integration of values
1. The definition of 'category mistake' is useful for Natural Research Management (NRM)	✓✓	✓✓	✓
2. The definition of elements is appropriate for NRM	✓✓	✓	O
3. Definition of processes is appropriate for NRM	✓✓	✓	O
4. Definition of properties is appropriate for NRM	✓✓	✓	O
5. Definition of state is appropriate for NRM	✓✓	✓	O
6. Definition of system is appropriate for NRM	✓✓	✓	O
7. Definition of end-state values is appropriate for NRM	✓✓	✓	✓✓
8. Definition of values as principles is appropriate for NRM	✓✓	✓	✓✓
9. Model 1 provides useful insights for planning and decisions in NRM	✓	✓	✓✓
10. Model 2 provides useful insights for planning and decisions in NRM	✓	✓	✓✓
11. The ontological framework, as outlined during the workshop, provides a useful method for better integrating values and wellbeing into NRM planning and decisions	✓✓	✓	✓✓
12. The VbP approach, as outlined during the workshop, helps expose and address category mistakes	✓✓	✓✓	✓

Although most propositions relate to all core assumptions, some, such as the last two in Table 2, invite experts to directly assess (b) and (c). Table 2 was generated to check that all core assumptions are strongly linked (✓✓) to at least one proposition. This table is subjective and designed to elucidate coverage of the assumptions. It is not intended to represent a quantitative relationship.

4.1. Selection and characteristics of experts, and workshop details

From Burgman (2016) and Woolley et al. (2015) it is clear that, apart from appropriate domain expertise, a diversity of experts is required to maximise group intelligence, but that groups can be too diverse. Woolley et al. (2015) found that groups that were too similar lacked cognitive diversity, but if too diverse, groups had communication problems. Furthermore, an examination of the literature on group size and effectiveness (e.g., Amir et al., 2018; Skulmoski et al., 2007; Treen et al., 2016; Yahosseini and Moussaïd, 2020) suggests that the effects of group size are complex and situation-dependent. Nevertheless, small groups of about five (Treen et al., 2016) seem to be reasonable for face-to-face interactions in relation to maximising group intelligence.

Consequently, we aimed for face-to-face workshop group sizes of 5–9 experts, with a total, overall expert group size >15 (see, e.g., Skulmoski et al., 2007). The maximum, individual workshop group size was based on facilitator experience in explaining complex content. The compromise between domain knowledge and diversity was met by aiming for each workshop to have a mix of natural resource management professionals comprising: researchers, including PhD students and postdoctoral fellows; and policy, planning, and operational personnel from government and consultancy services. Experts from these backgrounds were expected to have sufficient knowledge of terms, concepts, and environmental issues to provide expert critique, with more recent graduates providing current knowledge of definitions and concepts and more experienced personnel providing an understanding of applied planning.

To ensure a diversity of perspectives and minimise the potential effects of institutional bias, organisations across four Australian states (Queensland, Tasmania, Victoria, and Western Australia) were invited to participate. Senior staff were emailed or personally contacted at five natural resource management agencies, seven tertiary institutions, and four natural resource consultancies/non-government institutions. States were selected to maximise biogeographical diversity consistent with other travel arrangements. All those from the target groups who volunteered to participate were accepted; however, some interested experts were not available on the workshop dates. No remuneration or equivalent compensation was provided to participants. Information collected on the background of experts during each workshop is detailed in Appendix 3 and summarised in Table 3. All workshops were held during 2018 (see Appendix 3 for details).

4.2. Exploring the framework with experts

Ethics processes and approvals met University of Western Australia requirements (File Reference: RA/4/1/9288). To help avoid halo effects and similar biases (Speirs-Bridge et al., 2010), and to encourage critical responses, written scores and comments were anonymous, with a unique numeral assigned to individual sets of review sheets. Thus, all captured data could be linked to one individual, while preserving the participants' anonymity. All workshops were facilitated by the same researcher.

The following, standardised process was followed with each group:

a. At the start of each workshop, a group of natural biological elements familiar to participants were defined, by each group, as the basis for their case study. For example: 'the biota of the Great Barrier Reef'. All element sets selected were very broad, thus allowing all end-state values to be explored, which was sufficient for the learning component of the workshops.
b. Following (a) but prior to any presentation, participants in each group were asked to list, individually and anonymously, the 'values' generated by the element set and to define 'human values'.
c. Explanation of definitions and models described in Section 3 were then presented (see Appendix 1). Experts were encouraged to ask questions and discuss concepts throughout the presentation. Discussion was unconstrained except in respect to the overall workshop time allocated (5 h). The aim was to explore concepts and share views so that all participants were well-informed concerning the

Table 3
Background and years of experience of the 22 experts. Participants could check more than one box in each group, except for 'length of experience'.

Disciplinary area					Where experience obtained			Length of experience (yrs)		
Planning	Operations	Research	Policy	Other	Goverment	Tertiary	other	0–5	6–10	>10
9	6	16	9	3	12	14	8	10	4	8

ontological framework and its potential strengths and weaknesses. There was no intention to achieve consensus; rather, the intent was to achieve a searching, anonymous evaluation informed by group discussion. Each workshop took about 5 h to complete (4.5–5.25 h) and included explanatory information (Appendix 1) not described in Section 3.

d. Using a classification of end-state values (Appendix 2) taken from Wallace et al. (2020), and an elicitation methodology based on Wallace et al. (2016), participants then undertook two values elicitations during which they rated the importance of each end-state value, separately answering the following two questions:

'From the perspective of the population of [your stakeholder group], how important is obtaining [value X] from the defined natural elements?' and'From your perspective, how important is obtaining [value X] from the defined natural elements?'

This double elicitation is used in real-world applications to explore whether participants' assessments from their personal perspectives differ from those representing their stakeholders, which often proved to be the case. It was expected to provide experts with a sound understanding of the end-state values and the type of elicitation process that could be used during real-world application of the framework. The scoring method used (see Section 4.3) was also used for the expert evaluation of the propositions in Table 2; thus, the case study served as practice for experts' later assessments of the framework. Outputs from the values elicitations were conveyed to participants but form no part of the results reported here.

e. At the end of each workshop, participants were again asked to list the 'values' generated by their element set and to define 'human values', as in step (b) above. On this second occasion, experts were also asked to describe any values they considered to be missing from the classification of end-state values used during the workshop.

4.3. Evaluation of the framework by experts

Experts scored propositions on a continuous scale from 0 to 100, where 0 = disagree with the proposition; 100 = agree with the proposition; and 50 = neither agree nor disagree with the proposition. For each proposition, experts were asked to:

a. place a dot on the continuous scale for their best estimate;
b. Draw an ellipse, incorporating their best estimate, to capture their degree of certainty in respect to their response;
c. Add free text comments and suggestions if they wished.

See Fig. 3 for a synthetic example of the type of quantitative responses received, and for how agreement across interval responses is subsequently modelled at the group level. The propositions ask the experts to assess the usefulness of definitions, models, and overall approach for natural resource management. That is, experts are being asked to rate usefulness/appropriateness *in general*, not to themselves as *individuals*. In this situation, there are many potential sources of both epistemic and linguistic uncertainty, as defined by Regan et al. (2002). We have not sought to separate these sources of uncertainty here beyond that revealed in the experts' comments.

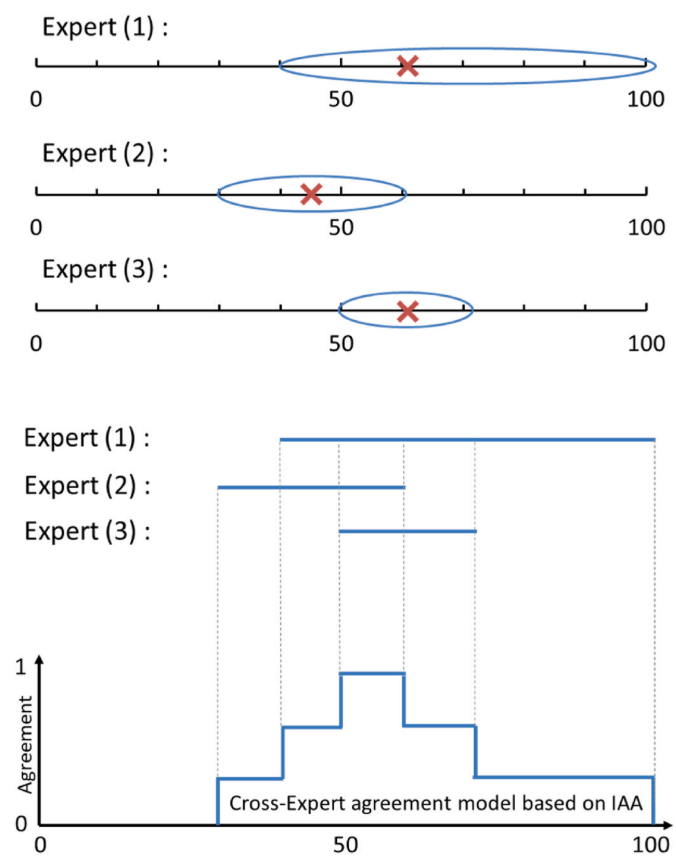

Fig. 3. A synthetic example illustrating the Interval Agreement Approach (IAA) applied to three experts: each expert provides their response by putting a cross for their best estimate on a continuous scale. Experts then draw ellipses capturing their degree of certainty concerning their estimates. Ellipses are encoded as intervals (left and right end points), which in turn are aggregated using the IAA (Wagner et al., 2015) into a non-parametric distribution (type-1 fuzzy set), where the x-Axis reflects the axis of the original response scale and the y-Axis reflects the degree of agreement (modelled as the degree of overlap across individuals' responses) across the group.

4.4. Data analysis

By using a combination of data capture (described above) and associated analytical techniques, a rich set of information was generated, providing a comprehensive assessment of the framework. Specifically, the following questions were addressed:

i. *Are the workshop groups consistent in their overall assessments?* Scores for four groups are presented from three different Australian states: two groups from Western Australia (labelled WA1 and WA2), one from Victoria (labelled Vic), and one from Queensland (labelled Qld). If these groups respond very differently to the workshop propositions, then, unless there is an alternative explanation, the aggregation of scores is questionable. This was assessed by comparing the workshop means of all best-estimates.

ii. *What is the collective view of the experts?* This information, generated in three ways, provides the primary assessment of the propositions and core assumptions. Firstly, statistics on best-estimates were calculated for each workshop group and for all experts as a whole. Secondly, statistics on the interval responses, such as the mean response interval, provide a quantitative measure of both the level of support for a given question (across experts) and the associated degree of uncertainty. Further, the mean size of the experts' intervals for each question provides a direct measure of the degree of uncertainty associated with their responses to questions. Finally, the Interval Agreement Approach (IAA) provides an aggregated model of responses at the group (of experts) level, graphically highlighting the distribution, level of agreement and uncertainty in the responses across the group of experts. Important properties of this approach are that it exposes bimodal and other distributions that are not revealed by means, medians, or standard deviations; and it shows the level of agreement among experts graphically. For the IAA, response scores captured in [0,100]) were standardised to [0,1]. Key statistics extracted from the IAA group models are: centroids (measure of central tendency), and absolute average deviation (from the centroid).

iii. *How (un)certain are the experts of their ratings?* At the individual level, this is assessed by analysing the average interval size across experts' response intervals for a given question. The interval-based approach draws on Ellerby et al. (2020, 2021). Further, the IAA models provide a group-level assessment of agreement across experts and their uncertainty for the given question.

iv. *Does the qualitative information explain and expand on the quantitative data?* Comments by experts allowed a more informed understanding of quantitative responses to propositions and thus core assumptions. For example, they may explain why they agree/disagree with a proposition, or why their response is uncertain. They also added advice and suggestions for improving communication of the framework.

An important question arising from the above is: at what numeric points, including for interval-valued data, should propositions and core assumptions be taken as adequately supported? Here, we have taken centroids ≥ 0.75 AND means and medians of best-estimates ≥ 75 as criteria showing support for propositions. This is based on the following assumptions:

a. Where centroids are ≥ 0.75 and means and medians of best-estimates are >75 there is considerable support for the proposition, including that $>50\%$ of the individual experts scored the proposition (median of best-estimates) equal to or greater than 75. This reflects the weight of ratings while ensuring that a few extreme scores do not determine the outcome. Interval-valued data and the absolute deviation from the centroid provide insight into sources of uncertainty, including the degree to which uncertainty is a characteristic of the group as a whole (based on IAA), or at the individual level (mean interval size), or both.

b. For propositions to have a reasonable probability of being adopted in practice, one would expect that they would at least need to be rated at 75 (0.75 for IAA) or higher. This is based on how difficult it has proven to eliminate the practice of value loading (Section 2.1). That is, despite the problem being described by Jamieson (1995) and others, the practice has not ceased.[7] Based on this, unless there is strong disciplinary support for change, it is unlikely to occur.

[7] Such matters are cross-disciplinary. For example, the problems of culturally-biased samples in psychology have been well recognised for over a decade, but progress in counteracting the problem has been slow (Rad et al., 2018).

5. Results

Analyses of the expert ratings are first considered (Section 5.1) according to the four questions posed above (Section 4.4), and then the overall results are summarised in relation to the propositions and core assumptions (Section 5.2).

5.1. Expert ratings of propositions and implications for core assumptions

(i) *Are the workshop groups consistent in their overall assessments?* With regard to the consistency of scores across the four workshop groups (Table 4), the mean best-estimate scores (with standard deviations) across all items per group are very close in three cases (WA1: 81 (15), Vic: 82 (15), and WA2: 83 (16)), while the score for Qld is lower 72 (18). Examination of the individual Qld scores reveals that the scores from two experts were largely responsible for the lower mean score, so it may be attributable to random variation. Alternatively, as the Qld workshop was the first held, scores may reflect that the facilitator's presentation improved with practice, noting also that three new slides were added to the presentation following this workshop (see Appendix 1). However, following an examination of individual experts' comments for each group, it was concluded that differences among the workshops probably reflected considered views rather than any significant, inherent differences in the workshop environments.

(ii) *What is the collective view of the experts?* Table 4 summarises analyses of the best-estimates. The overall position of the experts is strong support for the framework, with mean scores across all 22 experts of 80 or above for seven out of the 12 propositions, and median scores of at least 80 for nine out of 12. We note that three propositions had mean scores below 75. These included two propositions relating to definitions – properties: 74, and state: 69; and the proposition relating to the usefulness of Model 2: 73. Nevertheless, they are not far below 75 and, combined with the other scores, they do not alter our conclusion that there is strong support overall.

Fig. 4 shows the mean interval ranges for the propositions, calculated as the mean of the lower bounds and the mean of the upper bounds across the 22 experts. These show that, although there is some uncertainty displayed in the responses, the mean lower bounds all lie clearly above 50, the 'neither agree nor disagree point', reinforcing that all propositions are broadly supported by the experts as a group.

Fig. 5 shows the results of the IAA analysis. It depicts the relative frequency of different levels of agreement with each of the propositions. In most cases, the weight of agreement is mostly at high levels on the response scale, indicating that most participants agree with the propositions. In several cases, the weight of responses is distributed over a wider range of response levels: Category mistakes, States, Properties and Model 2. These are the propositions identified above as having relatively low mean or median responses.

Looking at all the results, the overall view of the experts, taken as a group, is in agreeance with the propositions. At the individual level, 22 experts assessed 12 propositions for a total of 264 ratings. Of these 264 ratings, only 13 best-estimates (5%) were <50, and these all related to definitions – not to either of the models or overall judgements.

(iii) *How (un)certain are the experts of their ratings?* Overall expert uncertainty is shown by the mean interval response size (Appendix 5, Fig. 4). This was largest (i.e., greatest uncertainty) for state: 24, followed by properties: 23, and Models 1 and 2: 22. The absolute average deviation from the IAA centroid (Table 5) suggests that experts are most certain as a group concerning their ratings of the propositions that the ontological framework and Model 1 are useful. The centroids for these propositions are also

Table 4
Analysis of best-estimates. Mean ratings of propositions (and their standard deviations) where: 0 = disagree; 50 = neutral; 100 = agree. All statistics are rounded to nearest integer after all calculations are complete for that item.

Propositions[a]	Workshop 1 (Qld)	Workshop 2 (WA1)	Workshop 3 (Vic)	Workshop 4 (WA2)	Mean scores for all 22 experts	Median scores for all 22 experts
Definition of 'category mistake'	73 (17)[c]	83 (12)	75 (15)	87 (14)[b]	79 (15)	80
Definition of elements	76 (19)[c]	81 (11)	81 (19)	95 (10)[b]	82 (16)	85
Definition of processes	73 (23)[c]	86 (4)	82 (20)	96 (6)[b]	83 (17)	89
Definition of properties	68 (25)[c]	69 (19)	78 (16)	85 (19)[b]	**74** (20)	76
Definition of state	57 (11)[c]	79 (21)[b]	78 (17)	59 (17)	**69** (19)	**70**
Definition of system	82 (8)[c]	82 (17)	85 (21)[b]	85 (12)[b]	83 (15)	90
Definition of end-state values	73 (19)[c]	89 (15)[b]	86 (20)	79 (19)	82 (18)	90
Definition of values as principles	71 (24)[c]	83 (22)	79 (20)	86 (10)[b]	79 (20)	88
Model 1 provides useful insights for planning	72 (11)[c]	82 (8)	81 (8)	91 (10)[b]	80 (11)	80
Model 2 provides useful insights for planning	69 (14)	68 (13)	87 (10)[b]	65 (12)[c]	**73** (15)	**70**
The VbP[c] approach is useful for integrating values and wellbeing into planning	75 (14)[c]	89 (7)[b]	82 (10)	85 (12)	82 (11)	84
The VbP approach helps expose and address category mistakes	75 (23)[c]	81 (16)	90 (10)[b]	88 (13)	83 (16)	90
Mean best estimate score by workshop (SD)	72 (18)	81 (15)	82 (15)	83 (16)		

[a] Abbreviated propositions – see Table 2 for full statements.
[b] = highest group score for that proposition.
[c] = lowest group score for that proposition; means and medians <75 are in bold; VbP = the ontological framework.

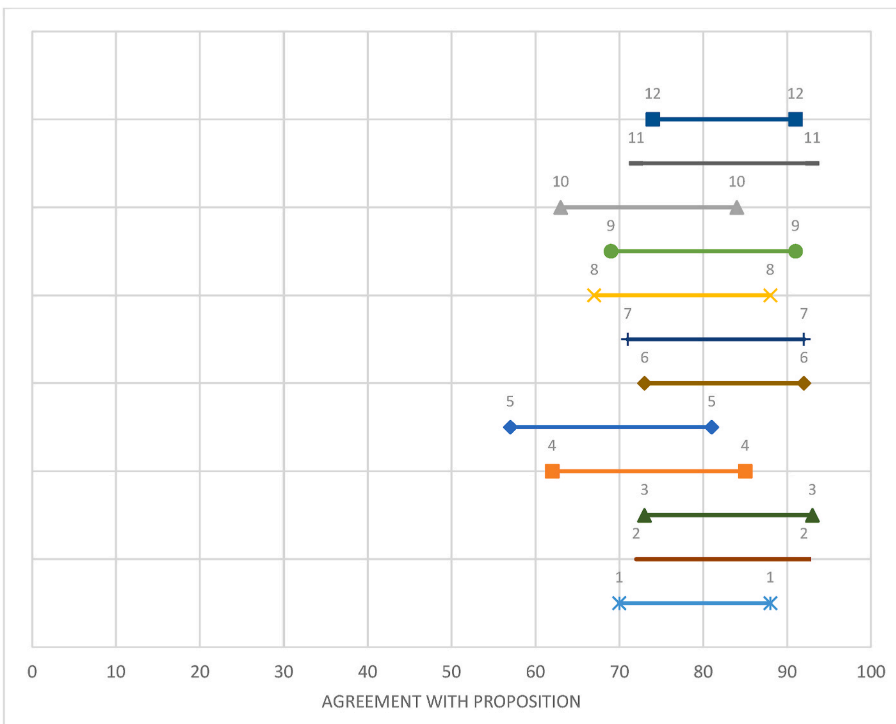

Fig. 4. Summary of mean intervals: as described by the mean of the left end points and the mean of the right end points of each proposition (from Table 2). Numbers on the propositions correspond with those used in Table 2. On the X-axis, 0 = disagree with the proposition; and 100 = agree with the proposition.

among the stronger ratings, indicating that experts strongly support these propositions.

(iv) *Does the qualitative information explain and expand on the quantitative data?* All experts' comments are provided in Appendix 4, with a summary sample and all expert suggestions concerning missing end-state values shown in Appendix 5. These provide useful insights and suggestions, and we return to these comments in the Discussion.

6. Discussion

6.1. Core assumptions

The framework promotes clearer communication by using explicit definitions of key terms as described in Table 1.

The evidence from the results is that this assumption is supported, with the caveat that the definitions of properties and state should be further refined, and the definition of end-state values clarified. Additional expert suggestions for improving clarity are documented in Appendix 4. If experts had judged that the proposed definitions are not useful in natural resource management, then scores below 0.5 would have been expected. That this is not the case suggests that better

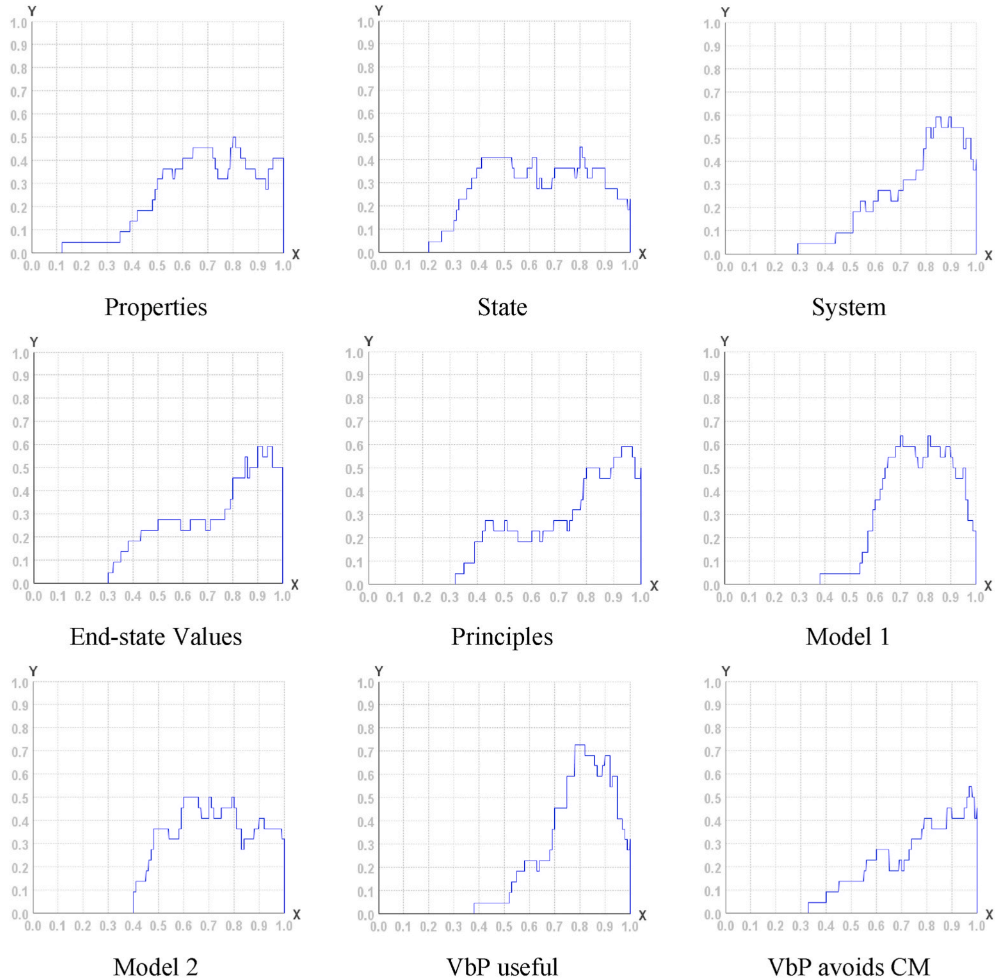

Fig. 5. Graphical representation of the expert group response (all 22 experts) to the propositions (Table 2) based on interval agreement model outputs.

Table 5
Comparative summary of IAA model statistics. Scores rounded to two decimal places after calculations complete for that item.

Propositions[a]	Centroid	Avge absolute deviation from centroid	Centroid rank
Definition of 'category mistake'	0.75	0.15	7
Definition of elements	0.76	0.17	6
Definition of processes	0.78	0.20	2
Definition of properties	**0.69**	0.19	11
Definition of state	**0.63**	0.20	12
Definition of system	0.78	0.16	3
Definition of end-state values	**0.74**	0.19	9
Definition of values as principles	0.75	0.18	8
Model 1 provides useful insights for planning	0.77	0.13	4
Model 2 provides useful insights for planning	**0.72**	0.16	10
VbP[b] approach is useful for integrating values and wellbeing into planning	0.79	0.13	1
VbP approach helps expose and address category mistakes	0.77	0.17	5

[a] Abbreviated propositions – see Table 2 for full statements.
[b] VbP = the ontological framework; Centroids <75 are in bold.

explanations are required, rather than a completely different approach.

The definition of properties had the highest level of uncertainty among individual experts, and the equal third greatest diversity of views among experts. It seems that many of the experts are themselves unsure concerning the definition of properties. The term is controversial in the philosophical literature (Effingham, 2013), and as with all definitions, the task and situation will ultimately determine how they are constructed.

In the case of end-state values, the implication of 'end-state'; use of the word 'enduring', and implication of 'stasis' in the definition drew comment from three experts (Appendices 4 and 5). It is clear that this aspect of the definition must be better explained, e.g., that the notion of 'enduring' is designed to differentiate these values from other types of attitudes such as 'fashions'. The experts provided some suggestions for additional values (Appendix 5), all of which could be accommodated using the current approach.

The framework exposes and addresses category mistakes, such as mixing of means and ends, which lead to fundamental errors in analysis such as double-counting.

Scores for the first and last propositions support this core assumption on all criteria. This suggests that, if adopted, the definitions in Table 1 combined with the overall planning approach would help to avoid category mistakes of the types outlined in Section 2.1. This result supports broader adoption of the ontological framework, or at least some adaptation of the approach.

6.1.1. *The framework encourages integration of values and wellbeing into natural resource planning and decisions*

The last four propositions directly relate to this core assumption, and except for issues around the usefulness of Model 2, these were all strongly supported. In the case of Model 2, scores on two criteria fall marginally below the required level. Experts' comments reflect that this model is inherently difficult and probably not suitable for general use with stakeholders, although it should help professionals (e.g., facilitators) understand the processes occurring during value elicitations. We agree with this analysis, while noting that it is an important model for understanding relationships among values and related entities (e.g., desires, personality, and other beliefs). Also, one would not normally attempt to explain such a complex model in the workshop time available, and as suggested by some experts, the explanation would be improved if accompanied by a practical example.

In summary, the expert assessments support the three core assumptions concerning the potential contribution of the ontological framework to planning, although there are caveats regarding the need to better define and explain some definitions, especially those for properties and state.

6.2. Benefits of combined analytical approaches

A challenge in evaluating planning approaches, as outlined in this paper, is the need to systematically capture and integrate information across a number of sources (experts), while at the same time, and without compromising nuance and detail, ensuring broad coverage of views arising from differences in expertise, context, and background. Traditionally, quantitative approaches based on discrete, and usually ordinal response scales (e.g., Likert scales) provided an efficient means to gather and aggregate data for statistical analysis. However, such quantitative approaches are limited in that they: (a) are not designed to capture open-ended (qualitative) feedback from experts, which may be essential to inform the evaluation (as here); and (b) are ill-equipped to measure intra- (or within-) expert uncertainty. The latter is important, as uncertainty in responses may highlight important shortcomings in a given framework, such as that key aspects are unclear, vague, or only partially applicable (Ellerby et al., 2020, 2021). This does seem to be at least partly the case with the explanations of 'properties' and 'state'.

To help avoid these analytical problems and provide multiple perspectives on expert views we adopted an integrated evaluation approach which, based on a questionnaire, combines more traditional single-point, best-estimate responses with recently developed approaches involving interval-valued responses. In addition to statistical analysis of best estimate and interval data, agreement (IAA) models were generated to provide a more comprehensive view of the group response (in terms of agreement/disagreement) and associated uncertainty. These approaches were complemented by qualitative feedback through open-ended text fields, which provided useful explanation of expert views as well as an avenue for experts to propose amendments to improve the framework and its communication.

Advantages of adopting this approach range from the intuitive interpretation and straightforward statistical analyses, including ranking, available from best-estimate scores; to the direct measurement of intra-expert response uncertainty from the interval-valued responses. In addition, the Interval Agreement Approach (IAA) distributions provide a graphical summary of the group response, highlighting both the degree of agreement (on the y-axis) and the degree of group-uncertainty (dispersion over the x-axis). They thus also highlight important aspects in the data, akin to a richer form of histograms (as used for discrete data). Wagner et al. (2015) and Ellerby et al. (2020, 2021) provide a more detailed description of the advantages of interval-based approaches.

Triangulating across these different data provided important insights into the perception of experts with, for example, the greater uncertainty associated with the definitions of property and state reflecting the lower scores attracted by these terms as best estimates and centroids. At the same time, the mean intervals for all propositions (Fig. 4) lie clearly above 50 (point of 'neither agree nor disagree') emphasising that the experts were in broad agreement with all propositions, requiring only some improvement of definitions and models. Qualitative comments from experts provided valuable guidance on where change should occur.

6.3. Practical application of framework

The importance of effectively defining and delineating terms, such as those defined in Table 1, is shown by work where they have been applied in practice. Smith et al. (2016) describe an applied example of quantitatively linking system elements to end-state values through element properties; and using this relationship to generate measures of utility (wellbeing). In this case end-state values had been prioritised by stakeholders (e.g., Wallace et al., 2016), thus system elements could be rated for their capacity to deliver on priority end-state values, and thus utility. Such analyses linking elements and their properties to end-state values and wellbeing would be difficult to accomplish if the key concepts outlined in Table 1 were unclear or confused. In general practice, we have also found that using consistent definitions of terms, such as those in Table 1, can help to provide a common language in work groups, thus reducing linguistic ambiguity. For example, we have defined and discussed terms at the beginning of a stakeholder workshop as one means of reducing linguistic ambiguity. The importance of avoiding value-loading onto properties is underlined by the literature cited in Section 2. Even where ontological frameworks differ among collaborative groups, making these differences apparent and, where practicable, resolving them, may contribute to improved outcomes.

The ontological framework was applied in a study examining the preferences of different stakeholder groups for a variety of potential future development scenarios in the Kimberley region of Western Australia (Kiatkoski Kim et al., 2022). Despite considerable challenges resulting from contestation between stakeholder groups, which varied in culture, priorities and, in some cases, language, the framework was found to be helpful in supporting a structured, systematic process for assessing the scenarios.

7. Conclusions

Based on the evaluation of experts, we conclude that the ontological framework described in Section 3 can contribute to environmental planning by helping to avoid communication and analytical problems that arise from poor delineation of terms and their relationships, at least within cultures and government systems similar to those in Australia. Specifically, the framework could reduce the probability of value loading, double counting, category mistakes and other problems outlined in Section 2. Secondly, we conclude that the combination of interval-valued data capture, together with 'best-estimates' and expert comments, allows a multi-perspective analysis of expert ratings. This provides for a nuanced analysis of experts' responses, including direct measurement of individual uncertainty, and the grouping of expert opinion (e.g., whether unimodal, bimodal, etc.). At the same time, expert ratings and comments have provided sound guidance as to where the framework may be improved, particularly with regard to some definitions and its communication. We suggest that interval-valued approaches be considered for application wherever documenting expert uncertainty is important.

Finally, it is emphasised that we view the ontological framework as complementary to existing planning approaches. It provides one ontological framework for considering values in planning and could help minimise issues surrounding ambiguity and the phenomenon of category mistakes. Undoubtedly, alternative frameworks will be preferred depending on the specific situation, especially where this involves non-western worldviews.

Author credit statement

Ken Wallace: conceptualisation, methodology, formal analysis, investigation, writing original draft, writing response to reviews and editing. **Christian Wagner**: methodology, software, formal analysis, writing reviewing and editing. **David Pannell:** methodology, writing, reviewing, editing, supervision and writing response to reviews. **Milena Kiatkoski Kim**: methodology, writing reviewing and editing. **Abbie Rogers**: methodology, writing reviewing and editing.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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