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1 Beauty and the reef: Evaluating the use of non-expert ratings for monitoring  
2 aesthetic values of coral reefs.

3  
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14

## 15 Abstract

16 UNESCO World Heritage sites are affected by global change. The Great Barrier Reef (GBR) is  
17 an iconic World Heritage site whose values for which the site was inscribed, including its natural  
18 beauty, are dramatically declining. However, there is currently no program or documented  
19 methods for long term monitoring of aesthetics for coral reefs. Here, Here, we quantified and  
20 assessed the drivers of the GBR aesthetic value perception from a survey of 1,417 individuals  
21 who rated 181 photos on a 10-point scale for their level of attractiveness. Each photo was rated  
22 at least 380 times. Coral topography, fish abundance and visibility were positively correlated

23 with aesthetic ratings. Older people and those with interest in coral reefs and who dived on the  
24 reef rated photos more highly. Reporting on aesthetic values of the UNESCO World Heritage  
25 Sites will become increasingly as declines in their ecological state continue.

## 26 Keywords

27 Aesthetic, value, beauty, appreciation, cultural ecosystem services, attitudes, perception,

28 Great Barrier Reef

## 29 1. Introduction

30 The reframing of nature by the Millennium Ecosystem Assessment report (Millennium  
31 Ecosystem Assessment, 2003), in particular, as providing goods and services, has enabled a  
32 mechanism by which the importance of natural places can be reconsidered (Diaz et al., 2011).  
33 The aesthetic services that are provided by nature have become formally acknowledged and  
34 valued, where the provision of aesthetic services is strongly related to all other cultural services  
35 including recreation (Ghermandi et al., 2010; Junge et al., 2015). Areas with conditions for  
36 recreation and leisure are often valuable due to their aesthetic and cultural heritage and identity  
37 qualities (e.g. (Chan et al., 2012; Comberti et al., 2015; Gee and Burkhard, 2010; Jobstvogt et  
38 al., 2014)). Likewise, areas with scenic beauty often provide inspiration and opportunities for  
39 education, holding significant existence values (e.g., (de Oliveira and Berkes, 2014; Fletcher et  
40 al., 2014; Hashimoto et al., 2014; Martínez-Pastur et al., 2015; Outeiro et al., 2015)).  
41 Furthermore, De Groot et al. (2002) refers to 'aesthetic information' as an ecosystem service  
42 category, provide 'scenery' as an example of an aesthetic service, and a feeling of 'enjoyment'  
43 as the benefit of this service. Boyd and Banzhaf (2007) suggest that 'amenity and fulfilment' are  
44 examples of aesthetic benefits and 'natural land cover in viewsheds' is the ecosystem service  
45 providing the benefits. They argue this differentiation is essential in defining a workable  
46 accounting system to facilitate land-use decision-making and management.

47

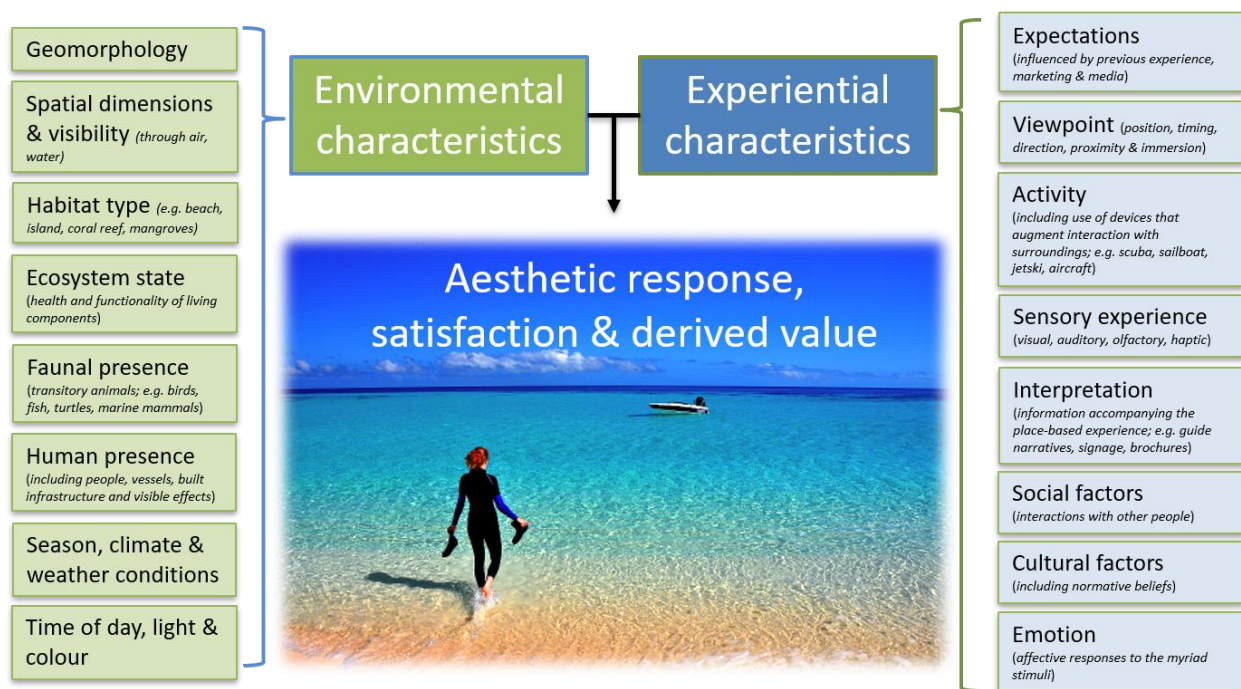
48 For the purpose of this paper, the term *aesthetic value(s)* has been taken as defined by Context  
49 Pty Ltd (2013 p. 33), being:

50 *".. the response (the aesthetic response) derived from the experience of an environment*  
51 *or parts of an environment. Human senses – sight, touch, smell, sound, movement –*  
52 *are important in how humans experience an environment. And culture, knowledge,*

53 *expectations and experience mediate sensory perceptions. Aesthetic response can*  
 54 *therefore be said to be linked to:*

- 55 • *the characteristics of an environment*
- 56 • *culturally or personally derived preferences.”*

57 Furthermore, we have summarised the by the many contributing environmental and experiential  
 58 characteristics that contribute to aesthetic response, satisfaction and derived value in a natural  
 59 setting (Fig. 1).



60  
 61 Fig. 1. Characteristics and attributes that contribute to aesthetic response, satisfaction and  
 62 derived value in a natural setting (Great Barrier Reef context).

63  
 64 The natural beauty and aesthetic appreciation of landscapes has previously been studied in  
 65 various terrestrial ecosystems around the world (Arriaza et al., 2004; Beza, 2010; De Pinho et  
 66 al., 2014; Frank et al., 2013; Gobster et al., 2007; Hoffman and Palmer, 1996; Howley, 2011;  
 67 Rosley et al., 2013; Schirpke et al., 2013; Sheppard, 2004; Van den Berg et al., 1998; van der

68 Jagt et al., 2014; van Zanten et al., 2016; Wet Tropics Management Authority, 2017; Xu et al.,  
69 2003), however very few studies have occurred in marine ecosystems (Fenton and Syme, 1989)  
70 or more specifically within coral reefs (Dinsdale and Fenton, 2006; Fenton et al., 1998). Coral  
71 reef ecosystems worldwide are significant sources of consumptive and non-consumptive  
72 economic values (Wielgus et al., 2002) and supply vast numbers of people with goods and  
73 services such as seafood, tourism and recreational opportunities, coastal protection, as well as  
74 aesthetic and cultural benefits (Martin et al., 2016; Moberg and Folke, 1999; Werner et al.,  
75 2014). Many attributes have been described as to what contributes to these non-consumptive  
76 aesthetic values including the abundance of fish and corals (Dixon et al., 1993; Wilkinson, 1996;  
77 Williams and Polunin, 2000), existence of iconic species/habitats (Jobstvogt et al., 2014; Levin  
78 et al., 2010; Werner et al., 2014), and water clarity (Dixon et al., 1993; Hatton MacDonald et al.,  
79 2015; Lee, 2017; Tosic et al., 2014; Wilkinson, 1996).

80

81 The development of indicators and quantifying the aesthetic value that people place on different  
82 landscapes, seascapes, and ecosystems has been approached in a number of ways by  
83 researchers over time. Primarily these have focused on using landscape assessment methods  
84 which either focus on understanding experiential preferences, the physical  
85 attributes/attractiveness of a place (Tardieu and Tuffery, 2019), landscape preferences, (Atauri  
86 et al., 2000; de la Fuente de Val et al., 2006; de Lucio and Múgica, 1994; Huang, 2013; Múgica  
87 and de Lucio, 1996), scenic quality, or the experience of the place. Two different methodological  
88 approaches that assess landscape aesthetics either from an objective or a subjective point of  
89 view have been established in the past (Frank et al., 2013). More recent approaches such as  
90 those by Casalegno et al. (2013) and van Zanten et al. (2016) have used crowd-source  
91 datasets, machine learning, (Haas et al., 2015; Seresinhe et al., 2015; Spalding et al., 2017)  
92 and geo-tagged digital photographs uploaded to social media platforms to quantify and  
93 objectively measure the perceived aesthetic value of ecosystems.

94

95 The emergence of aesthetic values methods in the Australian heritage practice although only  
96 new, is important as there is no established World Heritage methodology for assessing natural  
97 beauty and aesthetic values under Criterion vii (i.e. contain superlative natural phenomena or  
98 areas of exceptional natural beauty and aesthetic importance). In the Great Barrier Reef and  
99 Wet Tropics World Heritage Areas in Australia attempts have been made to define and measure  
100 aesthetic values (Context Pty Ltd, 2013; Wet Tropics Management Authority, 2017). More  
101 recently new methods have been developed utilising non-expert visual assessments (Marshall  
102 et al., 2019) and innovative technologies using artificial intelligence (Becken et al., 2018). Given  
103 the importance of the tourism industry in these areas, those features and attributes that  
104 currently draw visitors to these areas are important, particularly to tourism operators in the  
105 areas. Furthermore, a number of values for which the Great Barrier Reef was originally  
106 inscribed for are on the decline after back to back coral bleaching events recently in 2016 and  
107 2017, terrestrial run-off of sediments and nutrients and associated Crown-of-Thorns Starfish  
108 (COTS) (*Acanthaster planci*) outbreaks, acidification associated with climate change, impacts  
109 from severe cyclones, and coral diseases (Brodie and Waterhouse, 2012; De'ath et al., 2012;  
110 Hughes et al., 2015; Hughes et al., 2017), which have all affected the aesthetics and natural  
111 beauty of some parts of the Region above and below the water (Great Barrier Reef Marine Park  
112 Authority, 2019).

113

114 Appealing features of methods which use non-expert rating scores of aesthetic beauty include  
115 simplicity and scalability, and as Marshall et al. (2019) and Haas et al. (2015) have shown,  
116 relevance/correlation to environmental attributes associated with Reef health. However, before  
117 such a method can be implemented and used in a management context, managers need to  
118 understand the method's sensitivity, extrapolative power, and any potential biases associated  
119 with non-expert visual ratings of scenes. In this study we evaluate (a) the sensitivity of rating

120 scores used in Marshall et al. (2019) to compare underwater coral reef scenes, (b) the sampling  
121 design requirements to establish appropriate confidence levels, and (c) biases associated with  
122 demography and knowledge levels/expertise.



## 123 2. Methods

### 124 2.1 Study site

125 The Great Barrier Reef (GBR) of Australia is one of the world's largest coral reef systems. It  
126 houses globally-significant biodiversity, a rich diversity of underwater habitats, and a scenic  
127 appeal that is universally recognised (Hughes et al., 2003). These values make it an  
128 international tourism attraction: in 2013, the Great Barrier Reef received an estimated 53.3M  
129 days of use, with 98% of all days comprising tourism visitation (Marshall et al., 2016). Tourism  
130 operators and commercial fishers are particularly appreciative of the natural beauty of the  
131 region, with the tourism industry alone worth over \$5.2 billion each year (Marshall et al., 2016).  
132 It also holds immense value for local communities, where 'beautiful' is one of the first words that  
133 come to local residents' minds when thinking of the GBR (Marshall et al., 2016). Residents and  
134 tourists seek opportunities to appreciate the natural aesthetics of the GBR through experiences  
135 such as diving and snorkelling, visiting beaches, boating and scenic flights (Marshall et al.,  
136 2016).

### 137 2.2 Data analysis

138 We developed a linear mixed effect model to generate expectations of how image scores were  
139 related to eight covariables expected to influence the aesthetic score. These included coral size,  
140 fish size, fish diversity, presence of algae, coral cover, topography, fish density, and visibility  
141 (Marshall et al., 2019). Respondents and images were used as random effects. Variance  
142 inflation factor (VIF) scores 3.28, indicating low collinearity among covariates. We then identified  
143 XXXX and YYYY, defined as respondents scoring more than two standard deviations higher or  
144 lower than expectations from our model, respectively. Our approach thus reveals the

145 respondents that tend to provide more extreme scores given the general characteristics of the  
146 images they evaluate. Finally, we assessed the link between socioeconomic characteristics and  
147 whether a respondent was XXXX, average, or YYYY using a Fisher's exact test.

148

149 In order to help practitioners find a balance between low cost and high accuracy, we examined  
150 how error in the image scores varied according to the number of respondents (i.e. sample size).  
151 Specifically, we calculated the error (i.e. score's 95% confidence interval) at varying sample  
152 sizes (N = 3 to 380 respondents in increments of 2, taken randomly without replacement from  
153 the original pool of respondents). This process was repeated 100 times for each of the 181  
154 images in order to calculate the median error each image add at various sample size.

155

156 Five indicators were selected that reflected distinct attributes of coral reefs: (i) coral cover; (ii)  
157 coral pattern; (iii) coral topography; (iv) fish abundance; and (v) visibility (Marshall et al., 2019).

158

159 All analyses were implemented in R statistical analysis software v3.4.0.

160

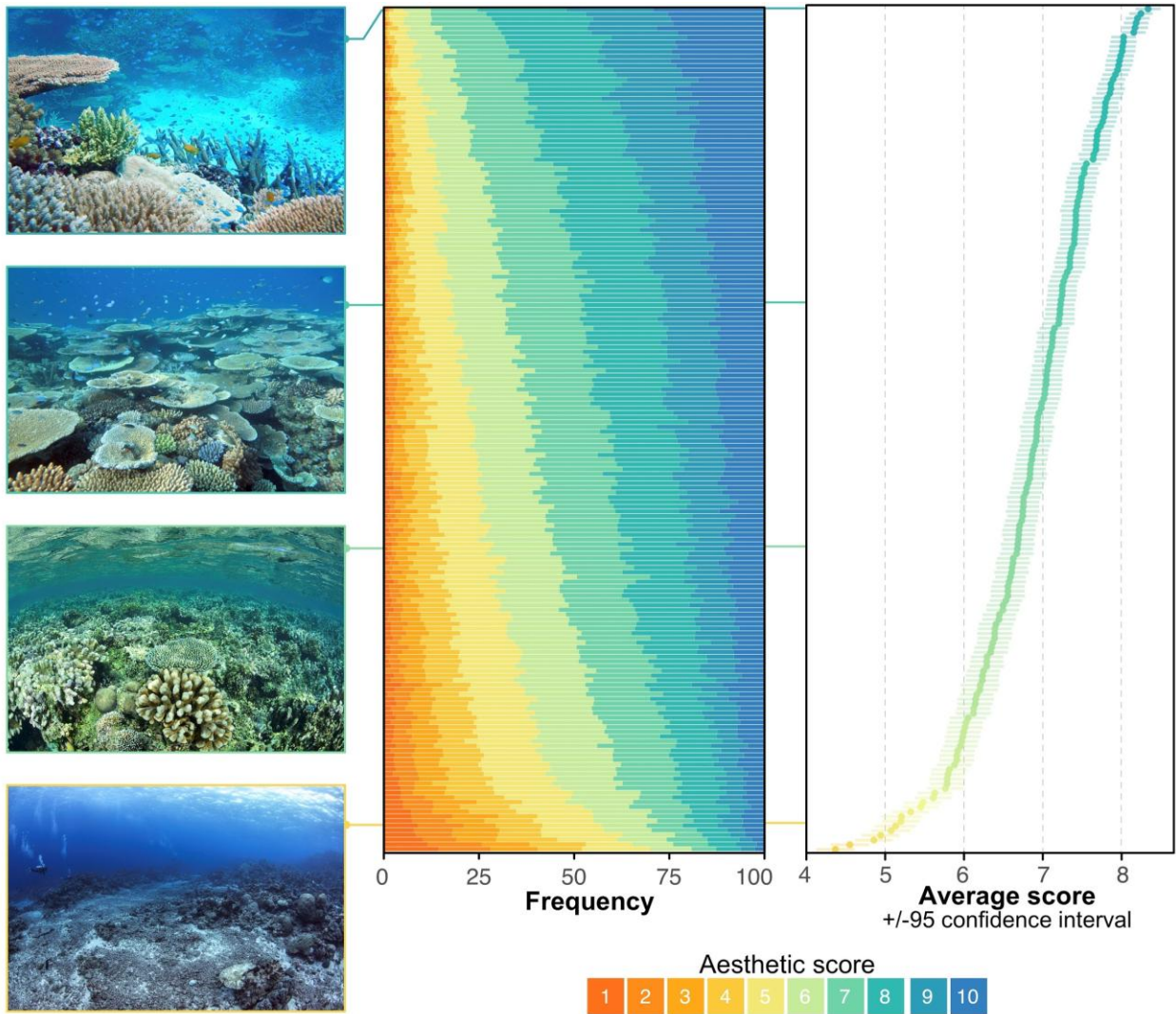
161

162

163 3. Results

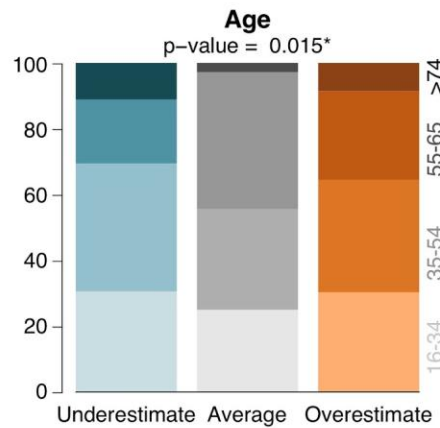
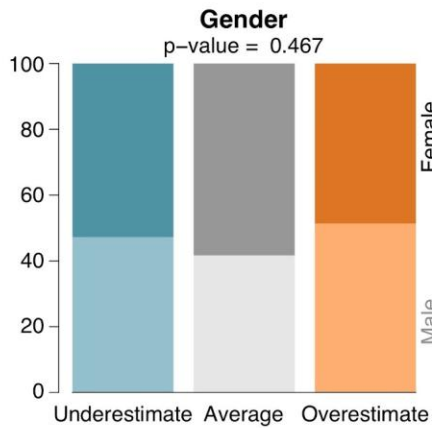
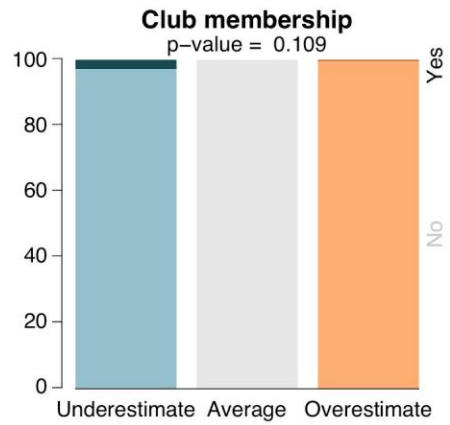
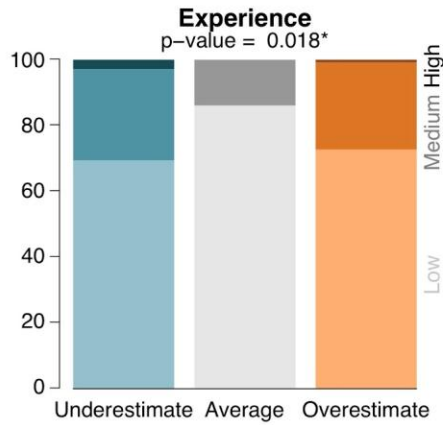
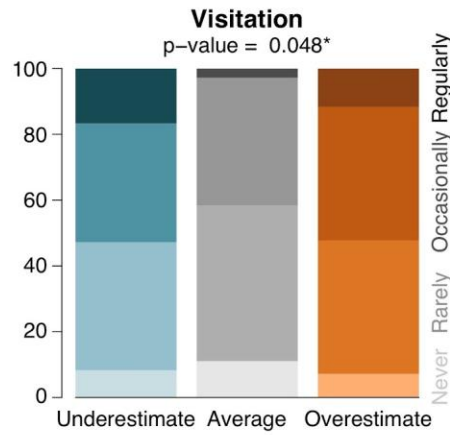
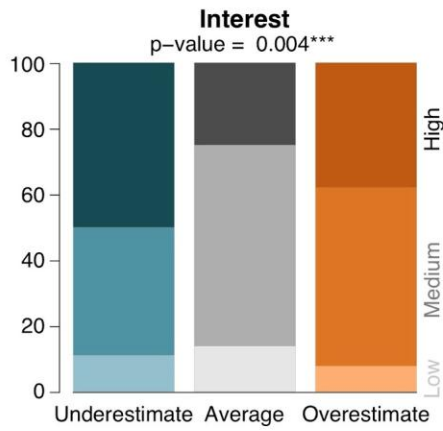
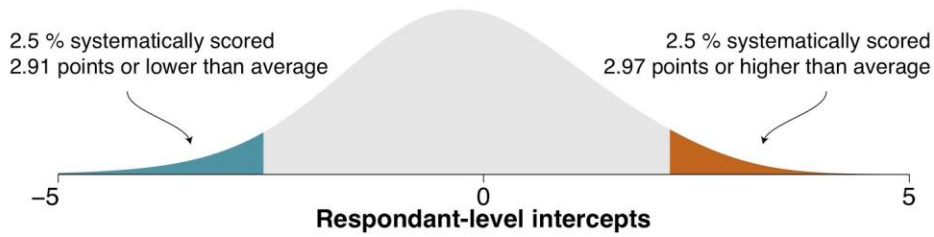
164 The average aesthetic score ranged between X and X. Four images (Fig. 2) indicate the  
165 frequency and average aesthetic score.

166



167

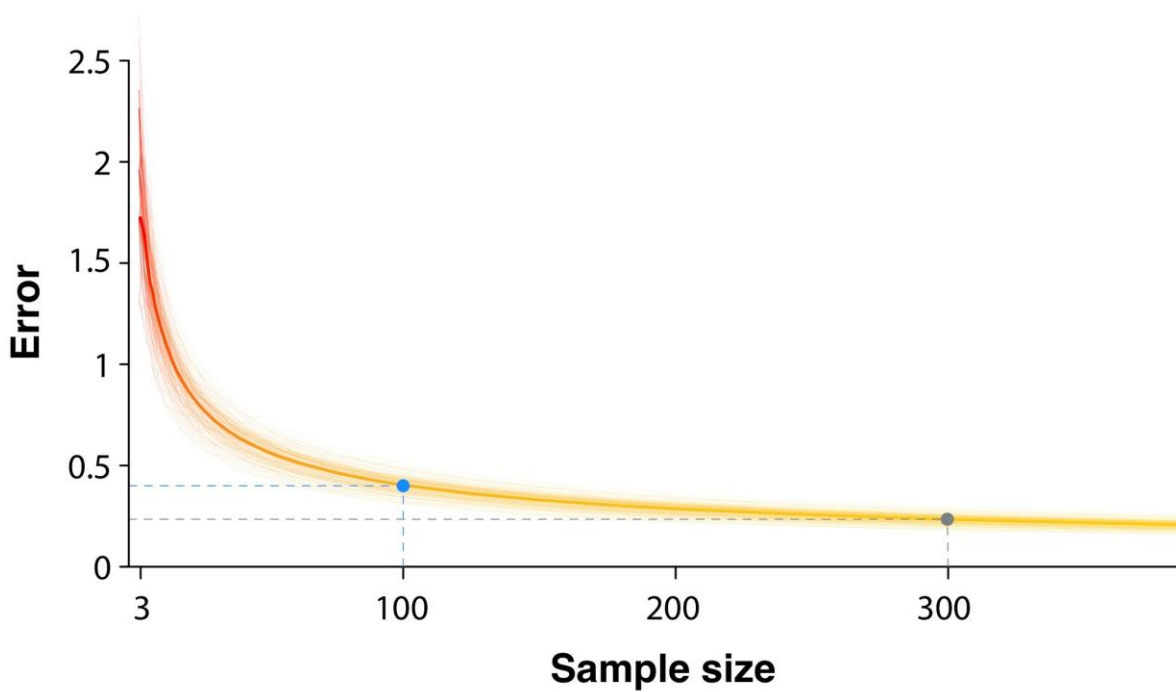
168 Fig. 2 XXXXXXXXXXXXXXXXXXXXXXX



169

170 Fig. 3 XXXXXXXXXXXXXXXXXXXX

- 171 • Have a higher level of interest in coral reefs ( $p=0.004^{***}$ )
- 172 • More likely to visit reef regularly ( $p=0.048^*$ )
- 173 • Higher self-assessed coral reef experience ( $p=0.018^*$ )
- 174 • Higher proportion of >65's ( $p=0.015^*$ )
- 175 • No apparent prevalence of bias in either positive or negative direction
- 176 • While these groups inflate the error margin, they tend to cancel each other out around
- 177 the mean score.



179  
 180 Fig. 4. Sample size describes how many people you would need to assess a photo/coral reef  
 181 scene, to be confident in the representativeness of the mean score and at what point do you no  
 182 longer change the mean response.

183  
 184

## 185 4. Discussion

### 186 • CHALLENGES

187

188 Reporting through monitoring, and actively managing, aesthetic quality is potentially a critically  
189 useful strategy for natural resource managers that aim to effectively deliver both conservation  
190 and social outcomes. The advantages of monitoring aesthetic values lie essentially around the  
191 opportunity to better engage with the public, correspondingly achieving conservation (Frank et  
192 al., 2013). People appreciate and relate to aesthetics more than any other aspect of the natural  
193 environment (Marshall et al., 2018; Marshall et al., 2016; Marshall et al., 2017). Aesthetics is  
194 also a unifying value associated with natural places, whilst biodiversity is often a divisive factor  
195 (Hill et al., 2016; Lecuyer et al., 2018; Schmidt and Peterson, 2009; Young et al., 2010). In the  
196 case of iconic places such as the Great Barrier Reef, aesthetic values were a major factor in the  
197 establishment of World Heritage Area status, and the reporting of aesthetic quality and its  
198 maintenance is likely to become mandatory. For these reasons, efforts are currently underway  
199 to explore how aesthetic quality might be recorded and reported on within the Great Barrier  
200 Reef (NESP reference).

201

202 Perhaps the reason that aesthetic values have not been explicitly used by natural resource  
203 managers to further conservation goals and support is because aesthetics are seen as  
204 subjective and essentially unmanageable (Context Pty Ltd, 2013; Dramstad et al., 2006).

205 However, preliminary work by the National Environment and Science Program (Becken et al.,  
206 2018; Marshall et al., 2019) has strongly suggested that developing indicators to rate aesthetic  
207 quality is possible (Marshall et al., 2019). In sum, the development of aesthetic indicators for  
208 use in specific environments such as marine environments are still very much in their infancy,  
209 but the momentum supporting the development of aesthetic metrics, or indicators, is growing

210 (Belhassen et al., 2017; Haas et al., 2015; Hein et al., 2019; Jaap, 2000; Tamayo et al., 2018;  
211 Turek, 2000; Vercelloni et al., 2018; Vlami et al., 2017; Wessel et al., 2018).

212

213 The emerging social-ecological field continues to expand methodologies to improve techniques  
214 in monitoring aesthetic heritage values, using potential indicators and computations of aesthetic  
215 value. However, ongoing examination of which locations or biophysical elements are the most  
216 important to the Reef's spectacular seascapes and scenery, remains an information gap.

### Summary of benefits

The large size of the property and the fact that it was inscribed on the World Heritage List under all four natural criteria supports the evidence for the wide array of benefits provided by the property to the people living both within and outside the property. In addition to nature conservation and conserving cultural and wilderness values, the property provides a wide range of ecosystem services, furnishes a wealth of scientific knowledge and provides jobs through tourism, fishing, park management, research and education. Local populations can benefit from traditional, recreational and commercial fishing and hunting (some Traditional Owners continue to hunt dugong) provided that it is sustainable. In 2011–12, recreational activities (including fishing) were the second largest direct use of the World Heritage Area, generating \$244 million (value-added), a substantial increase on the estimate of its value in 2006–07 (\$153 million). The activities generated employment equivalent of 2724 full-time jobs, up from approximately 1700 in 2006–07. Of the four recreational activities, recreational fishing is the most popular with an estimated 3.8 million fishing trips taking place in 2015–16, the expenditure generated from recreational fishing activities amounts to \$70 million. The total value of all recreational activity associated with the GBR in 2015–16 is estimated to contribute around \$346 million to the Australian economy (including \$284 million to the GBR Region).

217

218        **5. Conclusion**

219        There are numerous potential management (and other) uses of aesthetic assessments and  
220        monitoring with information needs that vary substantially. The rapid assessment approach is  
221        potentially useful for some purpose with statistical design requirements and limitations now  
222        better understood. Our findings can help World Heritage site managers better contextualise the  
223        results and limitations from such monitoring and ensure that future aesthetic monitoring  
224        programs can be designed to meet management and reporting needs.

225

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228

229

230



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