RESEARCH ARTICLE

Can we model cultural ecosystem services, and are we measuring the right things?

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Abstract

1. Cultural ecosystem services (CES), a key aspect of nature's contributions to people, remain a challenge to incorporate into decision making. One contributing factor is the difficulty of defining and describing these, due partly to: ongoing poor understanding of what drives people to interact with nature, a lack of appropriate data to quantify these interactions, and basic difficulties in measuring and modelling the complex array of social, psychological and behavioural attributes which help explain people's actions.

2. In this study we present a framework which develops the concepts of cultural capital, social capital and human capital as specific forms of human-centred capital, in the context of their contribution to understanding CES. Each form of capital encompasses separate attributes of beneficiaries.

3. Testing the framework with data from a separate trans-disciplinary study illustrated that the framework was readily applicable to specific situations. A measure of cultural capital, EcoCentrism, explained more variation than a suite of seven demographic variables.

4. Applying the framework also showed that despite using a wide range of explanatory variables, a large proportion of observed variation remained unaccounted for. This suggests that more work is needed to understand and to develop metrics which can measure additional factors which underlie peoples' motivations to engage with nature. The framework is applicable to other types of ecosystem service, and may also be useful for exploring relational values.

KEYWORDS

cultural capital, framework, human capital, nature's contributions to people, relational values

1 | INTRODUCTION

1.1 | Rationale

Policy makers and academics widely recognise the essential role that nature plays in contributing towards human well-being (IPBES, 2019). Wide ranging assessments of the benefits that nature provides are now seen as the premier approach to identifying and quantifying the benefits that people derive from provisioning, regulating and cultural ecosystem services (CES) and to feed these benefits into natural resource and other policy decisions (Dasgupta, 2021; IPBES, 2019; MEA, 2005; TEEB, 2010). While there has been significant progress in the operationalising of many ecosystem services, there is still an ongoing challenge in identifying, quantifying and modelling CES (Chan et al., 2012; Christie et al., 2019; Milcu et al., 2013). This paper aims to address this challenge.

Cultural services can constitute a significant proportion of the benefits that people attain from nature (UKNEA, 2011). However, apart from recreation other cultural services remain '*unquestionably difficult to measure*' (Chan et al., 2016). This is partly due to ongoing difficulties with framing and conceptualisation (Church et al., 2014; Jones et al., 2016; Kenter et al., 2015), and partly due to the challenges in measuring less tangible aspects of people's interactions with nature (Christie et al., 2019). Central to understanding the importance of ecosystem services is the question of '*How much of the benefit depends on the interaction between people and the environment?*'. This is particularly relevant for cultural services which, to a much greater extent than other services, arise from the interplay, physical and emotional interaction of people with the environment. However, how we understand the concept of values and benefits that people receive from interacting with ecosystems is relevant to all types of services and not just cultural services (Gould et al., 2015). IPBES explores such interactions through a recognition that non-material values arise through all forms of interaction with ecosystems (Díaz et al., 2018), and through the concept of 'relational values', which are defined as values that '*include preferences, principles and virtues about human-nature relationships*' (Chan et al., 2018). The IPBES (2018) European and Central Asia assessment provides examples of relational values associated with cultural services (Schröter et al., 2020), but difficulties in measuring such values and feeding these values into policy decisions remain (Christie et al., 2019).

Three key aspects are relevant to meeting these challenges and form the objectives of this paper. First, it is important to identify the beneficiaries of CES and to better understand the attributes or characteristics of those users which determine how they interact with nature. Second, CES models require adequate and appropriate data or qualitative information with which to quantify CES. Third, there is a need to develop generalisable approaches to modelling CES. We discuss each of these aspects in some detail below to provide the context to the study, and then outline how the paper addresses these.

1.1.1 | How to characterise the beneficiaries of CES

There are two components to this: identifying the particular beneficiaries of any ecosystem service, and understanding the reasons why people choose to interact with the environment in particular ways. A number of studies have made progress in defining the users of, or people benefitting from, a particular service (e.g. Wei et al., 2017). For example, the Final Ecosystem Goods and Services (FEGS) framework identifies classes of beneficiaries across all ES (Landers & Nahlik, 2013). However, most studies still fail to adequately consider the beneficiaries in ecosystem assessments (Chan & Satterfield, 2020). For example, even where studies purport to map demand, they usually only map or model simple proxies for demand. These are often based on pressures (usually a biophysical measure) such as combined tropical nights and hot days, for heat pressure (Baró et al., 2015). The second component involves better understanding the characteristics of beneficiaries, which have a bearing on their choice of how and where they choose to engage with the environment and thus their demand for CES. Individual case studies are starting to provide this information (Martín-López et al., 2014), but this area is vastly under-researched, particularly for situations at larger scales, outside of focused case studies. For example, research suggests that people get different benefits when they choose to visit green-space far from home compared with everyday nature experiences close to home (Bijker & Sijtsma, 2017; Coldwell & Evans, 2018), but we do not know what guides these choices. Understanding the motivations and attributes of individuals in engaging with greenspace can help model these interactions at a population level.

1.1.2 | Availability of appropriate data to measure, map or model CES

As a general rule, there is less data available with which to quantify cultural services than for the other types of ecosystems services, and it may not be the most appropriate data. This has implications for modelling CES, and incorporating CES more consistently into ecosystem assessments.

Most examples of quantifying cultural services in the literature centre on those services which are more tangible and therefore relatively easy to measure such as recreation (De Groot et al., 2012). Studies quantifying CES may use proxy indicators such as holiday homes (Queiroz et al., 2015), footpath networks, or biophysical proxies such as landscape aesthetic quality metrics (e.g. Norton et al., 2012; Swetnam et al., 2017). Very rarely do these studies consider social data or user characteristics (Christie et al., 2019).

More recently there has been an interest in evaluating social and shared values of ecosystem services (Kenter et al., 2015, 2019), where such values may be elicited through deliberative approaches (Kenter et al., 2016). Others (e.g. Gould et al., 2015; Schröter et al., 2020) highlight how the use of trans-disciplinary approaches,

including more qualitative approaches like semi-structured interviews and participant observation, can help elicit a richer and more locally constructed representation of non-material benefits which captures indigenous and local knowledge, local identity and sense of place.

There is also a shift in research towards the use of Big Data. This can be considered as revealed preference data since they show actual use, typically of locations rather than services per se. Examples include visitor numbers to locations, online geo-tagged photo repositories, and use of mobile phone location data (Wu et al., 2018). These provide large quantities of data, but as critics point out, they are non-random and subject to many potential sources of bias (Di Minin et al., 2015). These datasets have, however, so far primarily served the purpose of mapping ecosystem services, but not of modelling, although some interesting examples in medical applications show the potential for big data to be used at larger scales, for example at national scale to model dynamics of infectious diseases (Wesolowski et al., 2012).

1.1.3 | Challenges in how to model cultural services

Modelling provides an opportunity to quantify and map ecosystem services, to compare values across space and time, and to evaluate synergies and trade-offs with other services. Specifically, models enable predictions to be made on how people's activities might change in the future under different scenarios.

One strand of thinking argues that cultural services can only be considered within a place-based approach. This has many advantages, not least because it recognises and tries to define many of the characteristics of users that govern their interaction with space that is special to them (Fish et al., 2016). Place-based approaches allow detailed understanding of factors governing use of an individual location, but by definition each situation is unique and may not be transferable; particularly when considering relational values (Schröter et al., 2020). However, while the reasons for an individual to interact with a place are highly personal and indeed unique, at a population level it should be possible to develop generalisable rules that allow the understanding gained in one area to be applied in another. This is possible even if not all aspects are transferable, or there are cultural differences involved (Tew et al., 2019).

Other approaches include hotspot mapping (e.g. Bagstad et al., 2017; Brown & Fagerholm, 2015), and sophisticated economic models that utilise large-scale recreation survey data on visits to geo-referenced locations, coupled with demographic data on the visitors, to create random utility behaviour models. The latter approach underpins the ORVAL tool in the United Kingdom which values outdoor recreation (Day & Smith, 2016), and builds on extensive data collection on recreation visits using the Monitor of Engagement with the Natural Environment (MENE) survey. These models make considerable progress in allowing predictions of recreation visits based on relatively simple biophysical and demographic data; however, the characterisation of beneficiaries remains simplistic.

Overall, modelling approaches for ecosystem services have largely failed to incorporate cultural services, other than recreation, due to the challenges of predicting how people behave, and the data available to quantify that. Where approaches have tackled these issues, they are rarely transferable to other situations.

In this paper we use a systems approach to address some of these issues, as it allows us to separately identify how nature and people interact in the delivery of cultural services. We build on a framework put forward by Jones et al. (2016) which defines a common structure that is applicable to cultural, provisioning and regulating services (see Figure S1). That framework centres on three components: the left-hand side focuses on the potential supply of ecosystem services; the right-hand side focuses on user demand; and the interaction of these two sides is required to deliver realised ecosystem services. The approach defines a set of basic building blocks which provide a structure for characterising beneficiaries in more detail. These building blocks include different forms of human-derived capital, which are held by, and manifest in, people: social, cultural and human capital, as well as the built and financial capital which enable our interactions with the natural capital. The framework provides clear differentiation of the multiple roles that people play in all aspects of ES delivery, and it allows a focus on those components which shape the interactions between people and nature which underpin an ecosystem service. However, the 'user' side of the diagram requires further development to better support the development of analytical approaches for CES. Data-driven testing can demonstrate the real-world applicability of frameworks but is rarely conducted.

Therefore, in this study we aim to better understand the characteristics of people as beneficiaries of ecosystem services, and how those characteristics determine their interactions with the environment, with a stated focus on cultural ecosystem services. We achieve this by further developing an existing conceptual approach (Jones et al., 2016), and testing whether the improved framework could be used to model cultural services using additional data to represent user characteristics, compared with standard demographic data. The data used to test the framework came from an existing trans-disciplinary project in which manipulations of urban grassland in urban parks were used to assess peoples' perceptions of biodiversity and aesthetic value (Southon et al., 2017, 2018). Lastly, we summarise the lessons learned from operationalising this approach, and provide recommendations on its utility in other contexts.

2 | IMPROVING THE FRAMEWORK

2.1 | Refining the conceptual approach on user interactions with the environment

The conceptual approach was developed and refined via a multidisciplinary workshop, followed by virtual meetings of the workshop participants over a period of months. The participants came from a broad range of disciplines and expertise and included natural scientists, social scientists, economists and policy makers.

2.2 | Improving characterisation of beneficiaries of cultural services in the conceptual model

Development of the right-hand side (user/beneficiary characteristics) of the framework focused on three aspects: unpacking the varied forms of human capital (which we now collectively refer to as human-centred capital—HCC) that moderates how individuals behave; identifying and defining the types of beneficiary; and defining the nature of the interaction between beneficiaries and the potential service. All three of these ultimately shape the demand for the service, and therefore the amount of service that is realised. The improved conceptual model (Figure 1a) covers each of these components, which are discussed in detail below. The completed framework, combining the potential service and the user characterisation is shown in Figure 1b.

2.2.1 | Factors influencing behaviour which are encapsulated in individual-held capitals

There is a breadth and complexity of factors that may influence people's behaviour that is poorly captured in conventional demographic groupings. Our framework proposes that these influences can be represented using three types of capital: human, social and cultural capital, all of which are conceived as being held by the individual, but which can be influenced by interactions with other people and wider societal factors. Each is described in turn below.

Human capital largely follows conventional definitions (OECD, 2001) and relates to personal capacities and capabilities possessed by the individual such as physical, or cognitive capacities, including traditionally recognised aspects like knowledge, education and training. To this, we add related emotional, personality-based and psychological capacities possessed by the individual. For example, whether they are introvert or extrovert. Social capital is more relational and is concerned with relationship-building and maintenance, communication and participation and interaction through social networks and groupings. Thus interactions and networks forged within a local gardening group or through volunteering for a charity are both examples of social capital. Finally, cultural capital focuses more on the values and belief systems of an individual, while acknowledging that these are rooted in and reinforced by wider social interactions and cultural context. This influences the meaning and value that people attach to certain landscapes or aspects of biota and biodiversity by virtue of the individual being part of a social group or cultural collective. This has strong parallels with the emerging literature on relational values (e.g. Himes & Muraca, 2018; Kenter et al., 2015; Schröter et al., 2020), and affective relationships with nature (Richardson et al., 2019).

These three forms of capital are distinct, and to some degree independent, but they also have clear interactions. For example, an interest in wildlife is to a large extent independent of age or gender, socio-economic status and cultural background. An individual's knowledge about the species of insect, animal or bird they see while walking is held by them as an individual (human capital), but may be reinforced or augmented through interactions with a group of people in their social network (social capital). Their perceptions or feelings about those species have also been shaped through a cultural lens derived from their belief system and their personal values (cultural capital). Some species have very specific symbolism and therefore a different value depending on your cultural origin and strength of ties to tradition—a four-leaf clover is traditionally considered lucky in Ireland, while cranes have special symbolism in China, representing long life and wisdom.

2.2.2 | Characterising the beneficiaries

The large oval (Figure 1a) lists some possible types of beneficiaries, following principles outlined by Bagstad et al. (2013) and Landers and Nahlik (2013) among others, which recognise that ecosystem services are defined by identified beneficiaries making use of a specific service. In our framework, the diagram provides examples of groups of beneficiaries who interact with the environment in different ways, or for different purposes. In an urban setting, this may involve residents viewing a park from their window, commuters walking or cycling through a park on their way to work, or local greenspace users taking the dog for a walk, or taking children to play in the park. Creating categories of beneficiaries following this approach puts an emphasis on the mode and purpose of interaction with the environment, and helps to better understand which potential beneficiaries will use an ecosystem service, and in which way. The definition of categories and assignment to groups should be driven by the needs of the study.

2.2.3 | Interactions—How the service is delivered

Figure 1a shows how CES benefits are co-produced when the potential service and the user demand interact to realise the service, from which well-being benefits accrue. We first discuss the concept of benefit in detail below, as this helps understand the relationship between service and benefit. With CES, the benefits are primarily non-material and therefore do not produce a physical good that is independent of the beneficiary (e.g. a crop in the case of provisioning services). For CES the benefit is therefore generally a state or condition, conscious or sub-conscious, that arises from the interaction of the ecosystem and the beneficiary, and that the human user evaluates positively. Examples are listed in the box at the bottom right of Figure 1a, and include acquiring knowledge or understanding, being creatively inspired, or feeling spiritually, mentally or physically refreshed. One of the challenges of quantifying CES is that these benefits are difficult to measure. However, while many CES experiences do not produce material outputs and are only recorded in our memories, some can do. For example, improvements in physical health or mental well-being
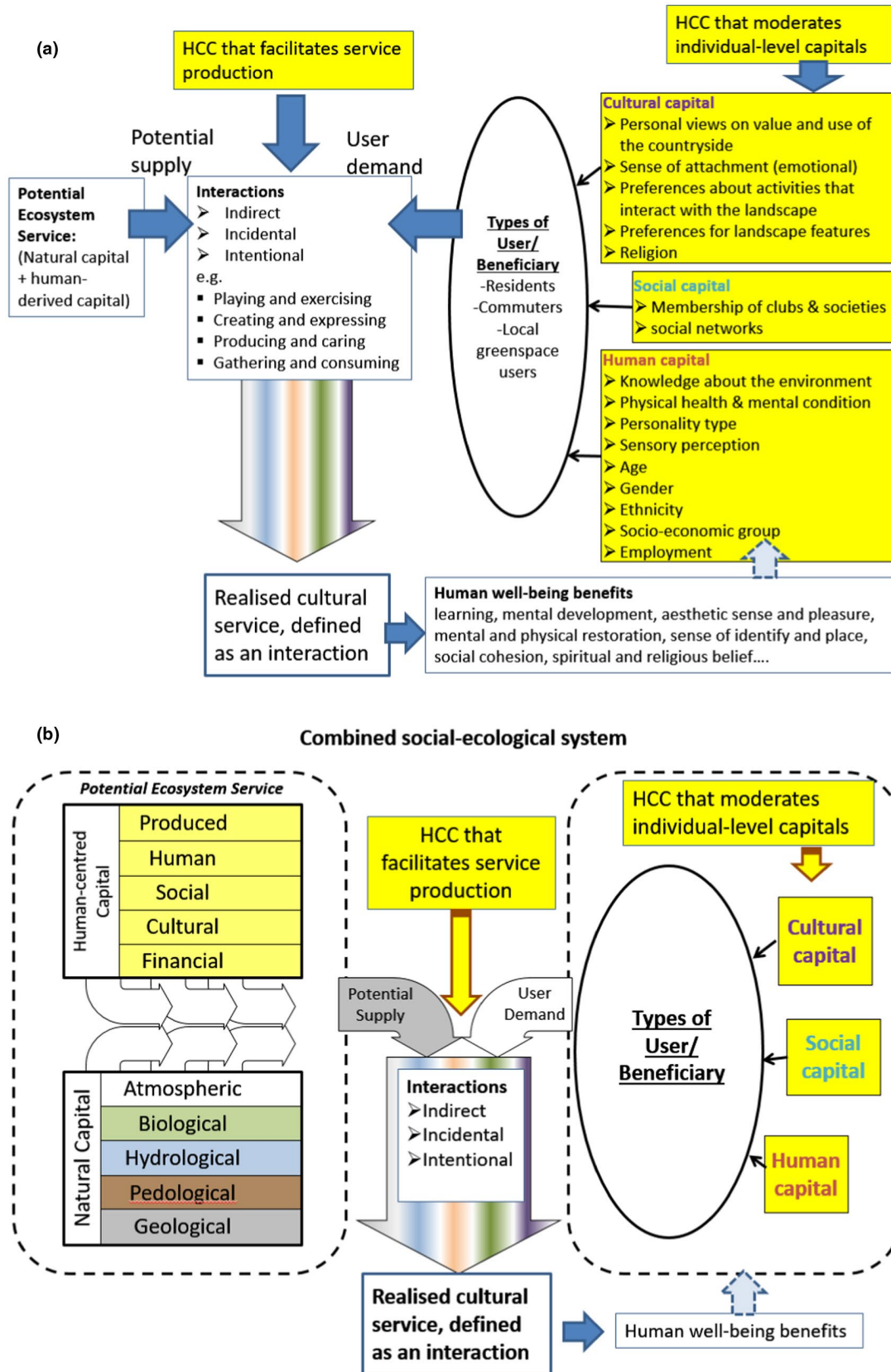
FIGURE 1 Improvements on the conceptual framework of Jones et al. (2016), showing (a) Expanding the beneficiary characteristics, and (b) the fully revised conceptual model

resulting from spending time in nature can be measured. Examples of other tangible outputs include photographs, and the creation of art or literature as a result of being inspired by nature. The framework has been designed so that this understanding of benefits can also be applied to provisioning and regulating services, as well as CES, which aligns to ideas embedded in the Nature's Contributions to People approach where non-material benefits arise from all interactions, and not just those defined as CES within original ecosystem services framings (Chan et al., 2011; Díaz et al., 2018).

Working backwards from the benefits, the service itself can be defined as the point of interaction between potential service and users. The possible range of interactions with nature or greenspace considered broadly follows the study by Church et al. (2014) in considering three main types of interaction: intentional (a planned leisure or recreational activity, including less 'active' intentions such as seeking solitude), incidental (interaction with aspects of the landscape or wildlife while doing other activities such as driving or walking to work) and indirect (through media activities such as watching a wildlife programme on television or reading). To the last category could also be added indirect or non-consumptive relationships with nature such as awareness of the existence of a species leading to existence, bequest or option value.

Studies are starting to explore the mechanisms and pathways of benefit generation. This has not been considered in detail here but is an emerging area of research, and frameworks have been devised that propose a series of pathways that conceptualise the benefit generation process. For example, a 'cognitive' pathway is mediated by knowledge or understanding, while a 'creative' pathway may relate to benefits associated with feeling creatively inspired (e.g. King et al., 2017). Other framings include aesthetic and non-aesthetic pathways (McGinlay et al., 2017, 2018), channels such as knowing, perceiving, interacting (Russell et al., 2013). They also include framings around the end benefit, that is, that green spaces promote exercise (Maas et al., 2008), facilitate social interaction and community cohesion (Jennings & Bamkole 2019), create a sense of place and identity for residents (Hernández et al., 2007; Poe et al., 2016) or provide passive stimulation (Kaplan & Kaplan, 1989). The wide range of possible pathways to benefit arising from interaction between user and environmental setting are represented by the broad multi-coloured downwards arrow linking interactions to benefits and well-being.

2.3 | Case study for testing the framework: Aesthetic appreciation of planted urban wildflower meadows

To demonstrate how our conceptual framework can be applied in a real-world situation to identify, quantify and model CES, we apply it to a case study which explores how the characteristics of beneficiaries were related to scored outcomes for a particular CES. The case study was drawn from a consortium project (F3UES) funded under an interdisciplinary research call: the Biodiversity and

Ecosystem Service Sustainability (BESS) programme on the role of biodiversity in the delivery of ecosystem services. One aspect of the F3UES project focused on the CES and biodiversity benefits of establishing perennial meadows as an alternative to short mown grassland in urban green-space. It manipulated environmental factors (levels of diversity and vegetation height of sown wildflower meadows), and conducted interviews and structured assessments with users of the urban parks to understand motivations of the beneficiaries. This allowed a co-ordinated assessment of variation in natural capital and human-derived capital with which to test the framework. The experiments are described briefly below. Full details of the experimental design, collection and in-depth analysis of environmental and social data are given in Southon et al. (2017), Southon et al. (2018) and Norton et al. (2019). The questionnaire survey was ethically approved by the University of Sheffield's Research Ethics Committee devolved to the Department of Landscape Architecture Ethics Panel. Participants were given written information about how their data would be used: anonymised prior to analysis, that the research findings based on the analysis would be published in a range of media, would be stored by the research team and NERC and may be used in future research, and that completed questionnaires would be destroyed at the end of the project in 2016. Participants gave consent by ticking a box on the questionnaire.

2.3.1 | Experimental set up

The experimental perennial urban meadows consisted of nine treatments that varied along two axes—height (short, medium and tall vegetation) and diversity (low, medium and high species richness). All low diversity treatments only contained grass species, contrasting with medium and high diversity treatments that also contained flowering forbs. The desired levels of height were maintained by the choice of component species and by cutting at different heights. The short + low diversity meadow treatment aimed to replicate mown amenity grassland. The experimental meadows were established in five different areas of urban greenspace that were surrounded by residential housing. Only data from four of the sites were used in this analysis. At the excluded site, the meadow was fully re-seeded in year two due to poor initial establishment. Vegetation height and diversity comprised the biophysical variables used in the analysis.

Demographic information characterising the respondents was also collected, including age, gender, income, educational attainment, employment status, ethnicity, and whether the respondent considered themselves a 'UK resident'. Other information about the respondents was collected. This included: the frequency with which people visited the site, other urban greenspace or the countryside, a proxy for their ecological knowledge based on the ability to correctly identify nine common plant species (EcoKnowledge score), and measures of their affinity for, or support for, nature (the extent to which people would like to see seven wildlife friendly

features at the site, e.g. a nettle bed for butterfly caterpillars, wood pile and bird feeding stations, and whether they had those features in their own gardens), summarised as an EcoCentrism score (Southon et al., 2017). These variables were assigned to our categories of human, social or cultural capital, as discussed in the next section.

Our measure of 'service' was based on Preference scores for each meadow. Thirty randomly selected individuals visiting each site were asked to assign a Preference score to each meadow, on a scale from 1 (strongly dislike) to 10 (strongly like). Preference was assessed for all treatments and sites during the summer flowering period, in the year following establishment of the meadows.

Tailoring a conceptual framework for 'aesthetic appreciation' of urban meadows

Working from first principles, a conceptual model based on the revised framework was generated which combined knowledge gained during the urban meadows project with a wider ecological and social understanding of the factors likely to influence 'aesthetic appreciation' service (see Figure 2). The Potential ES (see Jones et al., 2016) is summarised as the stock of attractive flowers [this would be the Final Ecosystem Good/Service in the FEGS scheme of Landers and Nahlik (2013)]. Factors which influence the stock of attractive flowers include natural capital components such as soil conditions (acidity, nutrient content and drainage) and climate, together with human-centred capital such as the management required to maintain the urban meadows. Weather patterns will determine the timing and duration of the flowering period, and other natural capital, for example pollinating insects, can contribute to the aesthetic experience. Aspects of built capital also moderate the level of potential service, including accessibility to the greenspace, and structural attributes of the parks themselves which govern the visibility of the meadows at a distance and to different potential users or beneficiaries.

A number of factors affect how beneficiaries might interact with the meadows. Beneficiaries can be grouped into different categories, depending on how they experience the site. They may be residents within line-of-sight of the meadow, people commuting past by bike or by car, or active users of the greenspace primarily from the local neighbourhood. Following the structure of Figure 1, the human-centred capitals were identified which might influence the preferences of the users to interact with the potential service. These included cultural capital (their affinity for nature), social capital in the form of social networks which draw them to the site, and human capital in the form of ecological knowledge as well as demographic descriptors such as their age, gender, income, ethnicity etc.

Statistical analysis

From the conceptual model for the service, we developed statistical models based on the available data collected within the F3UES project.

Natural capital components were described by two variables: height of vegetation (three levels: short, mid-height and tall) and diversity of meadows (three levels: low, medium and high). Human-centred capital components explored the larger set of variables: cultural capital (captured as the composite variable EcoCentrism—see Southon et al. (2017)), human capital which included ecological knowledge (captured as EcoKnowledge), age, gender, ethnicity, income and the variable 'UK resident'. We note that the composite variable for EcoCentrism also includes an element of ecological knowledge (Southon et al., 2017). However, statistical testing for this analysis showed that these variables were sufficiently orthogonal that inclusion of both was not a problem. Unfortunately, from the data available, it was not possible to test the contribution to the preference score of components linked to built capital such as accessibility of the parks containing the meadows, or whether the users were residents or commuters, or any variables linked to social capital which would be relevant to use of these urban green-spaces. We tested two types of model to demonstrate the flexibility of analytical approaches: a linear mixed model approach, and a Bayesian modelling approach.

Linear mixed model: In the linear mixed effects model approach, explanatory variables were tested for correlation (Spearman). Individual respondent was added as a random effect, then a number of models were tested, adding and removing each of the variables described above for natural capital and human-centred capital, and testing interaction terms. Performance of the models was compared using AIC.

Bayesian network approach: Given the discrete nature of both response and explanatory variables, a Bayesian Network approach was also tested. Preference score was set as the target response variable and the simplest network structure was built around that (Figure 3), based on our conceptual model. Variables were discretised to fewer classes where necessary, as required for Bayesian analysis: EcoCentrism (Low 0–4, Mid 5–8 and High 9–12), EcoKnowledge (None 0–1, Basic 2–4 and Good 5–7), Preference score (Low 1–3, MidLow 4–5, MidHigh 6–7 and High 8–10). For model calibration, data were split randomly into a training dataset (80% of records) and a validation dataset (20%), with 1,000 iterations of possible data combinations tested and aggregate results reported. Conditional probability tables (CPT) of nodes were learned through an expectation maximisation algorithm, then tested against the validation dataset.

2.4 | Results of modelling 'aesthetic appreciation' of urban meadows

2.4.1 | Mixed effects model

Of the natural capital variables, preference scores were greater for meadow treatments with higher diversity compared with low diversity, and medium height and tall meadows were preferred over short meadows (Figure 4). Among the human-derived capital components, preliminary analysis suggested that when assessed as single variables EcoCentrism explained the most variation in Preference
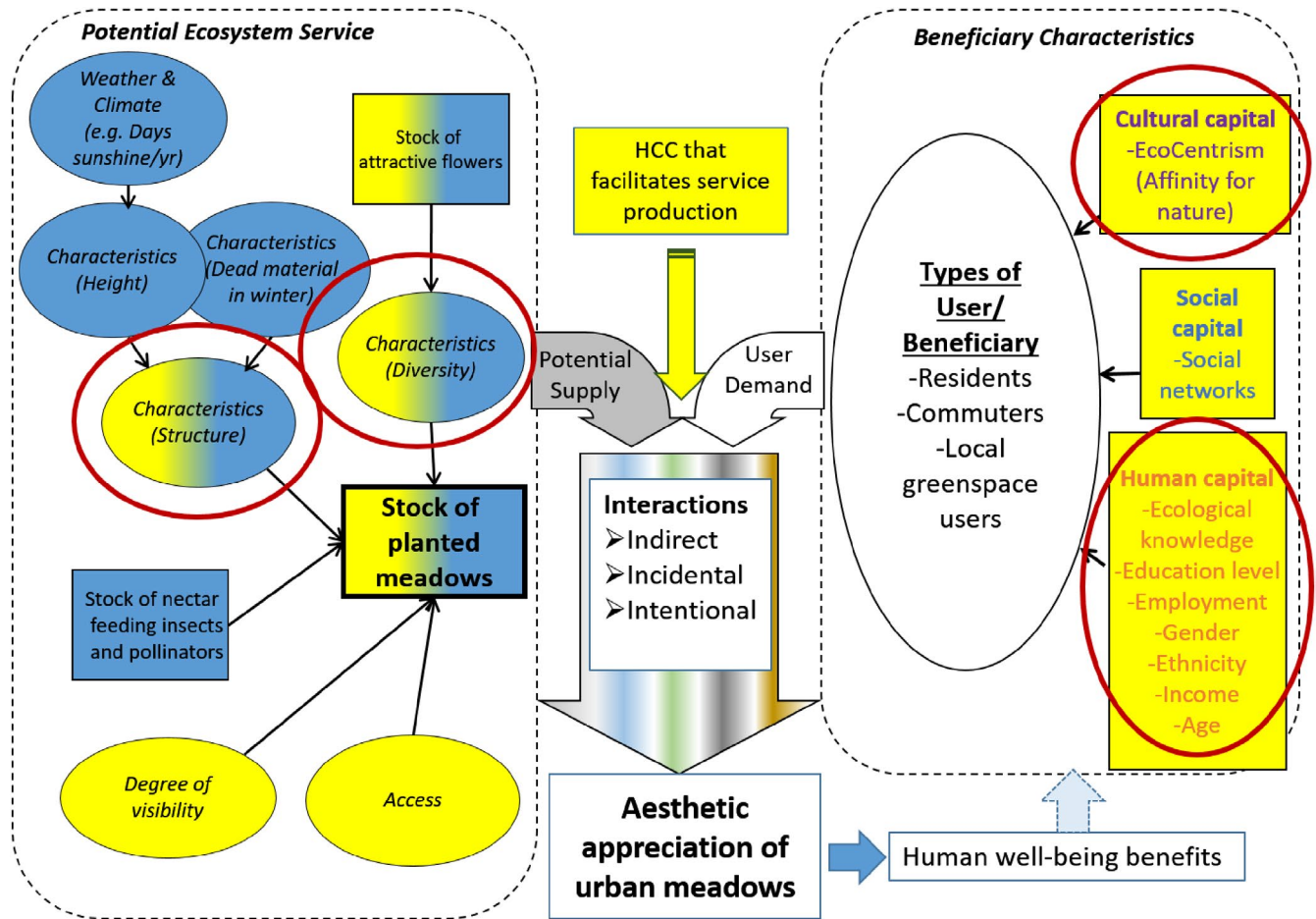
FIGURE 2 Tailored conceptual framework for 'Aesthetic appreciation' of urban planted meadows. Blue boxes/nodes signify natural capital, yellow boxes/nodes signal human-centred capital. Variables used for statistical testing of the framework circled in red

scores (3.1% of the variation), with Preference score increasing with EcoCentrism (Figure 5).

A model which combined diversity and height explained 28.2% of the variance. Adding in EcoCentrism as a measure of cultural capital significantly improved the model although did not explain much additional variation, the adjusted R^2 rising to 29.6%, with a lower AIC. The model which explained most variance included one more human capital variable, UK resident, which only increased the adjusted R^2 to 29.9%. For this variable, non-UK residents gave slightly higher preference scores. Other human capital variables typically recorded as demographic information such as age, income, education and gender were not significant as single variables. UK resident and ethnicity were the only other variables to explain more than 1% of the variation (explaining 1.2% and 1.8% respectively), although it should be noted that for UK resident the distribution of respondents for this binary variable was highly unequal (97% describing themselves as UK resident), while ethnicity contained 22 classes and was difficult to interpret (Southon et al., 2017). Other metrics of revealed behaviour such as the number of visits to the countryside were not significant as individual variables and did not improve the model.

Overall, the best model only explained 29.9% of the observed variation, which suggests that, despite the range of biophysical, cultural and other demographic variables measured, the designed measures in this experiment failed to capture many of the key factors which determine preference scores. Of interest for testing our framework is that inclusion of the cultural capital variable EcoCentrism significantly improved the model, and it explained more variation in the preference scores than did demographic variables. However, a large proportion of the variation remained unaccounted for.

2.5 | Bayesian network model

The Bayesian model performed comparably to the mixed effects model. Inclusion of biophysical variables alone gave a catch rate of 38%. Inclusion of EcoCentrism improved the model, giving a catch rate for fitted to observed discretised data of 40% (Table 1). Querying the network showed a response consistent with expectations, that is, that increased diversity and increased EcoCentrism led to a greater Preference Score. Inclusion of EcoKnowledge as a variable resulted in a slightly weaker model with fewer correct predictions, but was

Biophysical
variables
characterising
meadows

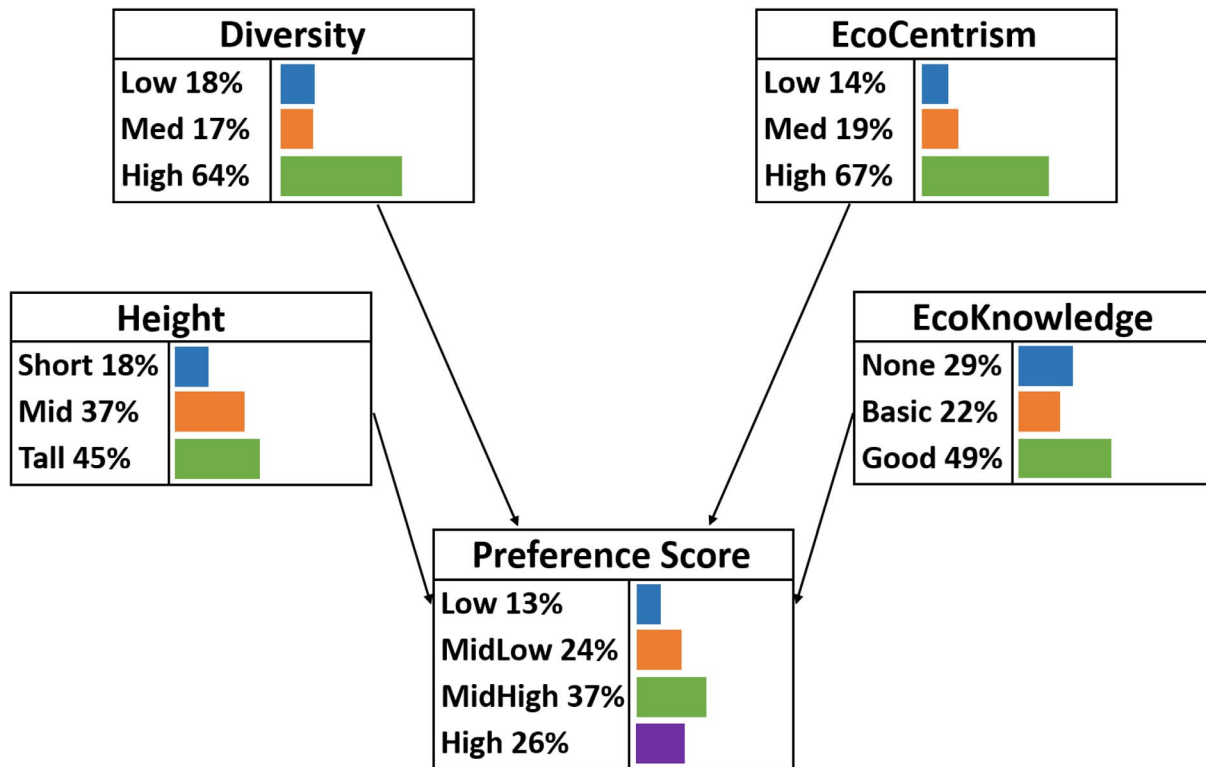Social
variables
characterising
users

FIGURE 3 Example of one of the Bayesian network models tested for aesthetic appreciation

able to better predict preference scores in the MidHigh category. Similarly to the mixed effects model, the Bayesian model showed a high level of uncertainty, reflecting the high variability in the preference scores of individuals.

3 | DISCUSSION

In this paper we discuss some key challenges around modelling cultural ecosystem services, and develop an improved framework to better capture those characteristics of beneficiaries which are important in shaping how benefit is received. We develop models structured around the new framework, and test its utility using two contrasting modelling approaches, using data from an existing trans-disciplinary study focusing on aesthetic appreciation of urban meadows. In support of the framework, the new variables related to cultural capital and human capital explain more variation than conventional demographic data (also considered to represent human capital). However, a large part of variation remains unexplained and further work is required to understand and quantify variability in individuals' responses to aesthetic appreciation.

The separation of user characteristics into different forms of human-centred capital allows a clearly defined structure which can be used to describe beneficiaries. It has long been recognised that interaction with the environment cannot be fully explained by knowledge about the environment and needs to incorporate measures of emotional attachment (Kals et al., 1999) and identity related issues such as nature connectedness (Richardson et al., 2019). In our framework, human capital encompasses a stronger focus on cognitive aspects like knowledge in addition to the physical attributes or demographic characteristics of the person, while cultural capital has a stronger focus on affective aspects linked to feelings and perceptions (Maxwell, 2008). However, we recognise that affective and cognitive states cannot be completely separated (Duncan & Barret, 2007).

Testing of the model showed that cultural capital provided the greatest explanatory power of the variables describing human-centred capital. Providing support for our improved framework, a single variable for cultural capital (EcoCentrism) explained more variation than a suite of seven variables including those most commonly collected as demographic data (e.g. age, gender, education, income, employment and ethnicity). Other studies have shown that
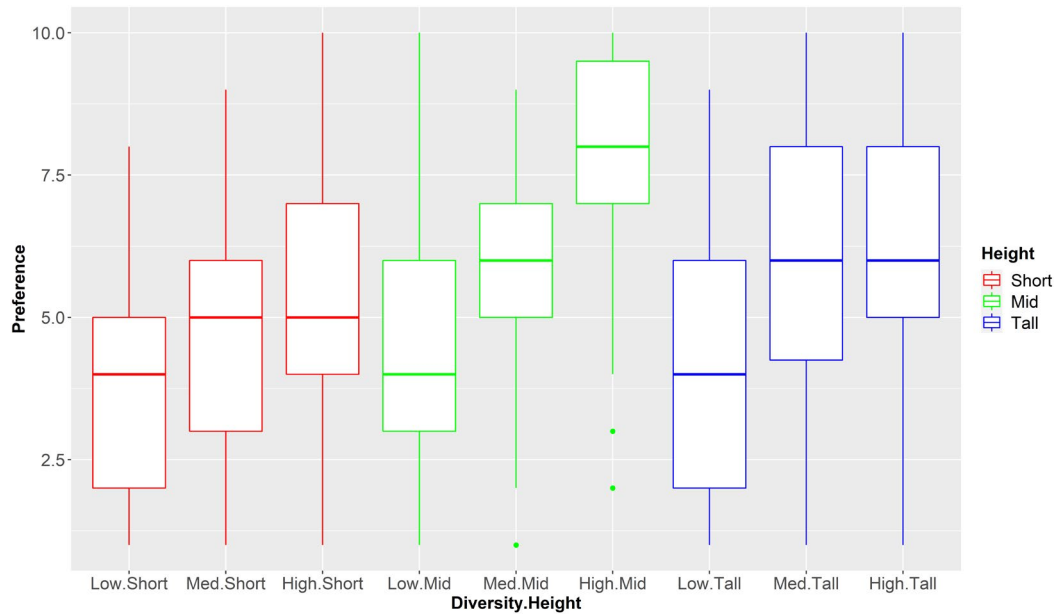
FIGURE 4 Boxplot of preference scores, broken down by natural capital components of diversity and height, showing scatter in response of individual scores
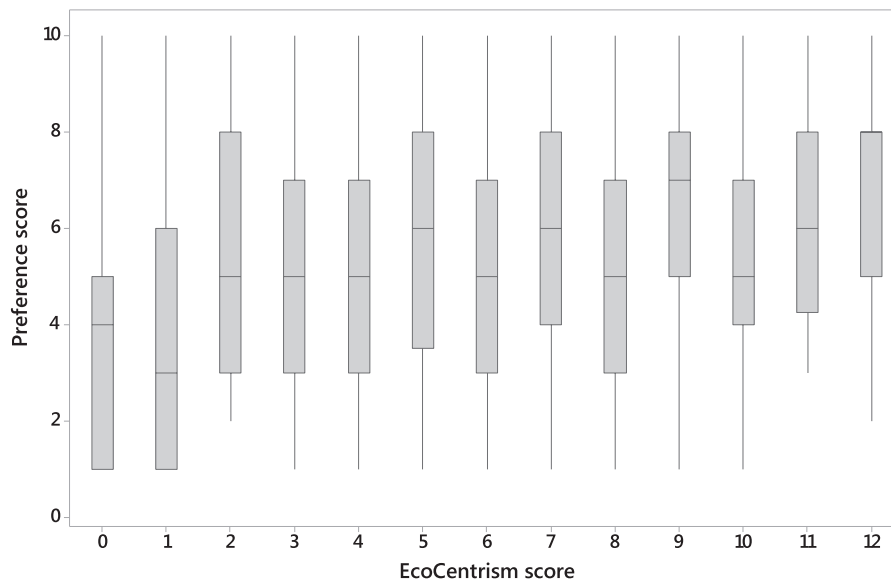

FIGURE 5 Boxplot of preference scores, broken down by EcoCentrism score (a composite measure representing affinity for the environment)

conventional demographic data are a poor predictor of engagement with nature (Dallimer et al., 2014). Graves et al. (2017) found that aesthetic preference for wildflower communities was unaffected by social group factors or by knowledge of nature. McGinlay et al. (2018) showed that reported CES benefits increased with age to peak in early retirement age group, but also increased in those reporting indicators of nature connectedness. Similarly, Richardson et al. (2019) found that a sense of nature connectedness varied with age, reaching a low in teenage years and a peak at early retirement age. This suggests that interest in and motivation to engage nature

are a function of a range of social factors partly related to biological age but also to other factors such as current concerns, peer group interests, cultural interests as well as knowledge and accumulated experiences. This suggests that the motivations for interacting with nature lie within the individual and are not easily explained by simple demographic data which are based on social structures and are easy to collect.

While most of the variance in preference was explained in the models by features of natural capital (sward height and diversity), even these aspects of natural capital will have associations with

TABLE 1 Confusion matrix on discretised response of modelled versus observed in the test dataset

		Observed				
		Low	MidLow	MidHigh	High	Correct/Total
Predicted	Low	16	11	6	1	16/45
	MidLow	17	14	8	4	14/47
	MidHigh	3	3	4	3	4/39
	High	9	19	21	36	36/44
						(0.40) 70/175

human capital through the socially constructed aspects of nature affinity, charisma and aesthetic appeal. Various researchers have investigated how people interpret and evaluate the charisma of different species or species assemblages (Czech et al., 1998; Lorimer, 2007; MacDonald et al., 2015; McGinlay et al., 2017), for example, the extent to which observers are able to detect aspects of grassland sward composition and structure and how this relates to aesthetic preferences (Lindemann-Matthies et al., 2010). Aspects of natural capital might therefore interact with human cultural capital through processes such as aesthetic appreciation and the evaluation of species charisma to co-produce CES benefits. Such processes might therefore draw on both instinctive/intuitive and also culturally derived understandings of aesthetics and charisma.

The main cultural capital variable used in this study, EcoCentrism, is a composite variable capturing affinity with nature (Southon et al., 2017). It has similarities with other metrics linked to affective relationships with nature, for example, reviewed in Tam (2013). Measures such as the Nature Connectedness Index have been shown to have strong relationships with other environmental behaviours and with self-reported well-being, including at the population scale (Richardson et al., 2019).

Cultural capital has some close affinities with the concepts of relational values, which explore peoples' relationships with nature in a broader sense (Himes & Muraca, 2018). Definitions of relational values include preferences, principles and virtues about human–nature relationships (Chan et al., 2018). However, they are often seen in a broader context, for example the connections of indigenous communities and their land, through knowledge and custom (Kilonzi & Ota, 2019), and aspects from each of cultural, social and human capital described here seem to capture aspects of relational values. The framework we propose might therefore help explore how relational values are involved in human interactions with nature and to quantify or describe these relationships in more detail. Further work would be useful to explore areas of commonality between these concepts, and the extent to which they can be used to predict the type of interaction with nature that an individual will choose in a particular context.

Our study also shows that there remains a high level of unexplained variation in the responses of individuals to nature. The additional variation explained by variables linked to cultural capital was relatively small compared with that explained by the biophysical variables in the model. The remaining variation was still not captured by the wide range of possible explanatory variables measured in this study, noting that EcoCentrism was itself a composite of four

component metrics. Similar variability is also apparent in population-level studies such as Richardson et al. (2019). This reflects the ongoing challenge in identifying motivations and bridging the gap between smaller scale studies of relatively few individuals where it is possible through open discussion, semi-structured interviews and content analysis to gain a fuller picture of motivations at the individual level, and the larger scale studies exploring and modelling responses at population level. Taken together, this suggests that we have still not found the best metrics to help predict how and why people choose to interact with the environment in particular ways. Existing demographic variables are probably worth including in models, and may be important in particular contexts, but they should be supplemented by additional variables for cultural, social and human capital which better capture the characteristics which shape people's engagement with the environment. The bigger challenge lies in finding attributes which account for the very high level of unexplained variation observed in this and other studies. Solving this issue would dramatically improve our ability to model or predict interactions with nature in different contexts.

For the purposes of developing predictive models, which was another objective of our study, the clarity of structure in the framework is particularly useful. All models benefit from a defined structure within which to consider explanatory variables, but this is particularly important for Bayesian modelling approaches. Bayesian models are often constructed uncritically, with little thought for hierarchies and relationships between nodes. Since the influence of a variable is inversely proportional to its network distance from the final node, a poorly constructed model can lead to biased or incorrect model predictions. Models constructed using a large number of nodes require a much larger dataset of training data which should representatively cover all possible combinations of paths through the network. Alternatively, where the conditional probability tables are constructed through expert opinion, it is often difficult for experts to estimate the relative probability of multiple permutations (Shaw et al., 2016). Our conceptual approach helps address some of these issues, by suggesting a clear structure for inclusion and testing of nodes which should lead to simpler, more efficient predictive models.

4 | CONCLUSIONS AND RECOMMENDATIONS

We demonstrate that inclusion of user characteristics in our revised conceptual framework takes us closer to being able to model

cultural services effectively. Testing of the framework is important and shows that variables associated with cultural capital, such as EcoCentrism, are a much better predictor of engagement with the environment than standard demographic data routinely collected in such studies. However, the additional variation explained by these new variables still falls short of explaining a considerable portion of the differences observed between individual respondent's scores of the aesthetic quality of urban meadows. This suggests a radical shift in the type of data we need to collect in studies on cultural services, moving away from traditional demographic descriptors and seeking and testing new approaches. For example, further analysis using related concepts such as the Nature Connectedness Index, and measures of relational values, and their utility as predictors of interaction with the environment, would be beneficial.

We feel that the framework gives great flexibility to apply this approach in other settings. For example, indigenous knowledge and connections with nature, which run from historical through present and to future generations, can conceptually be incorporated as different types of capital. Applying this framework suggests that the strength of the human-centred capital, in combination with the quality of the environment, will influence the benefits that come from those interactions.

Of interest for development of models of any cultural services is whether their predictive capacity holds across different types of activity where motivations for engagement may differ among users. A logical next step would be to design studies to explicitly test a variety of metrics using this framework, and including a range of quantitative and qualitative data collection approaches in different settings.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTIONS

L.J. conceived the ideas and led the research and writing of the manuscript; K.L.E. and G.S. contributed data from the F3UES project. All authors contributed to development of the framework, and writing and editing of the manuscript.

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