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RESEARCH ARTICLE

# Species diversity enhances perceptions of urban coastlines at multiple scales

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## Abstract

1. Biodiversity is increasingly understood as an important mediator of human aesthetic appreciation of scenes and landscapes, with implications for cultural services and well-being. However, the generality of biodiversity effects across affective emotions, scales and habitats remains unclear.
2. Urban coastal intertidal habitats on seawalls and other artificial structures are expanding worldwide. Despite growing calls to prioritise biodiversity in urban coastal planning and management, the potential co-benefits determined by people's responses to biodiversity in these novel intertidal communities are unexplored.
3. We investigated, using image-based questionnaires, how several facets of biodiversity influence how people perceive urban coastal structures at both landscape and close-up scales.
4. Species richness strongly enhanced people's ratings of images for aesthetic appeal, interest and calming potential at both scales, but was more pronounced at the close-up scale. Species evenness also increased ratings at the close-up scale, while functional diversity (Rao's Q) was associated with a decline in aesthetic appeal and interest at the close-up scale, indicating that people can disfavour scenes dominated by species with contrasting traits.
5. Analysis of free-text assessments showed that people strongly and positively valued scenes that were perceived to be 'diverse', a response that was much more common when viewing scenes with high species richness. The underlying structure type also clearly affected appraisals, with more obviously engineered structures being perceived to be less natural and thus less desirable.
6. Our results show that biodiversity's effects on aesthetic appreciation extend to multiple affective emotions and to unfamiliar urban intertidal habitats, suggesting that managing these environments for biodiversity may simultaneously support aesthetic, educational and well-being benefits. Nevertheless, the sensitivity of responses to the facet of biodiversity and viewing scale in our results underlines the context dependency and complexity of people's perceptions of urban environments.

**KEYWORDS**
aesthetics, biodiversity, coastal structures, cultural ecosystem services, interest, seawalls, well-being

## 1 | INTRODUCTION

Humans are driving significant changes in biodiversity across ecological communities globally (Chaudhary et al., 2021; Dornelas et al., 2014; Newbold et al., 2015), and understanding how biodiversity change influences ecosystem services remains a pressing ongoing research challenge (Balvanera et al., 2016; Gamfeldt et al., 2013; Isbell et al., 2017). Almost three decades of research have demonstrated that biodiversity of ecological communities profoundly influences provisioning and regulating services such as wild food production and carbon storage (Cardinale et al., 2012; MEA, 2005), but growing evidence also suggests that diverse natural systems are crucial in providing valuable aesthetic and well-being benefits (Bell et al., 2015; Ulrich, 1983; White et al., 2013). Increasingly, researchers are beginning to investigate how biodiversity simultaneously influences the flow of cultural services such as aesthetic inspiration, opportunities for tourism and recreation, and education (Chan et al., 2012; Hoyle et al., 2017; Lindemann-Matthies et al., 2010).

There is emerging evidence that biodiversity influences how people perceive and respond to nature. A long history of research in environmental psychology shows that exposure to nature can elicit positive aspects of perception such as aesthetic pleasure (Petrova et al., 2015; Ulrich, 1983), interest (Fairchild et al., 2018) and a sense of calm (Dallimer et al., 2012; Fuller et al., 2007; Houlden et al., 2018), which are key in driving inspiration, shaping positive attitudes and enhancing psychological restoration and well-being (Silvia, 2012; Thornhill, 2003; Ulrich, 1983). Consequently, landscapes that are aesthetically appealing, subjectively interesting or providing a sense of calm are important motivators for humans to visit and interact with natural ecosystems, while also providing satisfying and engaging nature experiences (Kim et al., 2015; Pasanen et al., 2018). Yet, rather than simply exposure to nature, it is likely that more biodiverse and naturalistic scenes or landscapes provide greater aesthetic appeal (Gunnarsson et al., 2017; Hoyle et al., 2017; Palliwoda et al., 2017), and enhance well-being benefits by providing calming spaces for relaxation and rejuvenation (Fisher et al., 2021; Hoyle et al., 2017; Wood, Harsant, et al., 2018; Wood, Jones, et al., 2018). However, previous studies have often taken a broad comparative or correlational approach, with more diverse settlings covarying with other factors, such as organism abundance, habitat type and landscape setting, leaving the specific role of biodiversity—and its multiple facets—poorly understood.

Indeed, it is important to consider that multiple facets of biodiversity may have different influences on aesthetic appeal and other affective emotions. Most simply, increasing richness (number) of species in a community can enhance visual complexity (Forsythe et al., 2011; Kaplan et al., 1972; Petrova et al., 2015) and the chances that species with favourable characteristics are included (Ulrich, 1983), intersecting strongly with empirical findings from the psychology of aesthetics where complexity and desirable traits can enhance aesthetic appeal (de Pinho et al., 2014; Palmer et al., 2013; Petrova et al., 2015). Species-rich communities are also generally *perceived* to be more diverse, which may lead to positive aesthetic appraisals of communities through intrinsic existence values (Dallimer et al., 2012; Fisher et al., 2021; Schebella et al., 2019), particularly as public awareness of the importance of biodiversity in maintaining healthy ecosystems has increased over the past decade (Hynes et al., 2021; Shwartz et al., 2014; Wu et al., 2020). Species richness is, however, a coarse measure of community structure; visual complexity and diversity may be more discernible where species abundances have higher evenness (Graves et al., 2017; Tribot et al., 2019), or where species have more distinctive traits (characteristics; e.g. colour or shape) and therefore encompass greater functional diversity (variety of different characteristics; Fairchild et al., 2018; Tribot et al., 2016, 2019).

Moreover, different affective emotions can be expected to vary in responses to biodiversity. For example, increasing visual complexity (Fry et al., 2009; Silvia, 2006; Sun & Firestone, 2021) and the inclusion of a variety of species with novel, unusual traits (e.g. high functional diversity) may elicit fascination or interest in a community by providing unfamiliar stimuli (Fairchild et al., 2018; Kashdan & Silvia, 2009), ultimately triggering fascination (Ballantyne et al., 2007; Krapp, 1999; Renninger et al., 2014) and facilitating learning experiences (Silvia, 2001, 2006, 2008). Conversely, restorative benefits may be enhanced in communities with high species evenness which may provide more visually coherent scenes (Fry et al., 2009; Kang & Kim, 2019; Zhang et al., 2013), or alternatively may be increased through increasing perceived health, ecological quality or naturalness of habitats (Fisher et al., 2021; Marselle et al., 2016; Wood, Harsant, et al., 2018; Wood, Jones, et al., 2018), which can be driven through higher species diversity (Hoyle et al., 2019; Purcell & Lamb, 1998; Winter, 2012). Collectively, these properties can provide calming spaces which in turn promote self-reflection and mental restoration (Kaplan, 2001; Pálsdóttir et al., 2018), reduce stress (de Kort et al., 2006; Pálsdóttir et al., 2018; Van Den Berg & Custers, 2011) and ultimately enhance mental and physical well-being (Garrett et al., 2019; Houlden et al., 2018; Koss & Kingsley, 2010; Schwind et al., 2017).

People also interact with natural environments at multiple scales, from viewing a landscape while walking or travelling, to closely exploring an environment to find organisms of interest. Although yet to be addressed, biodiversity effects on different aspects of human–nature perceptions are likely to be highly scale dependent. For instance, the role of abundant or conspicuous species and their differences may be most important when viewed from afar, with the total richness of organisms more discernible at close-up viewing scales.

The role of biodiverse, naturalistic spaces for providing aesthetic and well-being benefits is particularly important in urbanised areas, where opportunities to encounter nature are often limited. Here, important nature interaction experiences for residents centre around urban green and blue spaces, such as gardens, parks, lakes and, increasingly, coastal spaces (Chiesura, 2004; Mills et al., 2019; Palliwoda et al., 2017). But coastal spaces in particular, which are increasingly becoming recognised for their potential well-being benefits (Bell et al., 2015; Bell et al., 2020; Wheeler et al., 2012), are undergoing rapid and sustained change as coastal populations continue to grow (Barragán & de Andrés, 2015; Neumann et al., 2015), and the subsequent proliferation of urban coastal structures places them in greater intersection with local communities and tourists (Evans et al., 2019). This growth of fringing coastal infrastructure and hard engineering can substantially alter the visual properties of coastal vistas at both the landscape scale and more intimate close-up scales (Burak et al., 2004; Morgan, 1999b) through changes in shoreline structural complexity (Lawrence et al., 2021), with these simplified environments typically hosting depauperate ecological communities (Bulleri & Chapman, 2004; McKinney, 2006; Momota & Hosokawa, 2021). This has led to increasing calls to develop ecologically sensitive designs or management scenarios to retrofit coastal infrastructure, embracing varied naturalistic features to provide suitable habitat to support natural, biodiverse ecological communities (Evans et al., 2019; Firth, Schofield, et al., 2014; Firth et al., 2016). Indeed, features, such as rockpools (Evans et al., 2016; Hall et al., 2019) and surface roughness (Loke & Todd, 2016; Matias et al., 2010; Zawada et al., 2010) associated with older and eroded structures—or via ecological retrofitting—may markedly increase biodiversity along urban coastlines. In turn, the enhanced biodiversity may provide greater opportunities to explore and interact with organisms at local scales (Martens, 2016; Morgan, 1999a), together with creating more natural coastal landscape aesthetics (Cordell et al., 2017). But despite the potential biodiversity benefits provided by ecologically sensitive coastal management, there is a lack of knowledge as to how local communities and visitors—whose buy-in may be crucial in determining the successful implementation of conservation or enhancement schemes—might perceive more biodiverse urban coastal structures.

In urban coastal environments, the role of biodiversity in providing aesthetic and well-being experiences remains untested. Previous anecdotal or implicit evidence from aesthetic appraisal studies on artificial coastal structures—centred on how natural or congruent they are with natural shorelines—are often contradictory (e.g. Bell et al., 2020; Koutrakis et al., 2011; Morgan, 1999b), suggesting that traditional positive diversity perceptions may not apply universally across to coastal urban environments where clean architectural lines may be sometimes preferred (Bosman et al., 2016; Koutrakis et al., 2011). For other aspects of perception, such as interest and the ability to provide calming spaces, experimental evidence from coastal systems on biodiversity–benefit relationships is notably lacking, yet is becoming particularly pressing as we begin to understand the importance of natural blue systems for multiple cultural and well-being functions (Bell et al., 2020; Evans et al., 2019). Furthermore, there is limited evidence to suggest that many dominant intertidal species, notably seaweeds, can be negatively perceived by residents and visitors at coastal locations, providing hazards to access and egress, being associated with unfavourable aesthetics, smells or touch sensations (Limburg et al., 2010; MacLeod et al., 2002; Merkel et al., 2021). These potential negative perceptions of ecologically important, characteristic species may undermine any positive biodiversity effects—coupled with an overall lack of understanding of coastal biodiversity–perceptions relationships—leaving considerable uncertainty around the aesthetics and well-being benefits created by diversity in coastal ecosystems.

Here, we address the role of biodiversity in mediating human perceptions of artificial coastal structures. We assessed the role that species and functional diversity play in driving aesthetic appeal, human interest and creating relaxing or rejuvenating environments using an image-based questionnaire. We used a combination of image choice, rating scales and free-text motivation tools to understand the effect of biodiversity on different facets of well-being, and to explore the underlying motivations. Furthermore, we examine whether the scale which people view or interact with these environments—at both intimate, close-up scales associated with exploration of nature (such as rockpooling), and at whole structure scales where passive viewing typically occurs—may alter biodiversity–public perception relationships.

## 2 | METHODS

### 2.1 | Participant selection

Participants between the ages of 18 and 60+ were recruited through online social media channels and promotions which linked to the survey between 15th May and 28th September 2020. The survey was targeted at UK and Ireland residents as part of the Ireland-Wales ECOSTRUCTURE project, and entries submitted from participants outside of the geographical range were disregarded to reduce the influence of regional variation in attitudes. Participants were informed that the purpose of the experiment was to 'understanding attitudes towards coastal defence structures and the animals and seaweed that grow on them', but the specific aims were not explicitly stated to prevent bias. Participants were asked whether they consented to being included in the study using question-routed checkboxes ('I consent to be part of the study', or 'I DO NOT consent to be part of the study'—which routed to the exit page) before they progressed, and informed that they were free to withdraw, without penalty, at any time using a withdraw ('Exit') button at the top of the navigation page. The survey took approximately 15 min to complete. This study was granted ethical approval by the Swansea University Ethics Committee (SU-Ethics-Staff-260,520/246).

## 2.2 | Experimental design

For our study, we selected three distinctive yet complimentary aspects of perception: aesthetic appeal, interest, and providing a sense of calm. These aspects of perception have been identified as important determinants of the overall motivation to visit or interact with—and subsequent visitor satisfaction towards—natural environments (Dorwart et al., 2009; Kim et al., 2015; Pasanen et al., 2018). To elucidate how components of biodiversity influence these different indicators of cultural services (aesthetic appeal, interest and calming potential), we created an online study on Survey Monkey (see example questionnaire section in the supplementary materials) using images composited from photos of three different types of artificial coastal structure types and 10 species of intertidal organisms which are common throughout the north-east Atlantic (Hawkins et al., 2019; Table S1). The study was conducted at two focal scales: a whole-structure scale (~*c*. 30 m × 5 m) and a close-up scale (~*c*. 1 × 1 m). Within the images, we directly manipulated species richness (6 levels; 0, 1, 2, 4, 6, 8 species) and indirectly manipulated species evenness (Pilou's evenness) and functional diversity (here measured as Rao's *Q*—Botta-Dukát, 2005) through varying the community compositions within each richness level. Species richness was hypothesised to increase appeal, interest and sense of calm as we expected that naturalness and complexity, which can be enhanced by having a greater number of species, may be important in driving these perceptions. Functional diversity was included as we hypothesised that greater trait differences would lead to more visually obvious differences between species, and thus increase the ability of participants to discriminate between species. The traits used to generate the functional diversity measure were selected to broadly capture differences in visual properties—such as size or colour—and are presented in Table S2.

To assess aesthetic appeal, we used multiple different question types to understand preference order and self-reported appeal (Table S3). First, each participant was presented with 15 paired image preference questions with two randomised images, side-by-side, and asked to select which image they found most appealing (or if they found each image to be equally as appealing). Paired image preference approaches have been found to capture preference reliably and repeatably (Clark et al., 2018; Sankaran et al., 2021) and are less susceptible to directionality biases or central tendencies than other rating scales. As aesthetic appeal was not expected to be the only cultural service indicator affected by diversity, we also asked participants Likert-type questions on additional self-reported perceptual components of how interesting ('I find the structure interesting to look at') and calming ('I find the structure relaxing and calming to look at') participants found each of the image, which have been, respectively, seen to capture interest and the motivation to learn (Fairchild et al., 2018; Moss & Esson, 2010; Turpie, 2003), as well as providing relaxation and stress recovery (Christopher, 2019; de Kort et al., 2006; Moran, 2019; Van Den Berg & Custers, 2011). Additionally, a Likert-type question on aesthetic appeal ('I find the structure appealing to look at') to facilitate direct comparisons between the different components and allow for the testing of demographic effects on appeal. Participants were provided with 10 single images and rated aesthetic appeal, interest and calming using a 5-point scale, including a central 'neutral' option (e.g. Strongly Agree (5), Agree (4), Neutral (3), Disagree (2), Strongly Disagree (1); Table S3). Due to layout restrictions in the Survey Monkey platform, these three Likert-type questions were presented as a random order question matrix. To assess any influence of acquiescence bias, we validated results against a subset of participants with inversely worded statements and ranked ELO results, finding no evidence of systematic bias from positive question wording (see 'Assessing acquiescence and directionality biases from Likert-type scale data' in the Supplementary Materials for more information).

We also asked demographic questions (age, gender, educational/professional background, ocean connectedness (after Nuojua et al., 2021, in review and Schultz, 2002) to understand whether demographic differences modified relationships. Participants were given the opportunity to not disclose their answer ('prefer not to say') for each question. Further details are shown in Table S4. Finally, to understand the motivations, participants were asked to rate aesthetics using a Likert-type object and provide free-text comments on what they liked and disliked about three randomised images ('Thinking about this structure, what motivated you to find the structure unappealing or appealing? Please write, In your own words, in the box below'). These questions were presented after the demographic questions and were optional to complete.

## 2.3 | Image composition

We created composite images using photographs of different urban coastal structure types: stepped concrete walls, rip-rap (or 'rock armour') and an old heritage stone seawall (circa 1800s), and contained 10 common and ubiquitous north-east Atlantic intertidal species, comprising of six seaweed species, and one species each from the groups of barnacles, anemones, limpets and mussels (Hawkins et al., 2019; Table S1). While structure and species selections were not exhaustive and may not fully represent the diversity present across the country, they were chosen to represent the continuum of complexity in UK coastal artificial habitats and communities. Composites were created for both whole structure (*c*. 30 m × 5 m) and close-up (*c*. 1 × 1 m) focal scales and contained either 0, 1, 2, 4, 6 or 8 species. At the structure scale, we simulated randomly selected species combinations, across three different structure types, giving a total of 120 unique images. At the close-up focal scale, the number of structure types was reduced to two, as the riprap and old wall sections looked too similar, giving 85 unique images. Images of artificial structures were carefully manipulated to remove any existing seaweed or animal cover. Multiple photographs for each of the 10 intertidal species were taken across the south Wales coastline (UK) on different substrate types, and for different orientations and presentations. Both the structures and organisms were then digitally extracted from the images using the scissor lasso tool in GIMP 2.9.1., appropriately scaled, and layered to create images which varied in their community composition and diversity (Figure 1). Proportions and zonation of species were selected to realistically represent naturally occurring communities. Care was taken to ensure no large systematic differences in community coverage were present across the different diversity treatments or structure types, and the percentage of occupancy of the structure was calculated to control for residual variation. Structures were then resized to ensure the same total coverage in the images. Differences in the visual properties of wider viewsheds can affect overall aesthetic appraisal of scenes (Morgan, 1999b; Ulrich, 1983), so here, to focus on the role of different facets of biodiversity and to avoid biases due to differences in the landscape setting in which the structures were located, composite structures were displayed over a separate coastal background image which was held constant across structure types.

## 2.4 | Analysis

### 2.4.1 | Structural and image properties

The community structure within each image was quantified by examining percentage cover on the structure for each species in each image using the Vidana image analysis tool (Hedley, 2013). From the species-level data, we also calculated substrate occupancy by summing visual cover to calculate the proportion of the structure that was occupied by seaweeds or animals. Additionally, we quantified the perceptual colourfulness of the image—which has previously been observed to influence aesthetic appraisals (Fairchild et al., 2018; Tribot et al., 2016)—using a colourfulness algorithm developed by Hasler and Suesstrunk (2003) within the Matlab R2017A analysis software.

### 2.4.2 | Statistical analysis and visualisation

Analyses of data were performed in R statistical computing software 3.6.3 (R Core Team, 2013). To understand how diversity components and structural properties affected aesthetic appeal, we created aesthetic scores from image pair win/loss/draw data using the ELO algorithm package (Elo, 1978; Heinzen, 2017; following Tribot et al., 2016) to rank images. To verify that image choices were not random, we compared the distribution of the observed ELO aesthetic scores to randomly recompiled win/loss dummy data using a Kolmogorov–Smirnov test. Species richness and Pielou's evenness were calculated using the VEGAN package in R (Oksanen et al., 2017) and functional diversity (Rao's Q, Botta-Dukát, 2005) was calculated using the FD package (Laliberté &

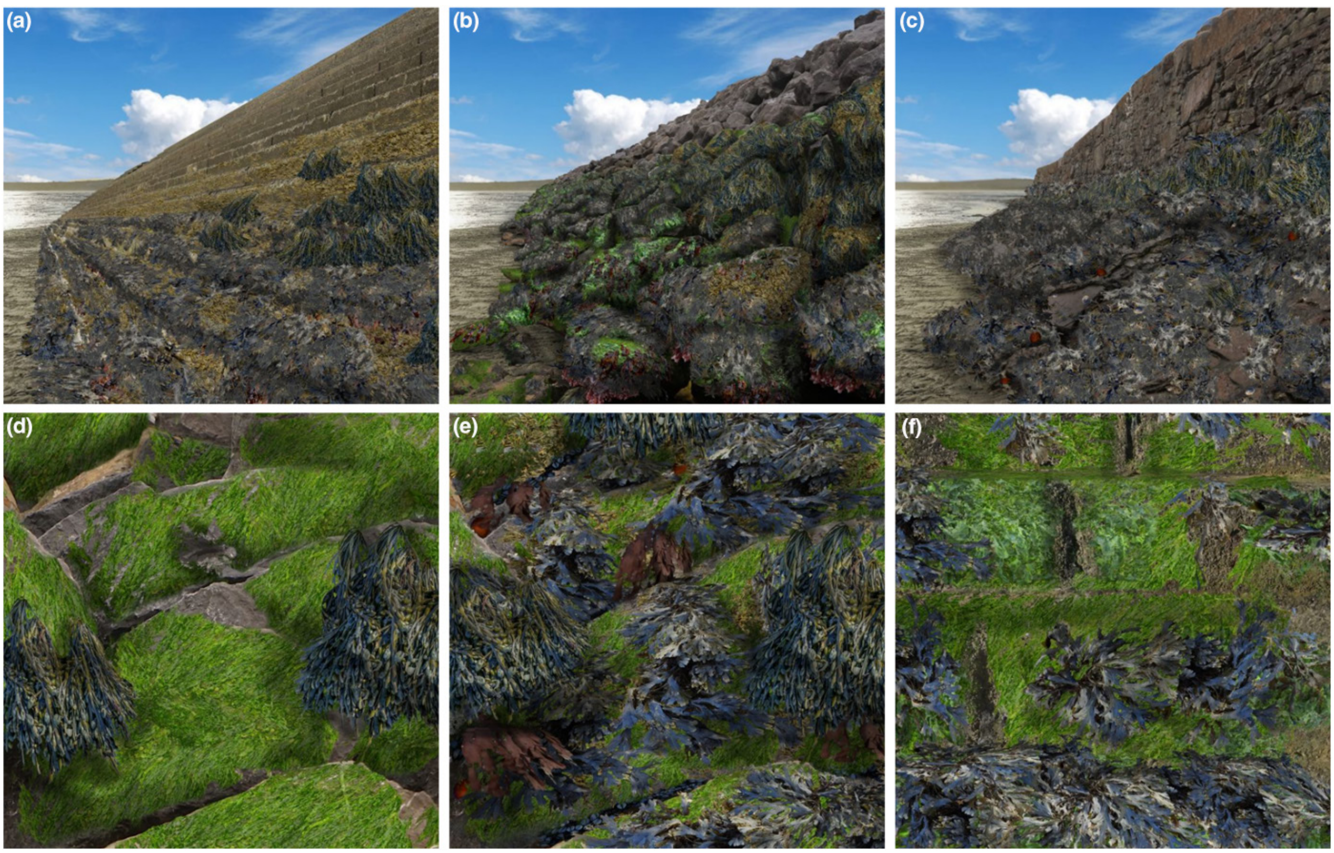


FIGURE 1 Examples of images of structures (a–c) and close-ups (d–f) used in the survey. Images a–c include variation in the underlying structures, from stepped walls (a) to rip-rap walls (b) and heritage stone walls (c). Images d–e show example close-up images with different underlying structures of rip-rap walls (d and e) and stepped walls (f)

Legendre, 2010). Rao's *Q* was selected as the sole measure of functional diversity in the study as it has been found to perform well for describing average community trait dissimilarity (Botta-Dukát, 2005), which we expected would be a crucial factor for people to discriminate between species. Rao's *Q* can also be calculated for communities containing ≥2 functionally distinctive species, and thus could be calculated for the majority of communities contained in our survey.

To analyse the roles of biodiversity facets (species richness, species evenness, functional diversity), structure type and overall image properties (colourfulness, substrate occupancy), we used two complimentary approaches. For the paired image preference data, we used log-linear regression mixed effects models for analysing ELO aesthetic score relationships, with the individual respondent as a random factor to account for different baseline appreciation or interest in coastal communities, and interactions which were expected to be important (e.g. the role of species diversity across different coastal structure types) were explicitly included within models. Cumulative Link Mixed Models (CLMM) with a logit-link function—via the ORDINAL package in R (Christensen, 2018)—were used for Likert aesthetic, interest and calming potential relationships, again with respondent as a random factor, and interactions included between key, interacting predictors. The individual-based modelling approaches with CLMMs also included participant demographics as predictors to understand the generality or specificity of relationships. Although every care was taken to capture representative survey populations, we also statistically controlled for demographic effects by including demographic data in our CLMM models, but some residual effects or uncaptured demographic properties, may still slightly influence ratings. Resulting model partial effects, after controlling for other variables, were then visualised using the plotting packages VISREG (Breheny & Burchett, 2016) and GGPLOT2 (Wickham, 2016). We also examined whether species identity effects altered aesthetic appraisals using log-linear mixed effects models (using the 'lmer' function in LME4 R package, Bates et al., 2015) at both focal scales—using abundances for the 10 species—along with the covariates of species richness and structure type as a random factor to control for diversity and structure differences.

#### 2.4.3 | Textual analysis

As well as the numerical collection of data, optional free-text questions were included to explore the motivations of participants to find structures appealing or unappealing. As free-text responses can feature different words or phrases by participants to describe the same thing, we identified motivational themes, that is, words corresponding to broad themes within the free-text answers. For instance, participants interchangeably used the words or phrases 'unnatural', 'not natural' and 'artificial' to describe the aesthetics of the structures, which were subsequently collapsed to the common theme of 'Artificial', as the use of the words has the same broad meaning. These themes were assessed by manually reading through responses and categorising individual observations by participants, adding new themes where observations did not fit into an existing category. These identified themes were then visualised using a word cloud, with the size of text scaled from the natural logarithm of the number of responses in each category using Adobe Illustrator (CC 2019).

## 3 | RESULTS

### 3.1 | Ecological communities

A total of 937 people from the UK and Ireland completed the image preference sections of the survey (for ELO analysis), and 754 completed the image preference including demographics (CLMM analysis). Participants responded strongly to species richness at both whole structure and close-up viewing scales, finding more species rich and even communities on the presented seawalls to be more appealing (Figure 2a,b), but also surprisingly found that more functionally diverse communities were less appealing (Figure 2c,f, Tables 1 and 2, Tables S5 and S6), interesting (Tables S7 and S8), and calming (Tables S9 and S10). The strength of these relationships was stronger in close-up images than at the whole structure scale. We found that the colourfulness of scenes positively influenced aesthetic appeal, and calming potential at close-up viewing scales (Tables S6 and S10) but had no apparent effect at the whole structure scale (Tables S5 and S9). We also found limited evidence suggesting that human preferences were driven by the composition of species, finding only a weak negative effect of mussels (*Mytilus)* and anemones (*Actinia)* at the structure-scale (Table S11), and weak positive effect of a red alga (*Palmaria)* at closer viewing distances (Table S12). As well as the effects of the ecological community there were strong preferences for the underlying structure type. The less regular old stone wall and riprap structures were far more appealing than the more regular concrete stepped wall (Table 1; Figure S1).

Participants also generally found diverse structures more interesting and calming than those with fewer, and less even, species (Figure 3; Table 3). Interest was particularly strongly related to species richness, and positive effects on interest accumulated faster than either aesthetic appeal or sense of calm. Structure type had a strong influence, with the more obviously artificial stepped concrete walls being found as less appealing, interesting and calming compared to the old wall and riprap structures (Table 3). As with aesthetic appeal, the positive relationships between diversity and interest/calming were more apparent at closer viewing distances than at the whole structure scale (Figure 3d,e,f). At the close-up scale, we also observed negative effects of functional diversity for interest (Table S8).

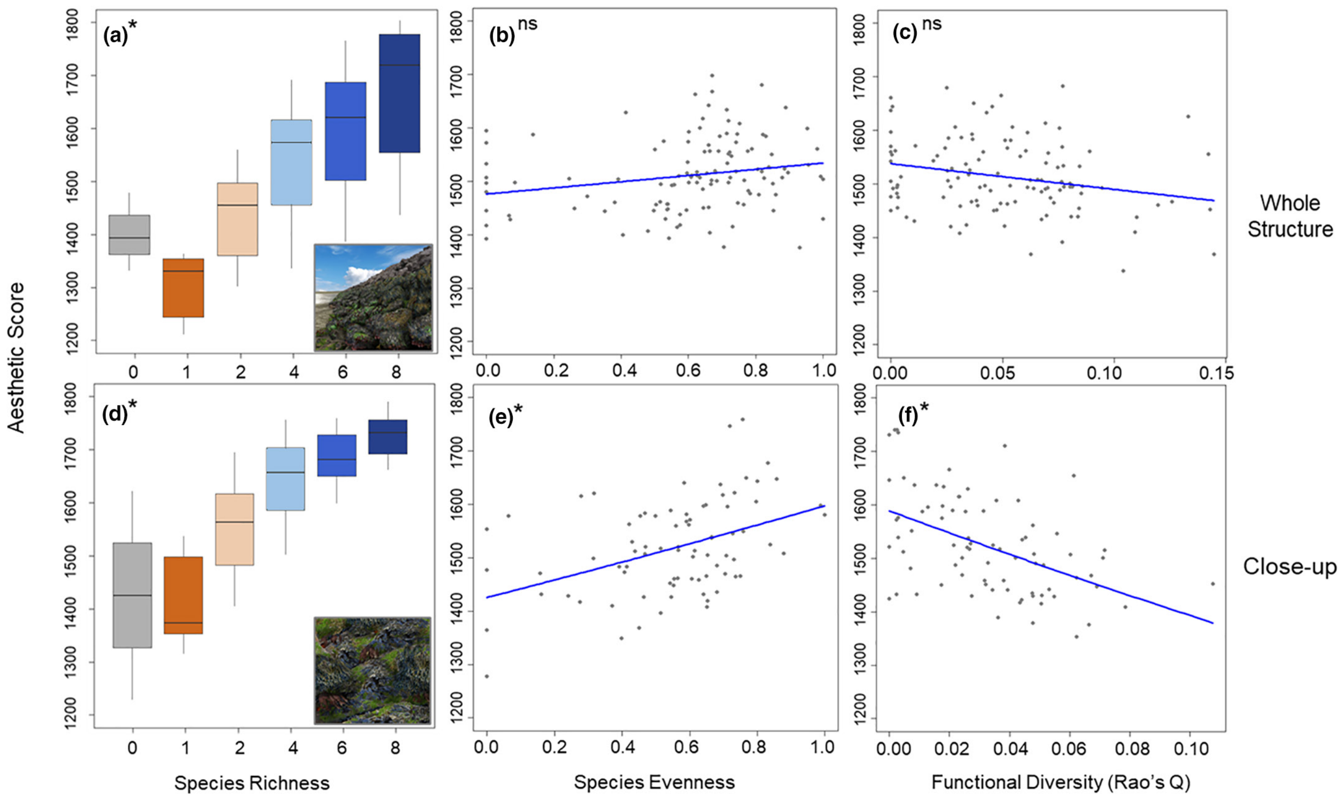


FIGURE 2 Species diversity, but not functional diversity, effects drive aesthetic preferences on artificial structures, and strengthen with decreasing viewing scale. The effect of species richness (left), evenness (Centre) and functional diversity (right) on aesthetic appeal scores at both the structure (a–c) and close-up scales (d–f). Centre lines on panel a and d represent the median, inner boxes represent 25th–75th percentile and whiskers represent the maximum and minimum values. Points and lines on panels b, c, e and f represent model partial residuals and model fits, respectively. Asterisks represent significance at $\alpha = 0.05$ (*), 0.01 (**) and <0.001 (***), and 'ns' represents non-significance

TABLE 1 Species richness and structure type influence aesthetic appeal at the whole structure scale. Regression model summary table examining the role of biodiversity, structure and image properties in driving aesthetic appeal scores (ELO). Asterisks for *p*-values represent significant results at α = <0.05 (*) and <0.001 (***)

| | Estimate | SE | *p*-value |
|---|---|---|---|
| Intercept | 6.350 | 0.563 | <0.001*** |
| Species richness | 0.068 | 0.013 | <0.001*** |
| Species evenness | 0.036 | 0.022 | 0.102 |
| Functional diversity (Rao Q) | −0.305 | 0.170 | 0.076 |
| rip-rap structure | −0.037 | 0.044 | 0.393 |
| Stepped concrete structure | −0.084 | 0.033 | 0.012* |
| Occupancy | 0.029 | 0.082 | 0.728 |
| Species richness: rip-rap structure | 0.014 | 0.017 | 0.385 |
| Species richness: stepped concrete structure | −0.010 | 0.016 | 0.547 |

## 3.2 | Participant motivations

The previous analysis showed that participants generally preferred biologically diverse communities with less regular underlying structures. We next conducted an analysis of free-text data to better understand what drove people's preferences for images of the presented artificial structures. In all, 500 people answered optional free-text questions, and generated 1333 valid text responses. We found 24 positive and 22 negative motivational themes for finding structures aesthetically appealing or unappealing. These included the positive attributes of 'natural', 'diverse', 'colourful', 'exploration' and 'interesting structure', as well as negative aspects such as 'inaccessibility', seaweed-related associations ('slimy', 'dirty' and the presence of 'green' algae), perceptually 'hard' structures, as well as the lack of diversity in 'depauperate' (low diversity) communities. Of these motivations, naturalness and diversity were the two most mentioned positive and negative drivers of appeal by far (Figure 4; Table S13), and were strongly related to reported aesthetic appeal

| | Estimate | SE | *p*-value |
|---|---|---|---|
| Intercept | 7.109 | 0.121 | <0.001*** |
| Species richness | 0.068 | 0.019 | <0.001*** |
| Species evenness | 0.079 | 0.034 | 0.023* |
| Functional diversity (Rao Q) | −1.113 | 0.385 | 0.076 |
| Stepped concrete structure | −0.154 | 0.034 | 0.393 |
| Occupancy | 0.213 | 0.157 | 0.728 |
| Species richness: stepped concrete structure | 0.047 | 0.020 | 0.385 |

TABLE 2 Different facets of biodiversity and structure type influence aesthetic appeal at close-up viewing scales. Regression model summary table examining the role of biodiversity, structure and image properties in driving aesthetic appeal scores. Asterisks for *p*-values represent significant results at α = <0.05 (*) and <0.001 (***)

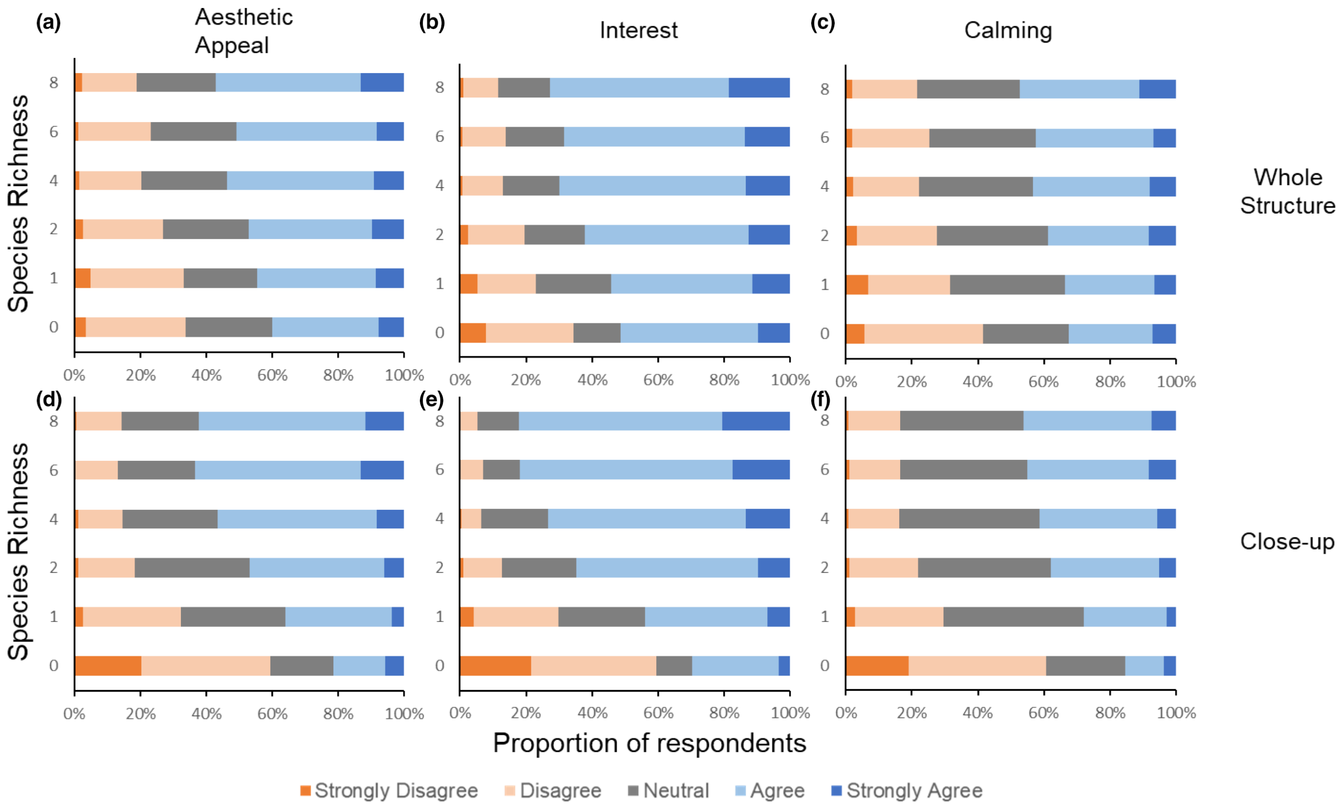


FIGURE 3 Species richness positively influences aesthetic appeal (left), interest (Centre) and sense of calm (right) at the structure scale (a–c), and increases in strength at close-up (d–f) viewing scales. The percentage of respondents from 5-Likert agreement categories (strongly disagree–strongly agree)

scores (Figure 5a,b). These motivations appeared to largely explain people's preferences of structure type and species richness. We found strong effects of structure type on mentions of naturalness vs. artificialness, with greater mentions of naturalness associated with the old wall and riprap shores, particularly as these shore types were perceived as appealing or strongly appealing. Species richness was only very weakly associated with mentions of naturalness (Figure 5c). On the other hand, positive mentions of diversity were associated with positive appeal rating irrespective of structure type (Figure 5b), while species richness was clearly associated with increased mentions of diversity. Thus, the influence of structure type appeared to be largely determined by a perception of naturalness, while the influence of species richness was determined by a positive perception of diversity.

## 3.3 | Demographic effects

Of the 937 people that answered the image questions in the survey, 754 people completed the demographics section. The analysis of demographic effects is presented above for the whole structure scale (Table 3), and full results table are provided in Tables S5, S7, S9 and S6, S8, S10 for structure and close up scales, respectively. Participants identifying as ‘female’ were overrepresented in the survey (71%; Table 4), but other demographic groups were well represented. While every care was taken to recruit a wide cross-section of the public, people working in biological, environmental or maritime roles were proportionally overrepresented compared to the UK and Irish general population (35% of sample). Within our sample population, we observed that demographic differences

**TABLE 3** Species richness enhances aesthetic appeal, interest and sense of calm provided by coastal scenes at the structure scale, whereas artificial stepped concrete structures reduced benefits. Model summaries for significant predictors of appeal, interest and calm from the Likert CLMM models, including demographic effects from 754 participants. Full model summary tables can be found in Tables S5–S10). Asterisks for *p*-values represent significant results at α = <0.05 (*), <0.01 (**) and <0.001 (***)

| | Estimate | SE | *p*-value |
|---|---|---|---|
| Aesthetic appeal (*n* = 3765) | | | |
| Species richness | 0.893685 | 0.185244 | <0.001*** |
| Stepped concrete wall (structure) | −1.34321 | 0.286337 | <0.001*** |
| Participant age | −0.35316 | 0.122385 | <0.001*** |
| Works in industry | −0.24605 | 0.102839 | 0.0163* |
| Ocean connectedness | 1.38458 | 0.694684 | 0.0462* |
| Species richness: ocean connectedness | −1.12187 | 0.435947 | 0.0100** |
| Interest (*n* = 3770) | | | |
| Species richness | 0.716235 | 0.195321 | <0.001*** |
| Stepped concrete wall (structure) | −2.30654 | 0.300249 | <0.001*** |
| Participant age | −0.35187 | 0.138959 | 0.0113* |
| Species richness: stepped concrete wall | 0.325097 | 0.159688 | 0.0417* |
| Sense of calm (*n* = 3770) | | | |
| Species richness | 0.490491 | 0.182809 | 0.0070** |
| Stepped concrete wall (structure) | −1.61119 | 0.290972 | <0.001*** |
| Participant age | −0.2915 | 0.134378 | 0.0300* |
| Works in industry | −0.3003 | 0.11293 | 0.0078** |

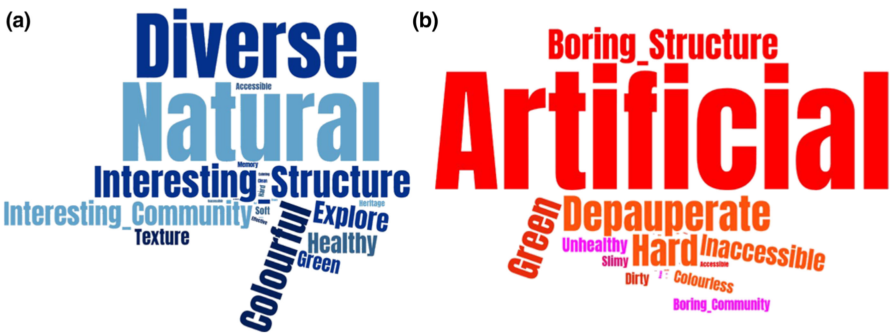


**FIGURE 4** Perceived naturalness and diversity were the most important drivers of aesthetic appeal of artificial structures. The word clouds visualise the number of mentions of different motivations for finding a structure appealing (panel a, blue hues) or unappealing (panel b, red hues). Letter size indicates the number of mentions. Underlying data are presented in Table S12

between participants led to slightly different participant aesthetic appeal (Tables S5, S7 and S9). Participant age had a slightly negative effect on aesthetic, interest and sense of calm appraisals, with older participants more likely to award lower scores, whereas increases in self-reported 'ocean connectedness' led to participants awarding slightly higher aesthetic appeal scores, but did not influence interest and calming scores. For aesthetic appeal, participants that reported high levels of ocean connectedness also responded more strongly and positively to species richness of communities than those reporting lower ocean connectedness. However, participants working in environmental or biology jobs were slightly more likely to award lower aesthetic appeal and sense of calm scores than those who did not work in an environmental industry. At the close-up scale, however, we found demographic effects did not influence any of the perception metrics (Tables S6, S8 and S10), and gender identity had no effect at either scale.

## 4 | DISCUSSION

Despite growing interest in how biodiversity affects cultural services, there have been few experimental tests of the role biodiversity's facets play in determining people's affective emotional responses to ecological communities. Furthermore, whether biodiversity elicits positive perceptions in more peripheral or unfamiliar habitats remains uncertain. Our experiment test, set across globally proliferating coastal urban environments, shows that biodiversity affects multiple affective emotions, but that these influences depend on both the biodiversity facet and viewing scale. Specifically, species richness and evenness increased aesthetic, interest and calming qualities, while functional diversity reduced these responses, and all influences of biodiversity were stronger at the small—close-up—scale. Alongside biodiversity, less uniform and more complex structures were preferred.

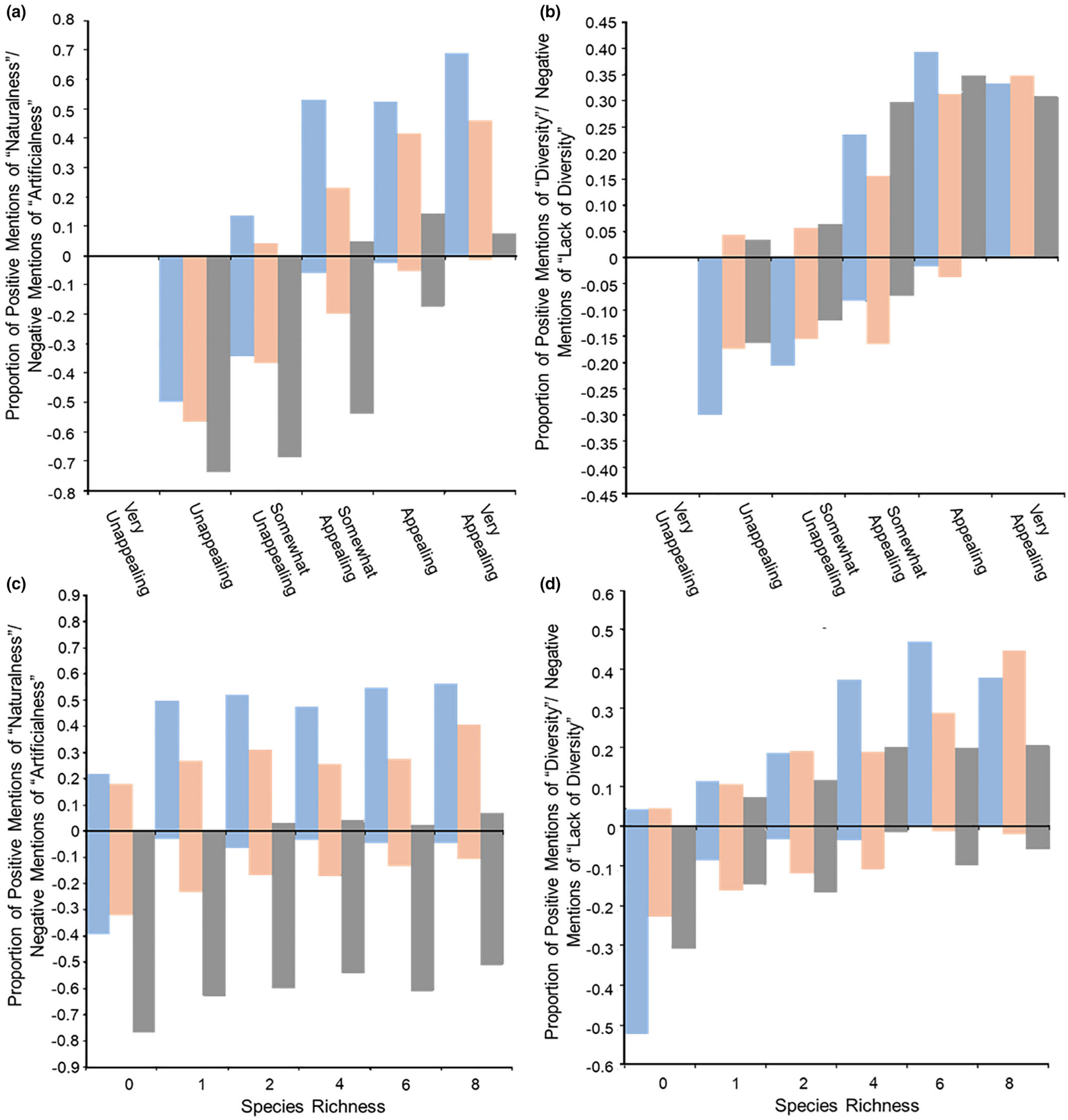


FIGURE 5 Positive mentions of the important motivators of 'naturalness' and 'diversity' increase in line with appeal, while positive mentions of 'diversity' increased with the species richness of communities. The top two panels represent the proportion of respondents mentioning (a) naturalness/artificialness or (b) diversity/lack of diversity as their motivations for finding scenes aesthetically appealing or unappealing. The bottom two panels represent the role of species richness in driving (c) perceived naturalness and (d) perceived diversity reported by participants

Finally, our text analysis suggests that species diversity has positive effects by increasing perceived 'diversity', while irregular underlying structures illicit positive responses by appearing more 'natural'. Collectively, these results imply that managing and designing urban coastal environments to encourage more biologically diverse and naturalistic environments, particularly with irregular structures that support more species, will serve to enhance the flow of cultural services.

How biodiversity of coastal structures is perceived by people was unknown and we suspected that the presence of disliked or unfamiliar species might generate weaker or even negative relationships between diversity and aesthetic appeal,

**TABLE 4** Demographic background summaries for the participants for the online study who completed the demographic questions

| Category | Number of participants |
|---|---|
| Gender identity | |
| Female | 537 |
| Male | 214 |
| Other gender identity | 3 |
| Age | |
| 18–30 | 166 |
| 31–45 | 278 |
| 46–60 | 221 |
| 61+ | 89 |
| Frequency of coastal visits | |
| I have never been to the coast | 1 |
| I rarely visit the coast | 153 |
| I visit the coast at least once a month | 201 |
| I visit the coast at least once a week | 129 |
| I live on the coast | 270 |
| Work in environmental related job | |
| No | 457 |
| Yes, for a port authority or in port operations | 8 |
| Yes, in a regulatory environmental role | 50 |
| Yes, in biological sciences | 214 |
| Yes, in civil engineering | 25 |
| Colour-blindness | |
| Yes | 10 |
| No | 744 |
| Ocean connectedness (see Table S3) | |
| No connection | 58 |
| Some connection | 295 |
| Strong connection | 290 |
| 'As one' | 106 |

if not interest. However, despite negative associations with seaweed species by participants—and previous evidence of negative seaweed associations (Limburg et al., 2010; MacLeod et al., 2002; Morgan, 1999b)—we found a strong positive effect of species diversity on the aesthetic appeal of common coastal structures, which persisted regardless of demographic background. The presence of this diversity–aesthetic relationship suggests that diversity effects can override potentially negative identity effects. The diversity–aesthetic relationship also appeared to be driven by speciose structures being accurately perceived as more diverse—even at the structure scale where species differences were hard to discern—with perceived diversity found to be a key driver of aesthetic appeal from our textual analysis. These findings are in line with previous work in terrestrial systems (Dallimer et al., 2012; Hoyle et al., 2017; Southon et al., 2018), where perceived diversity and naturalness have been seen to drive appeal and engagement (Dodds et al., 2010; Turpie, 2003).

The positive effects of richness and evenness also extended to other affective emotions of interest and calming potential, which can mediate educational (Kashdan & Silvia, 2009; Krapp, 1999; Renninger et al., 2014) and well-being (Cracknell et al., 2016; Fisher et al., 2021; White et al., 2017) cultural ecosystem service benefits. Self-reported sense of calm increased similarly to aesthetic appeal in our study despite a exhibiting a slightly lower baseline calming potential than was observed for appeal. Previous studies have indicated that restorative calming properties of scenes or landscapes may be strongly linked to aesthetic appeal, as the same properties such as naturalness and ecological quality are thought to be important in reducing stress induced by the psycho-evolutionary appraisal of habitat suitability, favouring perceptually 'healthy' ecosystems (Bratman et al., 2019; Kaplan, 1987; Orians & Heerwagen, 1992). Importantly, species diversity can substantially contribute to human appraisals of the perceptual naturalness and ecological health of landscapes (Barker & Fisher, 2019; Rapport et al., 1998; Tribot et al., 2018) and as such may promote a sense of calm and relaxation in people, ultimately reducing stress (de Kort et al., 2006; Fritz et al., 2010; Van Den Berg & Custers, 2011) and providing mental and physical well-being benefits (Gu et al., 2015; Pálsdóttir et al., 2018).

Interest, in particular, increased strongly with species richness and accumulated more quickly with diversity than aesthetic appeal or sense of calm. This rapid accumulation of interest with increasing diversity was likely driven through a combination of increasing visual diversity, complexity and increasing probability of including novel species—mechanisms which have been previously demonstrated to drive interest (Kashdan & Silvia, 2009; Krapp, 1999; Silvia, 2008)—and an increase in participant reported desire to explore the 'unseen' diversity potential which can be offered by seaweed canopies (Martens, 2016). These diversity–interest relationships are expected to provide strong motivations for exploration and facilitate learning experiences (Ballantyne et al., 2007; Fairchild et al., 2018; Simmons, 1998), ultimately providing educational opportunities (Kashdan & Silvia, 2009; Krapp, 1999; Renninger et al., 2014). Furthermore, this strong diversity–interest relationship, and the apparent decoupling of the magnitude of diversity–interest relationships from calming potential and the better understood aspect of aesthetic appeal (Cupchik & Gebotys, 1990; Kashdan & Silvia, 2009; Turner & Silvia, 2006), suggests that diversity independently drives multiple aspects of perception—and therefore supporting cultural and well-being services—through different mechanisms.

How biodiversity influences the functions and values of ecosystems has been a highly active area of research in ecology (Balvanera et al., 2016; Gamfeldt & Roger, 2017; Lefcheck et al., 2015), with theory suggesting these relationships can be strongly scale dependent (Isbell et al., 2017; Pasari et al., 2013). Our work shows that scale dependence also extends to diversity–aesthetics and diversity–interest relationships. Indeed, we found that viewing scale determined the impact of several facets of biodiversity on aesthetic, and interest benefits. Previous studies have tended to focus on broader, feature or landscape scale, effects of biodiversity (Dallimer et al., 2012; Lindemann-Matthies et al., 2010; Tribot et al., 2019), but close-up scales are also relevant because coastal structures are frequently used intimately, providing a setting for exploration and learning opportunities through close examination of the rocks and ecological communities which can inhabit them (Martin et al., 2006). Our study found a marked strengthening of species richness and evenness effects at the close-up scale, which was likely explained through differences between species and communities (e.g. identity, colour, texture and shape, dominance)—and the desirable property of 'diversity' underlined in the textual analysis—being more perceptible at close-up viewing scales.

While species diversity strongly contributed to multiple aspects of perception at both the landscape scale and close-up scale, we observed more complex relationships with functional diversity. We found no evidence that functional diversity (measured as Rao's *Q*) substantially affected aesthetic appraisal, interest or calming potential at the whole structure level, but we observed stronger, negative effects at close-up viewing scales. This suggests that the inclusion of organisms with the extreme trait differences may be undesirable at close viewing scales where species (and trait) differences can be more readily resolved, either through species with contrasting extreme traits being disliked (Ulrich, 1983), or by exceeding some threshold of visual complexity, which may lead to poorer aesthetic appraisals of structures (Forsythe et al., 2011). Combined with recent findings from coral reef fish assemblages that functional diversity metrics can have weak, or hump-shaped, relationships with aesthetic preference and be outweighed in importance by species richness (Tribot et al., 2019), this result suggests that—unlike ecosystem functions such as primary productivity, and related provisioning and regulating services, which are often strongly explained by functional diversity (Cadotte et al., 2011; Gross et al., 2017; Mensah et al., 2020)—functional diversity and cultural services related to aesthetics may be somewhat decoupled or even negatively associated and may trade-off against different functions and services. Overall, our results underline that different facets of biodiversity can have different impacts on people's preferences and at different focal scales, although more work is required to fully untangle the causes and generality of these differences, including across other systems and habitats.

Furthermore, the application of these scale-dependent relationships to other systems will depend on the spatial structure of communities. In our model communities, species were well-mixed spatially, such that close-up images contained a large proportion of the overall species pool. However, in some systems and contexts, systems can be patchy with different patches dominated by different species such that small-scale (close-up) diversity can be much lower than wider—landscape—diversity. In such cases, aesthetic appreciation and even interest may be greater at the larger landscape scale. Future work should explore the interaction between spatial community organisation and scales of diversity (i.e. alpha, beta and gamma) and human perceptions and well-being.

While more diverse structures were seen to be more natural, diverse and subsequently appealing, the structural characteristics of underlying coastal structures were highly important for aesthetic appraisals of appeal. More obviously engineered structures, such as the concrete stepped walls, were far less preferred than those which were perceived to be more natural. The less defined edges and facets of the riprap and heritage stone walls led to greater perceived naturalness and perceptions of diversity than for similar communities on the hard-edged, regular stepped concrete wall structure, with many participants noting the apparent 'hardness' of the structure as an undesirable trait which influenced their overall aesthetic appraisal. This desire for more natural or 'organic' shapes is a well-understood aesthetic driver of building architecture (Coburn et al., 2019; Vartanian et al., 2013), shifting baseline aesthetic appreciation, interest and calming potential of structures—underlining the multiple ecological and anthropogenic motivators for aesthetic appraisal, and the particular importance of structural properties which needs to be better integrated into future natural aesthetics studies.

The strong relationships between species diversity and aesthetics, interest and calming potential demonstrate the importance of human–nature interactions that healthy, diverse ecosystems can provide. This further strengthens growing arguments for the need to better integrate cultural ecosystem services into the discourse around the value of nature—which has tended to be neglected (Chan et al., 2012; Daniel et al., 2012; Martin et al., 2016)—into coastal management and planning activities. At the broad scale, our findings suggest that managing coastal structures to promote diverse communities is likely to positively contribute towards well-being commitments set out in international and national goals and legislation, such as the U.N. Sustainable Development Goals (United Nations General Assembly, 2015; Wood, Harsant, et al., 2018; Wood, Jones, et al., 2018) or the Wellbeing of Future Generations Act 2015 (Wales), as well as directly benefiting local communities. Given the importance of aesthetics in driving attitudes and generating local support for changes to—or creation of—artificial coastal structures, we found strong evidence that images of biodiverse seawalls are more desirable to communities than highly engineered, low diversity depauperate structures, and found that these biodiversity benefits were realised regardless of demographic background. However, it is important to note that other aspects of nature experiences may not be captured by visual senses alone (e.g. sound, smell or touch), with growing evidence suggesting that aesthetic experiences and well-being benefits can be further enhanced through non-visual stimuli driven by increased biodiversity (Austen et al., 2021; Fisher et al., 2021; Franco et al., 2017). This suggests that while the positive biodiversity–perceptions relationships presented here are likely to be good indicators of human benefits, our value estimates from image-based elicitation surveys associated with diverse coastal communities are likely to be conservative (Fisher et al., 2021; Franco et al., 2017; Schebella et al., 2019). Future studies, including controlled scenes as well as in-situ surveys, are important to address this uncertainty. Our results also suggest that increasing engagement with coastal areas may also generate greater biodiversity—well-being benefits, with the feeling of connectedness to the sea enhancing biodiversity–appeal relationships. Along with evidence that biodiverse communities can support a wide range of supporting and regulating services which sustain resilient and healthy ecosystems (Balvanera et al., 2016; Barbier et al., 2011; Cardinale et al., 2012), our findings support calls to explicitly include ecologically sensitive design into coastal defence projects, either through retrofitting existing infrastructure to improve biodiversity outcomes (Evans et al., 2016; O'Shaughnessy et al., 2020), or through including biodiversity-enhancing features on new or replacement structures (Firth, Thompson, et al., 2014; Perkins et al., 2015) to enhance well-being ecosystem service provisions.

## 5 | CONCLUSION

In this study, we provide experimental evidence that multiple aspects of perception—which are important mediators of a wealth of educational, aesthetic and well-being ecosystem services—are generally enhanced by specific facets of biodiversity in urbanised coastal settings. While limited evidence of biodiversity enhancement of individual aesthetic and well-being benefits exists for marine systems, we show how despite negative preconceptions of intertidal species, more diverse artificial coastal habitats can still provide attractive, interesting and restorative spaces for people. This simultaneous facilitation of the perceptions of interest, aesthetic appeal and sense of calm in this study, coupled with previous evidence of provisioning and regulating services, suggests that biodiversity plays a crucial role in providing multi-functional coastal urban spaces which maximise human benefits at multiple scales of use. As such, management interventions that enhance diversity on urban coastal structures may help offset some of the negative ecological and cultural costs associated with coastal urbanisation. However, the unexpected effects of functional diversity and evidence of scale dependence of biodiversity–benefit relationships highlight those mechanisms driving often-neglected cultural and well-being benefits need to be explored more fully to maximise the impact of sustainable biodiversity management and enhancement efforts.

### 5.1 | Study limitations

A further discussion on the limitations of the methodologies and study system is found in the 'Limitations' section in the Supplementary Materials.

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**CONFLICT OF INTEREST**

The authors declare no conflict of interest.

**AUTHORS' CONTRIBUTIONS**

T.P.F. and J.N.G. conceptually conceived and developed the study and contributed equally to the writing of the manuscript; T.P.F. and J.W. created the composite images, online survey templates and led participant recruitment; T.P.F. led the analysis of survey results and was supported by J.N.G. and J.W.

**DATA AVAILABILITY STATEMENT**

Anonymised summary data used in the analysis of this experiment are archived on Figshare at https://doi.org/10.6084/m9.figshare.19551037

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**REFERENCES**

Austen, G. E., Dallimer, M., Irvine, K. N., Maund, P. R., Fish, R. D., & Davies, Z. G. (2021). Exploring shared public perspectives on biodiversity attributes. *People and Nature*, *3*(4), 901–913. https://doi.org/10.1002/pan3.10237

Ballantyne, R., Packer, J., Hughes, K., & Dierking, L. (2007). Conservation learning in wildlife tourism settings: Lessons from research in zoos and aquariums. *Environmental Education Research*, *13*(3), 367–383.

Balvanera, P., Quijas, S., Martin-Lopez, B., Barrios, E., Dee, L., Isbell, F., Durance, I., White, P., Blanchard, R., & Groot, R. S. d. (2016). The links between biodiversity and ecosystem services. In *Routledge handbook of ecosystem services* (1 ed., pp. 45–61). Routledge. https://doi.org/10.4324/9781315775302-5

Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E. W., Stier, A. C., & Silliman, B. R. (2011). The value of estuarine and coastal ecosystem services. *Ecological Monographs*, *81*(2), 169–193. https://doi.org/10.1890/10-1510.1

Barker, T., & Fisher, J. (2019). Ecosystem health as the basis for human health. In *Water and sanitation-related diseases and the changing environment: Challenges, interventions, and preventive measures* (2nd ed., pp. 244–254). John Wiley & Sons.

Barragán, J. M., & de Andrés, M. (2015). Analysis and trends of the world's coastal cities and agglomerations. *Ocean & Coastal Management*, *114*, 11–20. https://doi.org/10.1016/j.ocecoaman.2015.06.004

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01

Bell, S. L., Phoenix, C., Lovell, R., & Wheeler, B. W. (2015). Seeking everyday wellbeing: The coast as a therapeutic landscape. *Social Science & Medicine*, *142*, 56–67. https://doi.org/10.1016/j.socscimed.2015.08.011

Bell, S., Mishra, H. S., Elliott, L. R., Shellock, R., Vassiljev, P., Porter, M., Sydenham, Z., & White, M. P. (2020). Urban blue acupuncture: A protocol for evaluating a complex landscape design intervention to improve health and wellbeing in a coastal community. *Sustainability*, *12*(10), 4084. https://doi.org/10.3390/su12104084

Bosman, C., Dedekorkut-Howes, A., & Leach, A. (2016). *Off the plan: The urbanisation of the Gold Coast*. Csiro Publishing.

Botta-Dukát, Z. (2005). Rao's quadratic entropy as a measure of functional diversity based on multiple traits. *Journal of Vegetation Science*, *16*(5), 533–540. https://doi.org/10.1111/j.1654-1103.2005.tb02393.x

Bratman, G. N., Anderson, C. B., Berman, M. G., Cochran, B., de Vries, S., Flanders, J., Folke, C., Frumkin, H., Gross, J. J., Hartig, T., Kahn, P. H., Kuo, M., Lawler, J. J., Levin, P. S., Lindahl, T., Meyer-Lindenberg, A., Mitchell, R., Ouyang, Z., Roe, J., … Daily, G. C. (2019). Nature and mental health: An ecosystem service perspective. *Science Advances*, *5*(7), eaax0903. https://doi.org/10.1126/sciadv.aax0903

Breheny, P., & Burchett, W. (2016). *visreg: Visualization of regression models*. Retrieved from https://CRAN.R-project.org/package=visreg

Bulleri, F., & Chapman, M. G. (2004). Intertidal assemblages on artificial and natural habitats in marinas on the north-west coast of Italy. *Marine Biology*, *145*(2), 381–391. https://doi.org/10.1007/s00227-004-1316-8

Burak, S., Dogˇan, E., & Gaziogˇlu, C. (2004). Impact of urbanization and tourism on coastal environment. *Ocean & Coastal Management*, *47*(9), 515–527. https://doi.org/10.1016/j.ocecoaman.2004.07.007

Cadotte, M. W., Carscadden, K., & Mirotchnick, N. (2011). Beyond species: Functional diversity and the maintenance of ecological processes and services. *Journal of Applied Ecology*, *48*(5), 1079–1087. https://doi.org/10.1111/j.1365-2664.2011.02048.x

Cardinale, B. J., Emmett Duffy, J., Gonzalez, A., Hooper, D. U., Perrings, C., Venail, P., Narwani, A., Mace, G. M., Tilman, D., Wardle, D. A., Kinzig, A. P., Daily, G. C., Loreau, M., Grace, J. B., Larigauderie, A., Srivastava, D. S., & Naeem, S. (2012). Biodiversity loss and its impact on humanity. *Nature*, *486*(7401), 59–67.

Chan, K. M. A., Satterfield, T., & Goldstein, J. (2012). Rethinking ecosystem services to better address and navigate cultural values. *Ecological Economics*, *74*, 8–18. https://doi.org/10.1016/j.ecolecon.2011.11.011

Chaudhary, C., Richardson, A. J., Schoeman, D. S., & Costello, M. J. (2021). Global warming is causing a more pronounced dip in marine species richness around the equator. *Proceedings of the National Academy of Sciences of the United States of America*, *118*(15). https://doi.org/10.1073/pnas.2015094118

Chiesura, A. (2004). The role of urban parks for the sustainable city. *Landscape and Urban Planning*, *68*(1), 129–138. https://doi.org/10.1016/j.landurbplan.2003.08.003

Christensen, R. H. B. (2018). Cumulative link models for ordinal regression with the R package ordinal. *Journal of Statistical Software*. Submitted. Retrieved from http://cran.uni-muenster.de/web/packages/ordinal/vignettes/clm_article.pdf

Christopher, K. (2019). *Personalised Prediction of self-reported emotion responses to music stimuli*. Retrieved from http://researcharchive.vuw.ac.nz/handle/10063/8091

Clark, A. P., Howard, K. L., Woods, A. T., Penton-Voak, I. S., & Neumann, C. (2018). Why rate when you could compare? Using the "EloChoice" package to assess pairwise comparisons of perceived physical strength. *PLoS One*, *13*(1), e0190393. https://doi.org/10.1371/journal.pone.0190393

Coburn, A., Kardan, O., Kotabe, H., Steinberg, J., Hout, M. C., Robbins, A., MacDonald, J., Hayn-Leichsenring, G., & Berman, M. G. (2019). Psychological responses to natural patterns in architecture. *Journal of Environmental Psychology*, *62*, 133–145. https://doi.org/10.1016/j.jenvp.2019.02.007

Cordell, J. R., Toft, J. D., Munsch, S. H., & Goff, M. (2017). Benches, beaches, and bumps: How habitat monitoring and experimental science can inform urban seawall design. In *Living shorelines* (pp. 421–438). CRC Press. https://doi.org/10.1201/9781315151465

Cracknell, D., White, M. P., Pahl, S., Nichols, W. J., & Depledge, M. H. (2016). Marine biota and psychological well-being: A preliminary examination of dose–response effects in an aquarium setting. *Environment and Behavior*, *48*(10), 1242–1269.

Cupchik, G. C., & Gebotys, R. J. (1990). Interest and pleasure as dimensions of aesthetic response. *Empirical Studies of the Arts*, *8*(1), 1–14. https://doi.org/10.2190/L789-TPPY-BD2Q-T7TW

Dallimer, M., Irvine, K. N., Skinner, A. M., Davies, Z. G., Rouquette, J. R., Maltby, L. L., & Gaston, K. J. (2012). Biodiversity and the feel-good factor: Understanding associations between self-reported human well-being and species richness. *Bioscience*, *62*(1), 47–55.

Daniel, T. C., Muhar, A., Arnberger, A., Aznar, O., Boyd, J. W., Chan, K. M., & Grêt-Regamey, A. (2012). Contributions of cultural services to the ecosystem services agenda. *Proceedings of the National Academy of Sciences of the United States of America*, *109*(23), 8812–8819.

de Kort, Y. A. W., Meijnders, A. L., Sponselee, A. A. G., & IJsselsteijn, W. A. (2006). What's wrong with virtual trees? Restoring from stress in a mediated environment. *Journal of Environmental Psychology*, *26*(4), 309–320. https://doi.org/10.1016/j.jenvp.2006.09.001

de Pinho, J. R., Grilo, C., Boone, R. B., Galvin, K. A., & Snodgrass, J. G. (2014). Influence of aesthetic appreciation of wildlife species on attitudes towards their conservation in Kenyan agropastoralist communities. *PLoS One*, *9*, 2.

Dodds, R., Graci, S. R., & Holmes, M. (2010). Does the tourist care? A comparison of tourists in Koh phi phi, Thailand and Gili Trawangan, Indonesia. *Journal of Sustainable Tourism*, *18*(2), 207–222. https://doi.org/10.1080/09669580903215162

Dornelas, M., Gotelli, N. J., McGill, B., Shimadzu, H., Moyes, F., Sievers, C., & Magurran, A. E. (2014). Assemblage time series reveal biodiversity change but not systematic loss. *Science*, *344*(6181), 296–299. https://doi.org/10.1126/science.1248484

Dorwart, C. E., Moore, R. L., & Leung, Y.-F. (2009). Visitors' perceptions of a trail environment and effects on experiences: A model for nature-based recreation experiences. *Leisure Sciences*, *32*(1), 33–54. https://doi.org/10.1080/01490400903430863

Elo, A. E. (1978). *The rating of Chessplayers*. Past and Present.

Evans, A. J., Firth, L. B., Hawkins, S. J., Hall, A. E., Ironside, J. E., Thompson, R. C., & Moore, P. J. (2019). From ocean sprawl to blue-green infrastructure–a UK perspective on an issue of global significance. *Environmental Science & Policy*, *91*, 60–69.

Evans, A. J., Firth, L. B., Hawkins, S. J., Morris, E. S., Goudge, H., & Moore, P. J. (2016). Drill-cored tide pools: An effective method of ecological enhancement on artificial structures. *Marine and Freshwater Research*, *67*(1), 123–130.

Fairchild, T. P., Fowler, M. S., Pahl, S., & Griffin, J. N. (2018). Multiple dimensions of biodiversity drive human interest in tide pool communities. *Scientific Reports*, *8*(1), 15234. https://doi.org/10.1038/s41598-018-33155-x

Firth, L. B., Browne, K. A., Knights, A. M., Hawkins, S. J., & Nash, R. (2016). Eco-engineered rock pools: A concrete solution to biodiversity loss and urban sprawl in the marine environment. *Environmental Research Letters*, *11*(9), 094015. https://doi.org/10.1088/1748-9326/11/9/094015

Firth, L. B., Schofield, M., White, F. J., Skov, M. W., & Hawkins, S. J. (2014). Biodiversity in intertidal tide pools: Informing engineering criteria for artificial habitat enhancement in the built environment. *Marine Environmental Research*, *102*, 122–130.

Firth, L. B., Thompson, R. C., Bohn, K., Abbiati, M., Airoldi, L., Bouma, T. J., Bozzeda, F., Ceccherelli, V. U., Colangelo, M. A., Evans, A., Ferrario, F., Hanley, M. E., Hinz, H., Hoggart, S. P. G., Jackson, J. E., Moore, P., Morgan, E. H., Perkol-Finkel, S., Skov, M. W., … Hawkins, S. J. (2014). Between a rock and a hard place: Environmental and engineering considerations when designing coastal defence structures. *Coastal Engineering*, *87*, 122–135. https://doi.org/10.1016/j.coastaleng.2013.10.015

Fisher, J. C., Irvine, K. N., Bicknell, J. E., Hayes, W. M., Fernandes, D., Mistry, J., & Davies, Z. G. (2021). Perceived biodiversity, sound, naturalness and safety enhance the restorative quality and wellbeing benefits of green and blue space in a neotropical city. *Science of*

*the Total Environment*, *755*, 143095. https://doi.org/10.1016/j.scitotenv.2020.143095
Forsythe, A., Nadal, M., Sheehy, N., Cela-Conde, C. J., & Sawey, M. (2011). Predicting beauty: Fractal dimension and visual complexity in art. *British Journal of Psychology*, *102*(1), 49–70. https://doi.org/10.1348/000712610X498958
Franco, L. S., Shanahan, D. F., & Fuller, R. A. (2017). A review of the benefits of nature experiences: More than meets the eye. *International Journal of Environmental Research and Public Health*, *14*(8), 864. https://doi.org/10.3390/ijerph14080864
Fritz, C., Sonnentag, S., Spector, P. E., & McInroe, J. A. (2010). The weekend matters: Relationships between stress recovery and affective experiences. *Journal of Organizational Behavior*, *31*(8), 1137–1162. https://doi.org/10.1002/job.672
Fry, G., Tveit, M. S., Ode, Å., & Velarde, M. D. (2009). The ecology of visual landscapes: Exploring the conceptual common ground of visual and ecological landscape indicators. *Ecological Indicators*, *9*(5), 933–947. https://doi.org/10.1016/j.ecolind.2008.11.008
Fuller, R. A., Irvine, K. N., Devine-Wright, P., Warren, P. H., & Gaston, K. J. (2007). Psychological benefits of greenspace increase with biodiversity. *Biology Letters*, *3*(4), 390–394. https://doi.org/10.1098/rsbl.2007.0149
Gamfeldt, L., & Roger, F. (2017). Revisiting the biodiversity-ecosystem multifunctionality relationship. *Nature Ecology & Evolution*, *1*(7), 168. https://doi.org/10.1038/s41559-017-0168
Gamfeldt, L., Snäll, T., Bagchi, R., Jonsson, M., Gustafsson, L., Kjellander, P., Ruiz-Jaen, M. C., Fröberg, M., Stendahl, J., Philipson, C. D., Mikusiński, G., Andersson, E., Westerlund, B., Andrén, H., Moberg, F., Moen, J., & Bengtsson, J. (2013). Higher levels of multiple ecosystem services are found in forests with more tree species. *Nature Communications*, *4*, 1340. https://doi.org/10.1038/ncomms2328
Garrett, J. K., Clitherow, T. J., White, M. P., Wheeler, B. W., & Fleming, L. E. (2019). Coastal proximity and mental health among urban adults in England: The moderating effect of household income. *Health & Place*, *59*, 102200. https://doi.org/10.1016/j.healthplace.2019.102200
Graves, R. A., Pearson, S. M., & Turner, M. G. (2017). Species richness alone does not predict cultural ecosystem service value. *Proceedings of the National Academy of Sciences of the United States of America*, *114*(14), 3774–3779. https://doi.org/10.1073/pnas.1701370114
Gross, N., Bagousse-Pinguet, Y. L., Liancourt, P., Berdugo, M., Gotelli, N. J., & Maestre, F. T. (2017). Functional trait diversity maximizes ecosystem multifunctionality. *Nature Ecology & Evolution*, *1*(5), s41559-017-0132–017. https://doi.org/10.1038/s41559-017-0132
Gu, J., Strauss, C., Bond, R., & Cavanagh, K. (2015). How do mindfulness-based cognitive therapy and mindfulness-based stress reduction improve mental health and wellbeing? A systematic review and meta-analysis of mediation studies. *Clinical Psychology Review*, *37*, 1–12. https://doi.org/10.1016/j.cpr.2015.01.006
Gunnarsson, B., Knez, I., Hedblom, M., & Sang, A. A. O. (2017). Effects of biodiversity and environment-related attitude on perception of urban green space. *Urban Ecosystem*, *20*(1), 37–49.
Hall, A. E., Herbert, R. J. H., Britton, J. R., Boyd, I. M., & George, N. C. (2019). Shelving the coast with Vertipools: Retrofitting artificial rock pools on coastal structures as mitigation for coastal squeeze. *Frontiers in Marine Science*, *6*, 1–11. https://doi.org/10.3389/fmars.2019.00456
Hasler, D., & Suesstrunk, S. E. (2003). *Measuring colorfulness in natural images*, *5007*, 87–95. https://doi.org/10.1117/12.477378
Hawkins, S J., Pack, K. E., Firth, L. B., Mieszkowska, N., Evans, A. J., Martins, G. M., Åberg, P., Adams, L. C., Arenas, F., Boaventura, D. M., Bohn, K., Borges, C. D. G., Castro, J. J., Coleman, R. A., Crowe, T. P., Cruz, T., Davies, M. S., Epstein, G., Faria, J., … Jenkins, S. R. (2019). The intertidal zone of the north-East Atlantic region: Pattern and process. In G. A. Williams, K. Bohn, L. B. Firth, & S. J. Hawkins (Eds.), *Interactions in the marine benthos: Global patterns and processes* (pp. 7–46). Cambridge University Press. https://doi.org/10.1017/9781108235792.003
Hedley, J. (2013). *VidAna software for cover analysis from video footage or still images*. (1.0) [computer software]. Marine Spatial Ecology Lab, School of Biological Sciences, University Of Queensland. Retrieved from www.marinespatialecologylab.org/resources/vidana/
Heinzen, E. (2017). *elo: Elo Ratings*. (1.0.1) [R; R Statistical Computing]. Retrieved from https://CRAN.R-project.org/package=elo
Houlden, V., Weich, S., Albuquerque, J. P. de, Jarvis, S., & Rees, K. (2018). The relationship between greenspace and the mental wellbeing of adults: A systematic review. *PLoS One*, *13*(9), e0203000. https://doi.org/10.1371/journal.pone.0203000
Hoyle, H., Hitchmough, J., & Jorgensen, A. (2017). All about the 'wow factor'? The relationships between aesthetics, restorative effect and perceived biodiversity in designed urban planting. *Landscape and Urban Planning*, *164*, 109–123. https://doi.org/10.1016/j.landurbplan.2017.03.011
Hoyle, H., Jorgensen, A., & Hitchmough, J. D. (2019). What determines how we see nature? Perceptions of naturalness in designed urban green spaces. *People and Nature*, *1*(2), 167–180. https://doi.org/10.1002/pan3.19
Hynes, S., Ankamah-Yeboah, I., O'Neill, S., Needham, K., Xuan, B. B., & Armstrong, C. (2021). The impact of nature documentaries on public environmental preferences and willingness to pay: Entropy balancing and the blue planet II effect. *Journal of Environmental Planning and Management*, *64*(8), 1428–1456. https://doi.org/10.1080/09640568.2020.1828840
Isbell, F., Gonzalez, A., Loreau, M., Cowles, J., Díaz, S., Hector, A., Mace, G. M., Wardle, D. A., O'Connor, M. I., Duffy, J. E., Turnbull, L. A., Thompson, P. L., & Larigauderie, A. (2017). Linking the influence and dependence of people on biodiversity across scales. *Nature*, *546*(7656), 65–72. https://doi.org/10.1038/nature22899
Kang, Y., & Kim, E. J. (2019). Differences of restorative effects while viewing urban landscapes and green landscapes. *Sustainability*, *11*(7), 2129. https://doi.org/10.3390/su11072129
Kaplan, R. (2001). The nature of the view from home: Psychological benefits. *Environment and Behavior*, *33*(4), 507–542. https://doi.org/10.1177/00139160121973115
Kaplan, S. (1987). Aesthetics, affect, and cognition environmental preference from an evolutionary perspective. *Environment and Behavior*, *19*(1), 3–32.
Kaplan, S., Kaplan, R., & Wendt, J. S. (1972). Rated preference and complexity for natural and urban visual material. *Attention, Perception, & Psychophysics*, *12*(4), 354–356.
Kashdan, T. B., & Silvia, P. J. (2009). Curiosity and interest: The benefits of thriving on novelty and challenge. In *The Oxford handbook of positive psychology* (2nd ed., pp. 367–374). Oxford University Press. Retrieved from http://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780195187243.001.0001/oxfordhb-9780195187243-e-034
Kim, H., Lee, S., Uysal, M., Kim, J., & Ahn, K. (2015). Nature-based tourism: Motivation and subjective well-being. *Journal of Travel & Tourism Marketing*, *32*(sup1), S76–S96. https://doi.org/10.1080/10548408.2014.997958
Koss, R. S., & Kingsley, J. 'Yotti.' (2010). Volunteer health and emotional wellbeing in marine protected areas. *Ocean & Coastal Management*, *53*(8), 447–453. https://doi.org/10.1016/j.ocecoaman.2010.06.002
Koutrakis, E., Sapounidis, A., Marzetti, S., Marin, V., Roussel, S., Martino, S., Fabiano, M., Paoli, C., Rey-Valette, H., Povh, D., & Malvárez, C. G. (2011). ICZM and coastal defence perception by beach users: Lessons from the Mediterranean coastal area. *Ocean & Coastal Management*, *54*(11), 821–830. https://doi.org/10.1016/j.ocecoaman.2011.09.004

Krapp, A. (1999). Interest, motivation and learning: An educational-psychological perspective. *European Journal of Psychology of Education*, *14*(1), 23–40.

Laliberté, E., & Legendre, P. (2010). A distance-based framework for measuring functional diversity from multiple traits. *Ecology*, *91*(1), 299–305. https://doi.org/10.1890/08-2244.1

Lawrence, P. J., Evans, A. J., Jackson-Bué, T., Brooks, P. R., Crowe, T. P., Dozier, A. E., Jenkins, S. R., Moore, P. J., Williams, G. J., & Davies, A. J. (2021). Artificial shorelines lack natural structural complexity across scales. *Proceedings of the Royal Society B: Biological Sciences*, *288*(1951), 20210329. https://doi.org/10.1098/rspb.2021.0329

Lefcheck, J. S., Byrnes, J. E. K., Isbell, F., Gamfeldt, L., Griffin, J. N., Eisenhauer, N., Hensel, M. J. S., Hector, A., Cardinale, B. J., & Duffy, J. E. (2015). Biodiversity enhances ecosystem multifunctionality across trophic levels and habitats. *Nature Communications*, *6*, 6936. https://doi.org/10.1038/ncomms7936

Limburg, K. E., Luzadis, V. A., Ramsey, M., Schulz, K. L., & Mayer, C. M. (2010). The good, the bad, and the algae: Perceiving ecosystem services and disservices generated by zebra and quagga mussels. *Journal of Great Lakes Research*, *36*(1), 86–92. https://doi.org/10.1016/j.jglr.2009.11.007

Lindemann-Matthies, P., Junge, X., & Matthies, D. (2010). The influence of plant diversity on people's perception and aesthetic appreciation of grassland vegetation. *Biological Conservation*, *143*(1), 195–202.

Loke, L. H. L., & Todd, P. A. (2016). Structural complexity and component type increase intertidal biodiversity independently of area. *Ecology*, *97*(2), 383–393. https://doi.org/10.1890/15-0257.1

MacLeod, M., Silva, C. P. d., & Cooper, J. A. G. (2002). A comparative study of the perception and value of beaches in rural Ireland and Portugal: Implications for coastal zone management. *Journal of Coastal Research*, *18*(1), 14–24.

Marselle, M. R., Irvine, K. N., Lorenzo-Arribas, A., & Warber, S. L. (2016). Does perceived restorativeness mediate the effects of perceived biodiversity and perceived naturalness on emotional well-being following group walks in nature? *Journal of Environmental Psychology*, *46*, 217–232. https://doi.org/10.1016/j.jenvp.2016.04.008

Martens, L. (2016). From intergenerational transmission to intra-active ethical-generational becoming: Children, parents, crabs and rock-pooling. *Families, Relationships and Societies*, *5*(3), 447–462. https://doi.org/10.1332/204674316X14758498374746

Martin, C. L., Momtaz, S., Gaston, T., & Moltschaniwskyj, N. A. (2016). A systematic quantitative review of coastal and marine cultural ecosystem services: Current status and future research. *Marine Policy*, *74*, 25–32. https://doi.org/10.1016/j.marpol.2016.09.004

Martin, S., Thouzeau, G., Chauvaud, L., Jean, F., Guérin, L., & Clavier, J. (2006). Respiration, calcification, and excretion of the invasive slipper limpet, *Crepidula fornicata* L.: Implications for carbon, carbonate, and nitrogen fluxes in affected areas. *Limnology and Oceanography*, *51*(5), 1996–2007. https://doi.org/10.4319/lo.2006.51.5.1996

Matias, M. G., Underwood, A. J., Hochuli, D. F., & Coleman, R. A. (2010). Independent effects of patch size and structural complexity on diversity of benthic macroinvertebrates. *Ecology*, *91*(7), 1908–1915.

McKinney, M. L. (2006). Urbanization as a major cause of biotic homogenization. *Biological Conservation*, *127*(3), 247–260. https://doi.org/10.1016/j.biocon.2005.09.005

MEA. (2005). *Ecosystems and human well-being: Synthesis*. Island Press. http://chapter.ser.org/europe/files/2012/08/Harris.pdf

Mensah, S., Salako, K. V., Assogbadjo, A., Glèlè Kakaï, R., Sinsin, B., & Seifert, T. (2020). Functional trait diversity is a stronger predictor of multifunctionality than dominance: Evidence from an Afromontane forest in South Africa. *Ecological Indicators*, *115*, 106415. https://doi.org/10.1016/j.ecolind.2020.106415

Merkel, A., Säwe, F., & Fredriksson, C. (2021). The seaweed experience: Exploring the potential and value of a marine resource. *Scandinavian Journal of Hospitality and Tourism*, *21*(4), 1–16. https://doi.org/10.1080/15022250.2021.1879671

Mills, J. G., Brookes, J. D., Gellie, N. J. C., Liddicoat, C., Lowe, A. J., Sydnor, H. R., Thomas, T., Weinstein, P., Weyrich, L. S., & Breed, M. F. (2019). Relating urban biodiversity to human health with the 'Holobiont' concept. *Frontiers in Microbiology*, *10*, 1–8. https://doi.org/10.3389/fmicb.2019.00550

Momota, K., & Hosokawa, S. (2021). Potential impacts of marine urbanization on benthic macrofaunal diversity. *Scientific Reports*, *11*(1), 4028. https://doi.org/10.1038/s41598-021-83597-z

Moran, D. (2019). Back to nature? Attention restoration theory and the restorative effects of nature contact in prison. *Health & Place*, *57*, 35–43. https://doi.org/10.1016/j.healthplace.2019.03.005

Morgan, R. (1999a). Preferences and priorities of Recreational Beach users in Wales, UK. *Journal of Coastal Research*, *15*(3), 653–667.

Morgan, R. (1999b). Some factors affecting coastal landscape aesthetic quality assessment. *Landscape Research*, *24*(2), 167–184. https://doi.org/10.1080/01426399908706557

Moss, A., & Esson, M. (2010). Visitor interest in zoo animals and the implications for collection planning and zoo education programmes. *Zoo Biology*, *29*(6), 715–731.

Neumann, B., Vafeidis, A. T., Zimmermann, J., & Nicholls, R. J. (2015). Future coastal population growth and exposure to sea-level rise and coastal flooding—A global assessment. *PLoS ONE*, *10*(3), e0118571. https://doi.org/10.1371/journal.pone.0118571

Newbold, T., Hudson, L. N., Hill, S. L. L., Contu, S., Lysenko, I., Senior, R. A., Börger, L., Bennett, D. J., Choimes, A., Collen, B., Day, J., De Palma, A., Díaz, S., Echeverria-Londoño, S., Edgar, M. J., Feldman, A., Garon, M., Harrison, M. L. K., Alhusseini, T., … Purvis, A. (2015). Global effects of land use on local terrestrial biodiversity. *Nature*, *520*(7545), 45–50. https://doi.org/10.1038/nature14324

Nuojua, S., Pahl, S. & Thompson, R. (2021). Ocean connectedness and consumer responses to single-use packaging. Unpublished Data.

Oksanen, J., Blanchet, F. G., Friendly, M., Kindt, R., Legendre, P., McGlinn, D., Minchin, P. R., O'Hara, R. B., Simpson, G. L., Solymos, P., Stevens, M. H. H., Szoecs, E., & Wagner, H. (2017). *vegan: Community ecology package* (2.4) [Computer software]. Retrieved from https://CRAN.R-project.org/package=vegan

Orians, G. H., & Heerwagen, J. H. (1992). Evolved responses to landscapes. In *The adapted mind: Evolutionary psychology and the generation of culture* (pp. 555–579). Oxford University Press.

O'Shaughnessy, K. A., Hawkins, S. J., Evans, A. J., Hanley, M. E., Lunt, P., Thompson, R. C., Francis, R. A., Hoggart, S. P. G., Moore, P. J., Iglesias, G., Simmonds, D., Ducker, J., & Firth, L. B. (2020). Design catalogue for eco-engineering of coastal artificial structures: A multifunctional approach for stakeholders and end-users. *Urban Ecosystem*, *23*(2), 431–443. https://doi.org/10.1007/s11252-019-00924-z

Palliwoda, J., Kowarik, I., & von der Lippe, M. (2017). Human-biodiversity interactions in urban parks: The species level matters. *Landscape and Urban Planning*, *157*, 394–406. https://doi.org/10.1016/j.landurbplan.2016.09.003

Palmer, S. E., Schloss, K. B., & Sammartino, J. (2013). Visual aesthetics and human preference. *Annual Review of Psychology*, *64*(1), 77–107. https://doi.org/10.1146/annurev-psych-120710-100504

Pálsdóttir, A. M. K., Stigsdotter, U., Persson, D., Thorpert, P., & Grahn, P. (2018). The qualities of natural environments that support the rehabilitation process of individuals with stress-related mental disorder in nature-based rehabilitation. *Urban Forestry and Urban Greening*, *29*, 312–321. https://doi.org/10.1016/j.ufug.2017.11.016

Pasanen, T. P., Neuvonen, M., & Korpela, K. M. (2018). The psychology of recent nature visits: (how) are motives and Attentional focus related to post-visit restorative experiences, creativity, and emotional well-being? *Environment and Behavior*, *50*(8), 913–944. https://doi.org/10.1177/0013916517720261

Pasari, J. R., Levi, T., Zavaleta, E. S., & Tilman, D. (2013). Several scales of biodiversity affect ecosystem multifunctionality. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(25), 10219–10222.

Perkins, M. J., Ng, T. P. T., Dudgeon, D., Bonebrake, T. C., & Leung, K. M. Y. (2015). Conserving intertidal habitats: What is the potential of ecological engineering to mitigate impacts of coastal structures? *Estuarine, Coastal and Shelf Science*, *167*, 504–515. https://doi.org/10.1016/j.ecss.2015.10.033

Petrova, E. G., Mironov, Y. V., Aoki, Y., Matsushima, H., Ebine, S., Furuya, K., Petrova, A., Takayama, N., & Ueda, H. (2015). Comparing the visual perception and aesthetic evaluation of natural landscapes in Russia and Japan: Cultural and environmental factors. *Progress in Earth and Planetary Science*, *2*(1), 6. https://doi.org/10.1186/s40645-015-0033-x

Purcell, A. T., & Lamb, R. J. (1998). Preference and naturalness: An ecological approach. *Landscape and Urban Planning*, *42*(1), 57–66.

R Core Team. (2013). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. Retrieved from http://www.R-project.org/

Rapport, D. J., Costanza, R., & McMichael, A. J. (1998). Assessing ecosystem health. *Trends in Ecology & Evolution*, *13*(10), 397–402. https://doi.org/10.1016/S0169-5347(98)01449-9

Renninger, A., Hidi, S., & Krapp, A. (2014). *The role of interest in learning and development*. Psychology Press.

Sankaran, S., Derechin, J., & Christakis, N. A. (2021). CurmElo: The theory and practice of a forced-choice approach to producing preference rankings. *PLoS ONE*, *16*(5), e0252145. https://doi.org/10.1371/journal.pone.0252145

Schebella, M. F., Weber, D., Schultz, L., & Weinstein, P. (2019). The well-being benefits associated with perceived and measured biodiversity in Australian urban green spaces. *Sustainability*, *11*(3), 802. https://doi.org/10.3390/su11030802

Schultz, P. W. (2002). Inclusion with nature: The psychology of human–nature relations. In *psychology of sustainable development* (pp. 61–78). Springer. https://doi.org/10.1007/978-1-4615-0995-0_4

Schwind, J. K., McCay, E., Beanlands, H., Schindel Martin, L., Martin, J., & Binder, M. (2017). Mindfulness practice as a teaching-learning strategy in higher education: A qualitative exploratory pilot study. *Nurse Education Today*, *50*, 92–96. https://doi.org/10.1016/j.nedt.2016.12.017

Shwartz, A., Turbé, A., Simon, L., & Julliard, R. (2014). Enhancing urban biodiversity and its influence on city-dwellers: An experiment. *Biological Conservation*, *171*, 82–90. https://doi.org/10.1016/j.biocon.2014.01.009

Silvia, P. J. (2001). Interest and interests: The psychology of constructive capriciousness. *Review of General Psychology*, *5*(3), 270–290.

Silvia, P. J. (2006). *Exploring the psychology of interest*. Oxford University Press.

Silvia, P. J. (2008). Interest—The curious emotion. *Current Directions in Psychological Science*, *17*(1), 57–60. https://doi.org/10.1111/j.1467-8721.2008.00548.x

Silvia, P. J. (2012). *Human emotions and aesthetic experience* (pp. 250–275). Connecting Minds, Brain and Experience.

Simmons, D. (1998). Using natural settings for environmental education: Perceived benefits and barriers. *The Journal of Environmental Education*, *29*(3), 23–31. https://doi.org/10.1080/00958969809599115

Southon, G. E., Jorgensen, A., Dunnett, N., Hoyle, H., & Evans, K. L. (2018). Perceived species-richness in urban green spaces: Cues, accuracy and well-being impacts. *Landscape and Urban Planning*, *172*, 1–10. https://doi.org/10.1016/j.landurbplan.2017.12.002

Sun, Z., & Firestone, C. (2021). Curious objects: How visual complexity guides attention and engagement. *Cognitive Science*, *45*(4), e12933. https://doi.org/10.1111/cogs.12933

Thornhill, R. (2003). Darwinian aesthetics informs traditional aesthetics. In E. Voland & K. Grammer (Eds.), *Evolutionary aesthetics* (pp. 9–35). Springer. https://doi.org/10.1007/978-3-662-07142-7_2

Tribot, A.-S., Deter, J., Claverie, T., Guillhaumon, F., Villéger, S., & Mouquet, N. (2019). Species diversity and composition drive the aesthetic value of coral reef fish assemblages. *Biology Letters*, *15*(11), 20190703. https://doi.org/10.1098/rsbl.2019.0703

Tribot, A.-S., Deter, J., & Mouquet, N. (2018). Integrating the aesthetic value of landscapes and biological diversity. *Proceedings of the Royal Society B: Biological Sciences*, *285*(1886), 20180971. https://doi.org/10.1098/rspb.2018.0971

Tribot, A.-S., Mouquet, N., Villéger, S., Raymond, M., Hoff, F., Boissery, P., & Deter, J. (2016). Taxonomic and functional diversity increase the aesthetic value of coralligenous reefs. *Scientific Reports*, *6*, 1–12.

Turner, S. A., & Silvia, P. J. (2006). Must interesting things be pleasant? A test of competing appraisal structures. *Emotion*, *6*(4), 670–674. https://doi.org/10.1037/1528-3542.6.4.670

Turpie, J. K. (2003). The existence value of biodiversity in South Africa: How interest, experience, knowledge, income and perceived level of threat influence local willingness to pay. *Ecological Economics*, *46*(2), 199–216. https://doi.org/10.1016/S0921-8009(03)00122-8

Ulrich, R. S. (1983). Aesthetic and affective response to natural environment. In I. Altman & J. F. Wohlwill (Eds.), *Behavior and the natural environment* (pp. 85–125). Springer US. https://doi.org/10.1007/978-1-4613-3539-9_4

United Nations General Assembly. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development* (A/RES/70/1). Retrieved from https://sdgs.un.org/2030agenda

Van Den Berg, A. E., & Custers, M. H. G. (2011). Gardening promotes neuroendocrine and affective restoration from stress. *Journal of Health Psychology*, *16*(1), 3–11. https://doi.org/10.1177/1359105310365577

Vartanian, O., Navarrete, G., Chatterjee, A., Fich, L. B., Leder, H., Modroño, C., Nadal, M., Rostrup, N., & Skov, M. (2013). Impact of contour on aesthetic judgments and approach-avoidance decisions in architecture. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(Suppl 2), 10446–10453. https://doi.org/10.1073/pnas.1301227110

Wheeler, B. W., White, M., Stahl-Timmins, W., & Depledge, M. H. (2012). Does living by the coast improve health and wellbeing? *Health & Place*, *18*(5), 1198–1201. https://doi.org/10.1016/j.healthplace.2012.06.015

White, M. P., Pahl, S., Ashbullby, K., Herbert, S., & Depledge, M. H. (2013). Feelings of restoration from recent nature visits. *Journal of Environmental Psychology*, *35*, 40–51.

White, M. P., Weeks, A., Hooper, T., Bleakley, L., Cracknell, D., Lovell, R., & Jefferson, R. L. (2017). Marine wildlife as an important component of coastal visits: The role of perceived biodiversity and species behaviour. *Marine Policy*, *78*, 80–89.

Wickham, H. (2016). *ggplot2: Elegant graphics for data analysis*. Springer.

Winter, S. (2012). Forest naturalness assessment as a component of biodiversity monitoring and conservation management. *Forestry: An International Journal of Forest Research*, *85*(2), 293–304. https://doi.org/10.1093/forestry/cps004

Wood, E., Harsant, A., Dallimer, M., Cronin de Chavez, A., McEachan, R. R. C., & Hassall, C. (2018). Not all green space is created equal: Biodiversity predicts psychological restorative benefits from urban green space. *Frontiers in Psychology*, *9*, 1–13. https://doi.org/10.3389/fpsyg.2018.02320

Wood, S. L. R., Jones, S. K., Johnson, J. A., Brauman, K. A., Chaplin-Kramer, R., Fremier, A., Girvetz, E., Gordon, L. J., Kappel, C. V., Mandle, L., Mulligan, M., O'Farrell, P., Smith, W. K., Willemen, L., Zhang, W., & DeClerck, F. A. (2018). Distilling the role of ecosystem services in the sustainable development goals. *Ecosystem Services*, *29*, 70–82. https://doi.org/10.1016/j.ecoser.2017.10.010

Wu, Y., Xie, L., Yuan, Z., Jiang, S., Liu, W., & Sheng, H. (2020). Investigating public biodiversity conservation awareness based on the propagation of wildlife-related incidents on the Sina Weibo social media platform. *Environmental Research Letters*, *15*(9), 094082. https://doi.org/10.1088/1748-9326/ab9ed1

Zawada, D. G., Piniak, G. A., & Hearn, C. J. (2010). Topographic complexity and roughness of a tropical benthic seascape. *Geophysical Research Letters*, *37*(14), L14604. https://doi.org/10.1029/2010GL043789

Zhang, H., Chen, B., Sun, Z., & Bao, Z. (2013). Landscape perception and recreation needs in urban green space in Fuyang, Hangzhou, China. *Urban Forestry & Urban Greening*, *12*(1), 44–52. https://doi.org/10.1016/j.ufug.2012.11.001

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