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

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Abstract

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

1. Introduction

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

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

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

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

- the characteristics of an environment
- culturally or personally derived preferences.”

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

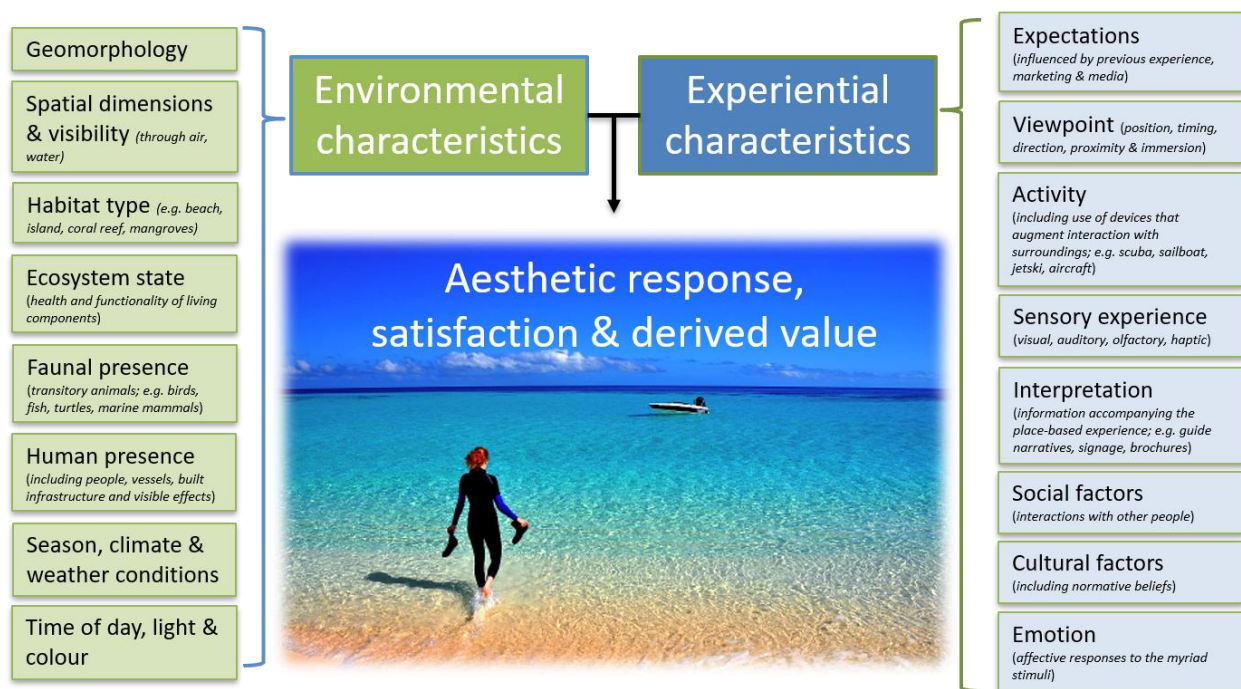


Fig. 1. Characteristics and attributes that contribute to aesthetic response, satisfaction and derived value in a natural setting (Great Barrier Reef context).

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

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

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

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

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

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

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

3. Results

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

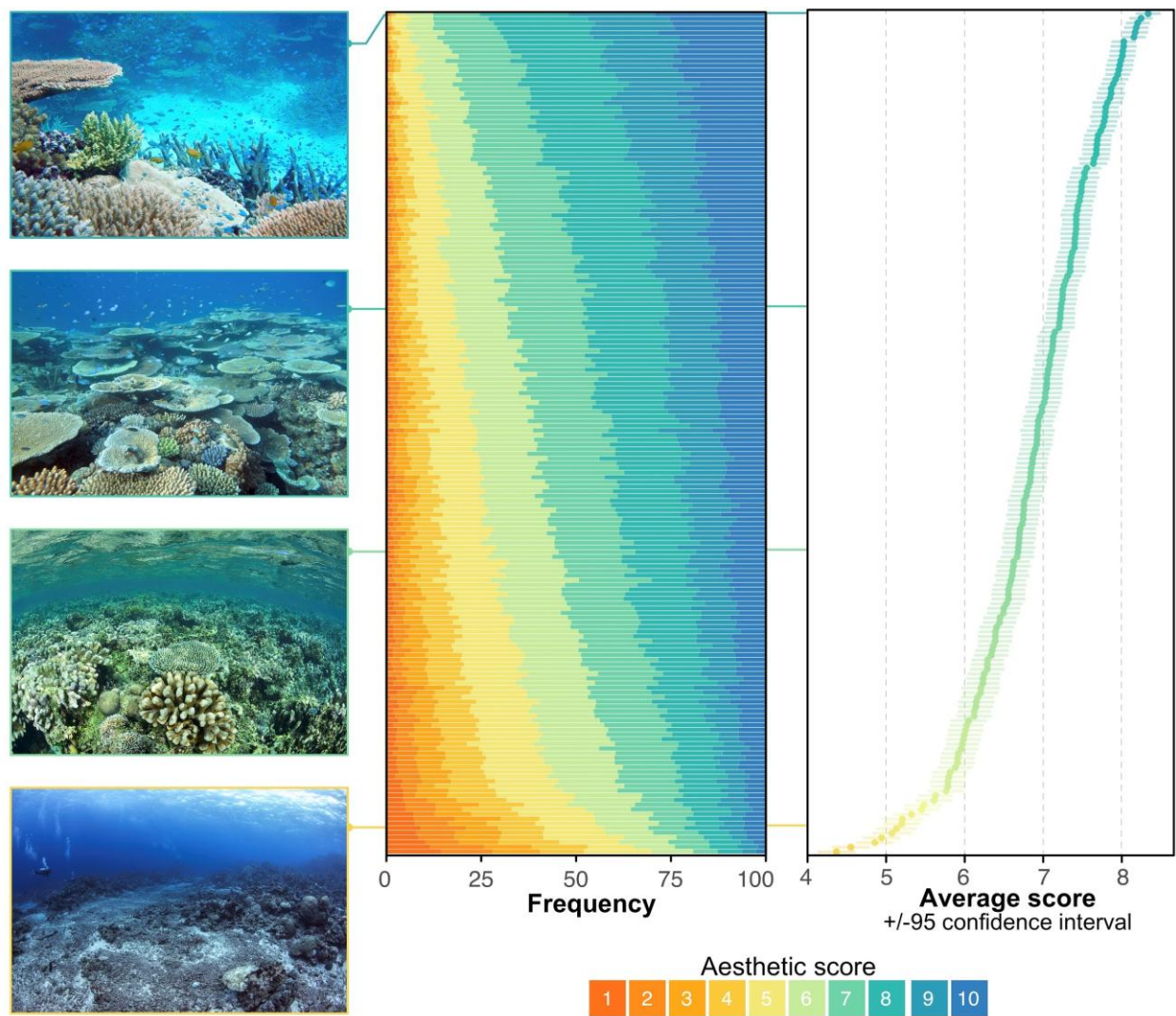
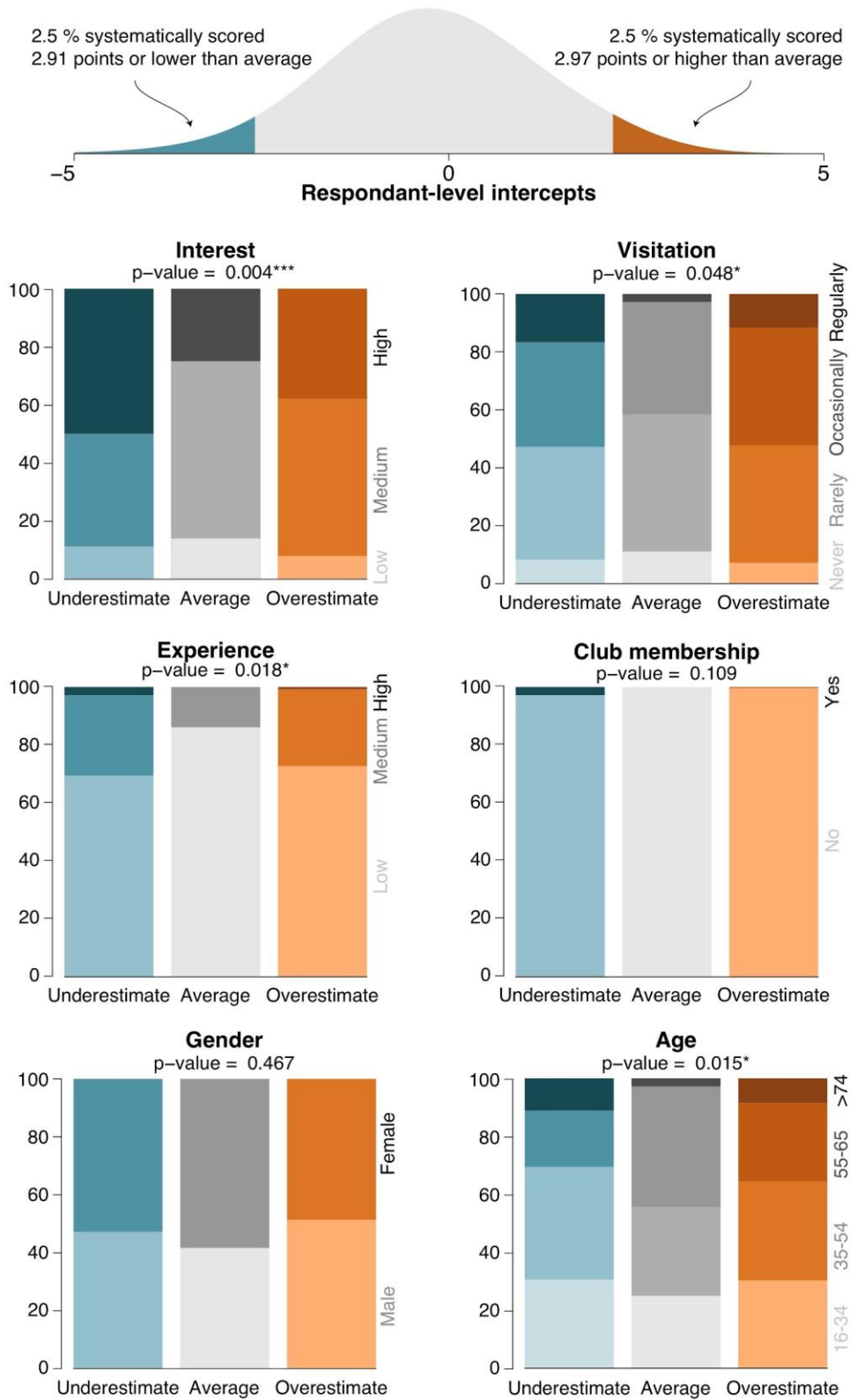


Fig. 2 XXXXXXXXXXXXXXXXXXXX



169

170 Fig. 3 XXXXXXXXXXXXXXXXXXXX

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

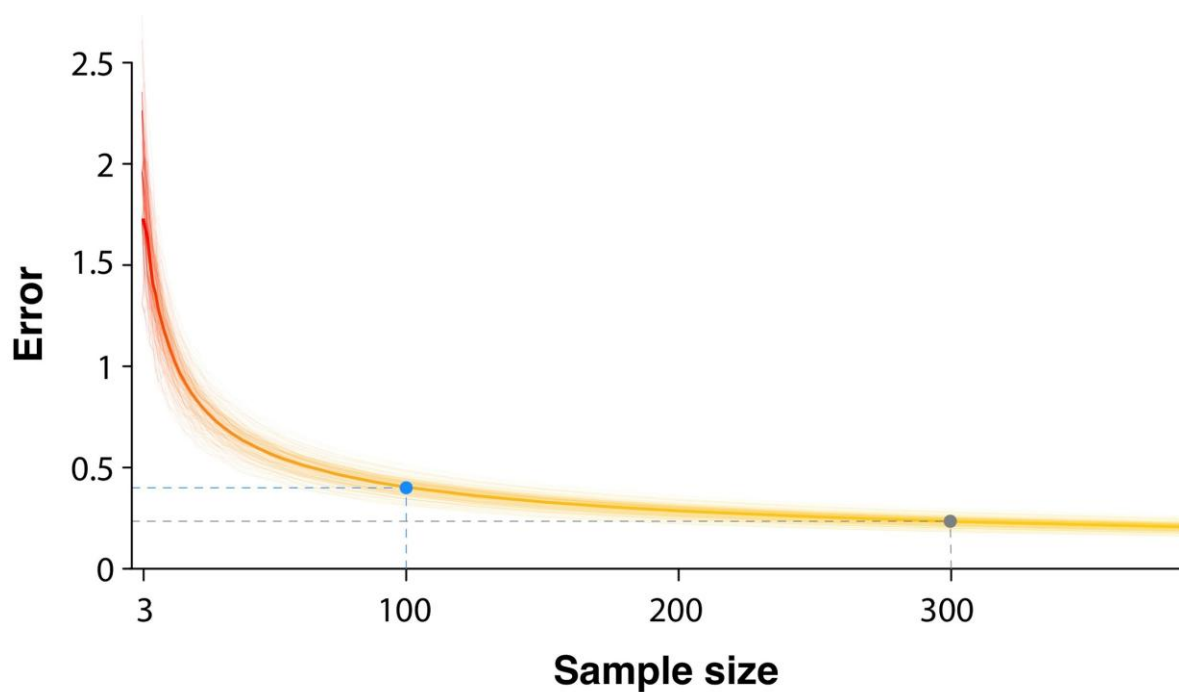


Fig. 4. Sample size describes how many people you would need to assess a photo/coral reef scene, to be confident in the representativeness of the mean score and at what point do you no longer change the mean response.

4. Discussion

- CHALLENGES

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

Perhaps the reason that aesthetic values have not been explicitly used by natural resource managers to further conservation goals and support is because aesthetics are seen as subjective and essentially unmanageable (Context Pty Ltd, 2013; Dramstad et al., 2006). However, preliminary work by the National Environment and Science Program (Becken et al., 2018; Marshall et al., 2019) has strongly suggested that developing indicators to rate aesthetic quality is possible (Marshall et al., 2019). In sum, the development of aesthetic indicators for use in specific environments such as marine environments are still very much in their infancy, 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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