

Managing for Aesthetic Values in the Great Barrier Reef: Identifying indicators and linking Reef Aesthetics to Reef Health

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ACRONYMS

EotR	Eye on the Reef (program)
GBR	Great Barrier Reef
GBRMP	Great Barrier Reef Marine Park
GBRMPA	Great Barrier Reef Marine Park Authority
GBRWHA	Great Barrier Reef World Heritage Area
NESP	National Environmental Science Programme
NRM	Natural Resource Management
OUV	Outstanding Universal Value
SELTMP	Social and Economic Long-Term Monitoring Program
TWQ	Tropical Water Quality
WHA	World Heritage Area

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EXECUTIVE SUMMARY

The aesthetic value of landscapes and seascapes contributes to human wellbeing, and the attachment that people have to the place within which they live and work. The Outstanding Universal Values (OUVs) of the Great Barrier Reef (Reef), which includes aesthetic values, were the key reason that the Reef was listed as a World Heritage site in 1981. However, there is little available guidance for Reef managers to record, monitor and manage for aesthetic values. Without standard protocols for assessing aesthetic values within the Great Barrier Reef, it is not possible to measure whether aesthetic values being maintained or degraded.

In this study, we address the need to develop robust and practical indicators of aesthetic values so that standard protocols might be developed for considering, assessing and reporting on aesthetic condition and trend, and to assist with management processes (e.g. permit assessments). We also link aesthetics and Reef health to assist managers to use aesthetic values to better engage with the public, whilst also achieving reef health outcomes. Better engagement using aesthetics is likely since 'beautiful' was the most frequently cited sentiment by 9,000 stakeholders when asked for the first words that come to mind when thinking of the Great Barrier Reef (SELTMP 2013). Managing for aesthetics has the potential to contribute to achieving reef health objectives if the relationship between reef health and reef aesthetics is better understood.

This project had three aims. Our first aim was to identify indicators of aesthetics that could be used for reporting, permitting and monitoring purposes. An analysis of variance of the aesthetic ratings of the 181 photos showed that coral topography, fish abundance, and visibility were significantly correlated with aesthetic ratings, suggesting that they can reliably be used as indicators of aesthetic value. Coral cover and coral pattern were not significantly correlated with respondents' ratings of the aesthetic value of each photo.

Our second aim was to investigate the link between reef aesthetics and reef health. Our results suggested that there was a strongly significant correlation between the two, suggesting that reef aesthetics could be used as an engagement tool for coral reef monitoring (e.g. through citizen science programs such as 'Eye on the Reef') whilst contributing to efforts to monitor and detect changes in reef health.

Our third aim was to explore with managers of the Great Barrier Reef the scope and pathway for incorporating indicators of reef aesthetics into current management processes as they relate to reef aesthetics and reef health.

We initially did qualitative surveys of 30 key individuals to identify 184 potential indicators of reef aesthetics. Five candidate indicators were selected for further testing because they regularly featured in the survey responses, were readily quantifiable and were either already accounted for in existing monitoring programs, or could be introduced into such programs: (i) coral cover, (ii) coral pattern, (iii) coral topography, (iv) fish abundance, and (v) visibility. We then asked 1,500 online Australians to rate 181 underwater coral reef images, chosen to represent combinations of each of the five factors, for their aesthetic appeal. Each photo was also rated for its reef health by experts during a workshop.

We note that many more indicators of aesthetic quality are likely to exist and suggest that development of a more comprehensive framework for analysis of aesthetic qualities and for identifying potential impacts on reef aesthetics would be a fruitful focus for future research. However, the results from this initial study suggest that meaningful progress toward integrating aesthetics into coral reef monitoring and management can be made using three indicators. The improvements in monitoring and reporting on aesthetic values enabled by this study have the potential to contribute to goals relating to improving wellbeing of communities, while also contributing to objectives around reef health.

1.0 INTRODUCTION

And the loveliness of these reefs and islands lends them an enchantment that works upon the mind like “all the drowsy syrups of the world”.

Beauty is the last thing we remember of these lonely isles, as it was the first thing that we knew of them; the beauty of their air and sea; the living beauty of their coral pools.

On the Great Barrier Reef

S. Elliot Napier 1934

We explore the drivers of aesthetic value in the Great Barrier Reef Marine Park and identify indicators that can be used for monitoring and management of aesthetic values. We analyse rankings of aesthetics and ecological health to derive an understanding of the potential for aesthetics to provide increased opportunity for non-experts to contribute to monitoring and detection of changes in reef health for improved coral reef management.

1.1 The importance of aesthetics in contributing to human wellbeing

Aesthetic appreciation of natural places is one of the most fundamental ways in which people relate to their environment. It contributes to wellbeing, recreation, spirituality, cultural connection, a sense of place, and to the development of identity. Aesthetic appreciation of a landscape is an instinctual and innate response that provides cultural enrichment, cognitive development, reflection and recreational experiences (Tribot et al. 2016, Mazlow 1949, Bengston et al. 1999; Larson et al. 2015; Needham 2010; Wynveen et al. 2010).

Our ability to appreciate aesthetic qualities within a landscape or seascape plays a central role in our relationship with nature. Well-being is imparted through restorative effects (Hartig, Mang, and Evans, 1991), greater agreeableness, stress reduction, empathy, and perspective taking (Van den Berg, Vlek, and Coeterier, 1998, Ulrich 1981, Bratman et al., 2015). Stress reduction theory suggests that natural environments have a restorative advantage over artificial environments due to the role that natural environments have played in our evolution as a species (Ulrich, 1981). Natural landscapes, particularly grasslands with clusters of trees, are well known to be most favoured by people probably because they evolutionarily provided shelter and refuge (the ‘savanna hypothesis’) (Lohr and Perason-Mims 2006).

The services provided by aesthetic values have been recently recognised as a natural resource in themselves, requiring similar environmental management controls as used to protect biodiversity (Tribot et al 2016). The aesthetic appreciation of nature can be as important as the provision of food, shelter and means for livelihoods (Mazlow 1943, Wynveen et al. 2010).

Aesthetic appreciation of landscapes is instinctive and is generally independent of people's formal knowledge of ecosystems. People's innate response to a landscape probably reflects our own ability to judge whether a landscape or experience is safe and healthy for us (Tribot et al. 2016). Humans, evolutionarily, seek beneficial habitats that are functional and support survival and wellbeing – where people may be interpreting environmental parameters, such as

environmental condition or health, through an aesthetic lens (Tribot et al. 2016). Tribot et al. 2016 argue that aesthetic preferences are led by people's relationship with information and by human survival. In their study, in Mediterranean France, they found correlations between how people rated the aesthetics of a range of coralligenous reef photos and the species richness and functional richness of the habitat in the photos. They also discuss the relatively recent relationship that people have had with experiencing underwater landscapes and whether it is possible that people have evolved to recognise safe and desirable underwater landscapes. Results from their study suggest that the aesthetic cues that people have with terrestrial habitats can be potentially transposed to marine habitats, and thus it should be possible to identify aesthetic underwater cues for the purposes of monitoring and reporting on aesthetic condition and trend.

1.2 The link between aesthetics and environmental management

Effective management of natural resources is increasing in importance as threats accumulate and demand on resources increase. As the science of environmental management matures, so does the environmental policy dialogue. No longer are people solely regarded as a threat to natural resources; a more contemporary understanding is characterized by explicitly recognizing the importance of nature to human wellbeing and economic sustainability, with the expectation that better returns on conservation initiatives will emerge. This reframing of nature (and the role of people within it), predominately inspired by the Millennium Ecosystem Assessment (MEA 2005), has enabled the importance of natural places to be reconceptualised as sources of goods and services (or 'Ecosystem Services'). Under the banner of 'cultural services' (one of the four categories of service offered by ecosystems in the MEA conceptualisation), 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 (MEA 2005).

The incorporation of aesthetic values into environmental management has been slow (Day 2012, Context 2013). Landscapes or seascapes such as the Great Barrier Reef were inscribed onto the World Heritage list for their Outstanding Universal Natural Value, which included the aesthetic values of the region. However, such values have not received anywhere near the prominence or attention given biodiversity values, and seldom considered explicitly in monitoring programs or management programs, plans or policies. The problem with not monitoring the aesthetic values of a region, and in particular special places that have earned World Heritage Area status in part because of their aesthetic values, is that it is difficult to report on whether the values underpinning initial listing and justifying persistence on the list have been adequately protected. Understanding the factors that contribute to aesthetic quality is central to the ability of environmental managers to make decisions about the appropriateness of specific activities and access to a natural resource considering potential impacts to aesthetic values. Improving the ability of natural resource managers to measure and monitor aesthetic qualities will significantly assist them to meet obligations and objectives, especially in the context of World Heritage sites like the Great Barrier Reef.

The experience of nature's aesthetics has changed considerably in the last 80 years. From images featuring land-based aesthetic experiences, the emphasis has shifted to include its underwater beauty. Glass-bottomed boats, underwater observatories, snorkelling, scuba diving and underwater cameras have changed the ways in which people experience the

underwater world and appreciate its aesthetic values (GBRMPA 2014). Being able to view the Reef from the air has also changed peoples' understanding of its size and beauty (Figure 1).

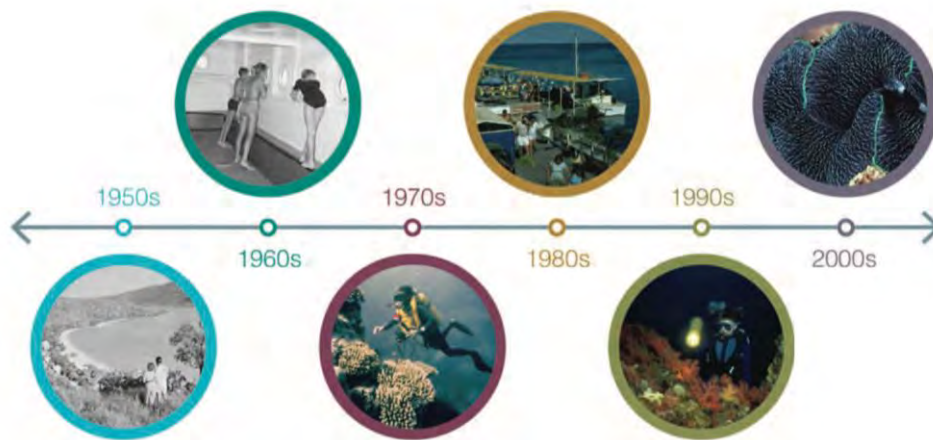


Figure 1: Changing experiences in reef aesthetics (GBRMPA 2014)

Aesthetics can be important for management for a range of reasons: the aesthetic appreciation of nature can shift people's perceptions and awareness of the need for environmental protection and more proactive management (Brady 2006; Waistel 2016). Incorporating aesthetic values into environmental management, as a conservation planning criteria, may increase the likelihood of maintaining aesthetically pleasing places, which will in turn inspire higher conservation priority within the public (Brady 2006, Mollinaro 2016).

Aesthetic values are probably the most widely appreciated aspect of the Great Barrier Reef, making them a very compelling foundation for engagement. Nine-thousand people surveyed during the baseline of the Social and Economic Long Term Monitoring Program (SELTMP 2013) for the Great Barrier Reef Great rated aesthetic values higher than economic values (Marshall et al. 2016). Similarly, when asked for the first words that come to mind when thinking of the Great Barrier Reef, the word 'beautiful' was most frequent, regardless of the economic dependence of people on the Reef (such as commercial fishers and marine park tourism operators). All stakeholder groups were similar (see Figure 2 for the words from online Australians).

Despite the prevalence and importance of aesthetics in the way people experience underwater nature, the aesthetics of underwater ecosystems are perhaps the least understood of all landscapes (Tribot et al. 2016, Haas et al 2015), although we note the work of Fenton & Syme, 1989; Fenton, Young & Johnson, 1998; Dinsdale & Fenton, 2006). Yet, underwater ecosystems, particularly coral reefs, have high aesthetic value and provide recreational and tourism opportunities for millions of people around the world (Nava and Ramirez-Herrera 2011, Haas et al. 2015, Marshall et al 2016). The Great Barrier Reef is a region attracting substantial international, national, and local tourism. Films, photos, paintings and media have all also helped to connect a wider audience with coral reefs (Moberg & Folke 1999; Pocock 2002). Despite the importance of maintaining high aesthetic levels in coral reef ecosystems for public appreciation and environmental conservation, aesthetic values are not well represented in policy decision making and management (Context 2012, Mollinaro 2017). We see that developing knowledge around aesthetic values, particularly in underwater coral reef systems, is key for adaptive coral reef management, and timely.

A key first step toward improved capacity to measure and monitor the aesthetic values of coral reefs is to develop robust and reliable indicators. Aesthetics can be a complicated human response to a scene or experience, involving a combination of visual cues, environmental context, prior knowledge, previous experiences, values, emotional state and desires (Datta et al., 2006). However, Dinsdale (2006) showed significant convergence in the way people perceived the status of coral reefs, regardless of their previous knowledge or exposure. This finding was also supported by Haas et al. (2015), working on Mediterranean reefs. They found that human perceptions of aesthetics were 'instinctive and innate reactions towards measurable visual cues'. Based on their results, they suggested that aesthetic judgments of

photographic images were sufficiently robust to be used as an inexpensive monitoring tool for reef ecosystems (Haas et al 2015).

Academics have been assessing the aesthetic value of landscapes since the 1970s (Ulrich 1981, Tribot et al 2016). Most of this work originates within terrestrial landscapes, but as Tribot et al. 2016) suggest, we can probably extrapolate into underwater landscapes. Tribot et al.'s (2016) work in Mediterranean reefs found that negative aesthetic judgments correlated to microbial abundance, or the health status of the system, which they interpreted as the 'innate emotion of disgust' towards less healthy looking images or places, which might be potentially harmful. They argued that aesthetic preferences are directed by human survival and by people's relationship with information, where humans seek beneficial habitats that are functional and support human survival and wellbeing. However, humans have shared only a short part of their evolutionary history within underwater landscapes. Given their ability to recognise less healthy underwater images, it may be that people are transposing aesthetic cues from terrestrial environments towards underwater environments (Tribot et al. 2016), providing confidence that aesthetic perceptions of coral reefs may also have an evolutionary, and therefore more robust and consistent, basis.

Within the terrestrial environment, several natural cues are known to inspire high aesthetic scores. Rare species, diversity, biodiversity and complexity within landscapes (Tribot et al 2016, Fuller et al. 20017, Krillova et al 2014, de Vries et al. 2013, Van den Berg, Vlek, and Coeterier, 1998), where complexity also includes the fine and sophisticated aspects of an environment (Kirillova et al., 2014, Kaplan et al.'s 1989) are important. People also prefer naturalness in its most generic form, where naturalness reflects the degree of wilderness, pristineness or minimum human influence (Tveit et al., 2006; Fry et al., 2009). Aesthetic appreciation is also influenced by composition, balance and harmony (Datta et al. 2006). Colour can both contribute and detract from landscape aesthetics. According to the ecological valence theory of human colour preference, humans prefer colours strongly associated with objects that they like (e.g., blue is associated with clear skies and clean water) and dislike colours strongly associated with objects they dislike (e.g., brown is associated with faeces and rotten food) (Tribot et al. 2016). Generally speaking, blue waters are preferred to yellow waters but yellow waters may be acceptable if they are perceived as "natural" (Smith, Croker, and McFarlane, 1995). Additionally, colour saturation and colour brightness further influence aesthetics: rich and bright colours tend to be positively correlated with high aesthetic ratings (Datta et al. 2006).

Previous research has found that people prefer 'openness, light and a good view' when viewing landscapes. Openness within a scenic environment refers to the degree of visibility and spaces within the surroundings and provides a sense of accessibility and movement (Tveit et al., 2006, Rosley, Rahman, and Lamit, 2014), where women prefer large areas of openness and men prefer landscapes with some trees (Sonntag-Öström et al., 2015). Scenic environments predictably include large areas of water, open blue skies or mountainous landscapes. Green areas congested with manmade objects such as buildings and roads are normally associated with lower 'scenic' ratings (Seresinhe, Preis, and Moat, 2015). Within the context of underwater environments, Tribot et al (2016), looking at coralligenous reefs of Mediterranean France, found that that the most important traits influencing aesthetic preferences were related to shape.

Aesthetic ratings have also been related to congruency and continuity, or people's sense of place, where familiarity as well as novelty (the contrast between a familiar and a new environment) are joint predictors of aesthetic judgment (Hekkert, Snelders, & van Wieringen, 2003, Brown and Raymond, 2007). The sense, or familiarity, that people have with a place can contribute to individuals' aesthetic judgment of that place, where familiar places and landscapes tend to be perceived as more beautiful. However, novelty can also be important when people visit other places. From a tourists' perspective, never-before seen aspects of a destination are rated as particularly beautiful (Kirillova et al., 2014).

Aesthetics can also be experiential. The sound or smell that is associated with an image can be important when responding to visual cues. For example, the aesthetic of water might be influenced by the sound of its travel or by the movement of the flow (Völker and Kistemann, 2013, context report). Social surveys with scales using 'clean-dirty' reflect the perceived hygienic conditions at a destination while scales such as 'well-maintained-run-down' emphasise the importance of upkeep of physical attributes (Kirillova et al., 2014). The 'lively-peaceful' scale highlights how tourists form aesthetic judgments based on the pace of sounds heard at a destination while 'nature-made-human-made' and 'loud-quiet' scales inform the importance of auditory cues and their source and volume (Kirillova et al., 2014).

1.2.2 Assessing coral reef health

The concept of health has been long used as a metaphor to represent the condition (state and function) of ecosystems. In the context of the Great Barrier Reef (GBR), an ecosystem is considered healthy if it can maintain its structure and function in the face of external pressures (Great Barrier Reef Outlook Report 2009, 2014). Reef health is a core theme in the management and reporting for the Great Barrier Reef Marine Park, which is the statutory responsibility of the Great Barrier Reef Marine Park Authority. It is also a focus for the monitoring programs that support GBR management, such as the Inshore and Long Term Monitoring Programs (LTMP) of the Australian Institute of Marine Science, as well as for citizen science programs such as Reef Check and GBMRPA's Eye on the Reef.

A wide range of characteristics contribute to overall reef health, but a smaller subset is usually sufficient to provide reliable and practicable indicators for assessment and monitoring. These tend to focus on the key drivers of reef health and resilience, such as the condition of coral and fish communities, and indicators of stress such as coral health (disease, etc) and macroalgal cover (often a response to nutrient pollution).

Given the intensive and extensive reporting of condition and trend of values that is required by managers of within natural landscapes such as the Great Barrier Reef Marine Park, citizen science approaches are increasingly being considered as important supplements to scientific monitoring and assessment. While a range of projects and tools (including 'Eyes on the Wild', 'Monitoring Through Many Eyes' and Sensiphi; Hass et al. 2015, University of Qld, 2017) have been recently developed to encourage citizen participation in monitoring using online imagery, the reliability and validity of citizen science approaches in measuring reef health continue to be prominent concerns affecting their widespread uptake by natural resource managers.

1.2.3 Linking reef aesthetics with reef health

Given that aesthetic judgements are innate and generally independent of people's formal knowledge of ecosystems, aesthetic ratings by experts and non-experts can be considered equally valid. In addition, given that people most frequently associate the word 'beautiful' with the Great Barrier Reef (Marshall et al. 2016), 'aesthetics' is a concept more likely to engage people than compared to 'biodiversity'. We hypothesize that if a reliable link exists between reef aesthetic ratings and reef health, it may then be possible to use the concept of aesthetics to improve engagement with the public about a range of reef values, including reef health.

Linking reef aesthetics with reef health is also important for enhancing the relevance of monitoring protocols to reef management. An ability to describe and document reef aesthetics has become increasingly important with recent emphasis on reporting on, and maintaining, the Outstanding Universal Value of the Great Barrier Reef. However, monitoring for aesthetics can only occur once indicators of aesthetic value have been developed, and only if they are able to be easily incorporated into existing or future monitoring programs such as 'Eye on the Reef'. Linkages between reef aesthetics and reef health could also inform advice on adaptation of expert and citizen science monitoring programs. For instance, reef health experts monitor coral cover, amongst other indicators of reef health. If coral cover is identified as an indicator of aesthetics, then the monitoring of coral cover could concurrently provide meaningful information on the status and trend of aesthetic values.

1.2.4 Aesthetic values and their management within the Great Barrier Reef Marine Park

The Great Barrier Reef (GBR) was listed as a World Heritage Area in 1981 and is widely recognized for containing superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance (Criterion vii; Johnston et al. 2013). Under the World Heritage Convention, the Australian federal and Queensland state governments have a responsibility to monitor and report on the GBR aesthetic values, as well as more traditional ecosystem-health measures such as water quality and biological diversity.

In the context of management, the aesthetic values of the Great Barrier Reef are experienced and described from a variety of perspectives (GBRMPA 2014):

- **Panoramic:** the Great Barrier Reef from above, including remotely from space, from the air or high lookout points. This perspective shows the Reef as a pattern of waters, reefs, cays and islands, and as a vast landscape.
- **At water or land level:** the Great Barrier Reef at eye level, as sky, water, and land emerging from water, and with a sense of a world beneath the water.
- **Below water:** the Great Barrier Reef as an underwater landscape. The three-dimensional qualities of the underwater landscape, its relative intimacy (with long-distance views rarely experienced), and the position of the viewer floating above and within the landscape are all distinctive. The aesthetic experience is also enhanced because this perspective is not part of everyday human experience.

The strategic context for aesthetics in the GBRMP is described in the GBR Outlook Report 2014 (and summarised in Table 1). The current condition is rated as 'good', the trend is 'deteriorating' and the management objective is to 'improve'.

Table 1: Summary assessment of condition, trend and overall management objectives of social values from the Strategic Assessment (GBRMPA, 2014).

Value	Area	Current condition	Trend	Management objective
Aesthetics	Reef-wide	Good	Deteriorating	Improve

Following international concerns about the potential impacts of proposed developments on the World Heritage values of the Great Barrier Reef, and specifically that aesthetic values of the property are less well understood than other aspects of the property, it was recommended that 'further work is needed in relation to identifying and documenting the attributes related to the aesthetic values of the property' (Day 2012).

At present, there is no clear methodology recommended by the IUCN to identify and measure aesthetic values within World Heritage areas, or the GBR region. Context (2013) developed a methodology drawing on existing heritage practice within Australia and internationally to identify experiential attributes, and a range of qualities that enhance the aesthetic values of the property. A case study was developed as an illustration of how the methodology can be applied, including an analysis of the sensitivity of aesthetic values to a range of threats. This work provides an initial discussion on the distinctive lens for considering impacts of development or other actions on aesthetics.

Research on aesthetics and the Great Barrier Reef were developed in the early 2000s (Greer et al 2000; Harrington 2004; Pocock 2002, 2003, 2005, 2006; McIntyre-Tamwoy 2004). Operationalising aesthetics associated with the Great Barrier Reef has been much more challenging as demonstrated in the Management considerations (Section 4.1) on scenic amenity for the Townsville Port Expansion Project (Port of Townsville 2016) and .

In our desktop review of the range of management tools used by the GBRMPA and stakeholders and their applicability to aesthetics, 6 of the 24 tools we found (25%) had discussed aesthetics: Plans of management, Policy, Education and Community Awareness, Reporting, Reef Blueprint and Ecosystem Restoration.

Table 2: Analysis of management tools and their applicability for managing coral reef aesthetics.

TOOLS	GBR APPLICATION	Use for aesthetics
Acts and Regulations	Enabling condition	No
Zoning Plans	Key and well known instrument for management	No
Plans of Management	PoMs, SMPs, SMAs, FHPP	Yes
The Permission system	Permits used comprehensively to manage a range of activities	No
Fees and Charges	EMC, leases, permits and offsets	No
Policy	Cover wide range of issues, species and activities	Yes
Traditional Owner Agreements	TUMRAs	No
Site Infrastructure	Moorings, no anchoring markers, fences.	No
Partnership	Diverse and strong partnerships with Government, industry and community	No
Field Management and Compliance	Penalties for zoning plan breaches, VMS	No
Stewardship and Best Practice	Reef Guardian program, Accreditation programs, Responsible Reef Practices	No
Education and Community Awareness	Key part of GBRMPA business. Including Reef HQ	Yes
Research and Monitoring	Most done by partners AIMS, JCU and citizens.	No
Reporting	Annual, 5yr outlook	Yes
Reef Blueprint	Plan for future- see page 18.	Yes
Species Protection and Control	Protection of species of conservation or health concerns. Control of COTS	No
Fisheries Management Plans	Qld Government	No
Management of Land uses	Qld Government	Yes
Payment for ecosystem services	Water Quality Protection Plan	No
Rights-based Management	NA	No
Marine Conservation Agreements	TUMRAs could be considered a form of conservation agreement	No
Ecosystem Restoration	Limited. Coral restoration following ship groundings; COTS control, Oyster reefs	Yes
Local Marine Management Agreements	NA	No
Private Ownership	Moorings and leases	No

One of the contemporary management tools is GBRMPA (2016) Guidelines: Social impact assessment in the permits system. This guideline provides detail on Aesthetic values and quantifies positive and negative impacts and the degree of severity (Table 3). We have tested the GBRMPA (2016) guidelines and management triggers from Table 3 using published data of reef aesthetics from Hass et al (2015) to bridge the link between research and management and inform the NESP Key Performance Indicators. Our suggestions are to:

- Trial methods to include aesthetics ratings as part of established monitoring programs such as the Integrated Eye on the Reef program for the Marine Park (above and below the water line).
- Develop standardized approaches (including monitoring regimes) to assist the GBRMPA to include aesthetic values into their policies and monitoring protocols such as permitting processes

- Work with the GBRMPA to explore and decide how aesthetic factors might be incorporated into decision processes, including through tools and capacity building

Table 3: Extract from consequence scale for social values, with colour highlights of degree of severity of impact (GBRMPA 2016).

Degree of severity						
Value	Positive	Negligible	Minor	Moderate	Major	Extreme
Aesthetics	Local, regional or widespread scale: The activity creates a long-term improvement in at least one aspect of community benefits.	Local, regional or widespread scale: The activity does not cause any noticeable decline in social values, even in the short term. AND/OR The activity creates a short-term improvement in social values which does not endure once the activity ceases.	Local scale: Temporary (<6 months) decline in social values for less than 10 % of a single community or stakeholder group. The affected group is able to cope with this temporary impact (for example, during construction), after which social indicators return to pre-disturbance levels within 5 years.	Local scale: Noticeable decline in social values for 10-30% of a single community or stakeholder group. The community is able to compensate for or recover from these impacts within 10 years, though this will require some effort and resources.	Local scale – Noticeable decline in social values for 30-60% of a single community or stakeholder group. The community may not be able to compensate for or recover from these impacts within 10 years, and major assistance is needed to help the community to transition through the change.	Local scale- Permanent reduction in social values for more than 60% of a single community or stakeholder group.

1.2.5 International guidance for measuring aesthetic values

In the global context of World Heritage, there is an almost exclusive focus on visual attributes of aesthetics (Johnson and Smith, 2012). In only one property, the Ilulissat Icefjord (Denmark), did aesthetic values explicitly include considerations beyond the visual. In this case, the dramatic sounds produced by the moving ice are described in the Statement of OUV as a ‘memorable natural spectacle’.

Hass et al. (2015) developed an online tool called Sensiphi for converting the aesthetic appearance of an ecosystem in simple numbers that potentially provides a cost efficient monitoring tool (see <http://www.sensiphi.com/>). Their research showed that mathematical approaches to assessing compositional features of a coral reef digital image can correlate with human assessments of the aesthetics of the image. As computational learning algorithms

improve (e.g. through AI), such tools are likely to produce results increasingly aligned with human assessments. However, thus far the relationship between coral reef health and the aesthetic appeal of such imagery has not been established empirically.

1.3 Purpose and approach

Our project had the overarching goal of exploring the feasibility of incorporating aesthetics into the monitoring and management of the Great Barrier Reef, and developing practical indicators for measuring and tracking reef aesthetics. We did this by pursuing three aims. Our first aim was to identify indicators of aesthetics that could be used for measuring and reporting on aesthetic condition of coral reefs. Our second aim was to investigate the link between reef aesthetics and reef health as a basis for exploring feasibility of using aesthetics as a high-level proxy for reef health. Our third aim was to work with managers of the Great Barrier Reef to incorporate indicators of reef aesthetics into current monitoring and assessment programs.

In achieving the above three aims, we also hoped to encourage the wider consideration of aesthetic values within the management of the Great Barrier Reef Marine Park. We were working from the hypothesis that aesthetic values could be effectively integrated into coral reef management through the development of robust indicators of reef aesthetics, and through an improved understanding of the relationship between reef aesthetics and reef health. In our study we explored the range of possible indicators that could be used within the Great Barrier Reef. We then tested whether a sub-set are sufficiently robust by inviting 1,500 people to judge the aesthetic appeal of 181 photos in which the sub-set of potential indicators are represented. We then related these judgements to assessments of reef health by reef experts.

1.3.1 Case study context

The Great Barrier Reef (GBR) is one of the world's largest coral reef system with a myriad of diverse marine life-forms and habitats (Hughes et al. 2007) (Figure 4). It is also an important national asset providing economic, social, cultural and aesthetic ecosystem services (Marshall et al. 2016, Context 2012; Hughes et al. 2007). Much of the economic activity associated with the GBR is derived from the tourism industry, where over \$5.2 billion is generated each year by people wanting to visit the reef (Deloitte Access 2017). Tourists seek opportunities to appreciate the natural aesthetics of the GBR through experiences such as diving and snorkelling, visiting beaches, boating and scenic flights (Hass et al. 2015). Like reef systems around the world, the GBR faces a combination of global and local pressures that threaten both its ecosystem health and aesthetic values (Marshall and Johnson, 2007; Context 2012; Hughes et al. 2007). Managers currently monitor and study reef health to detect changes over time so they can respond to negative impacts. Whilst aspects of the human dimension is assessed and monitored through the Social and Economic Long Term Monitoring program (SELTMP) for the Great Barrier Reef, very little information on how aesthetic values have changed since the inscription of the GBR on the World Heritage list exists.

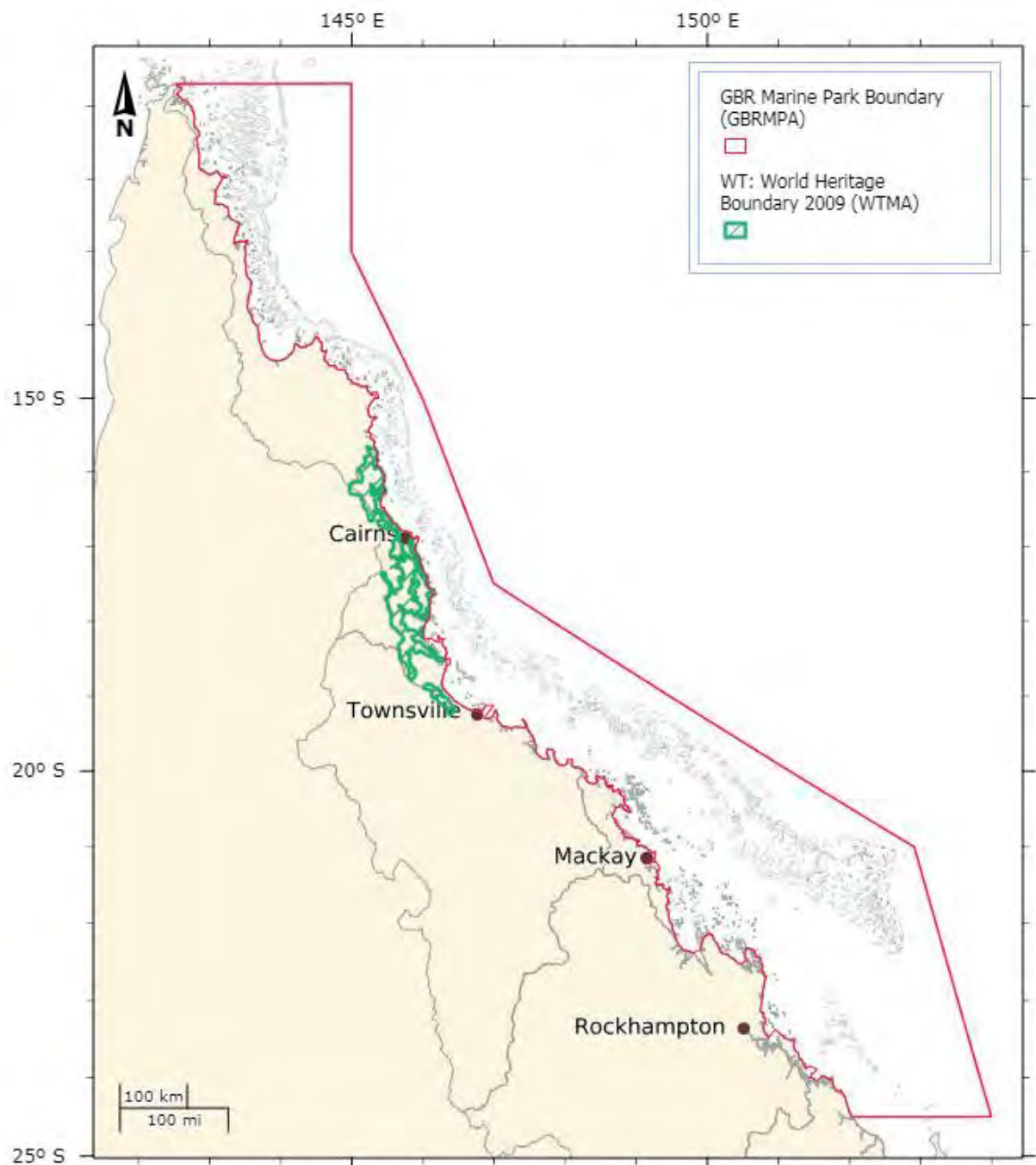


Figure 3: Map of the Wet Tropics and Great Barrier Reef World Heritage Areas (Source: eAtlas)

2.0 METHODS

2.1 A qualitative scoping study: possible indicators of aesthetic value

In this component of our study our aim was to establish reliable indicators of aesthetic value of coral reef habitat within the Great Barrier Reef through a survey of people with long-standing experience with the Great Barrier Reef. We identified a sample of individuals that were generally recognised for their experience with the Great Barrier Reef (GBR) using a standard snowball sampling technique. They were invited to contribute their opinions as to what the indicators should be via email. Ethics approval was received from CSIRO Human Ethics Committee (023/17). When respondents replied to our invitation, an appointment was set. Most interviews occurred as face-to-face interviews and generally lasted less than 30 minutes. Two interviews were conducted by telephone where it was too difficult to meet.

The interview questions were open-ended and broad in nature to capture the most comprehensive range of responses that we could. The questions included:

- What would you say are the important aspects of the GBR to protect, particularly those that relate to the aesthetic qualities of the Reef?
- What should we be monitoring in order to know whether these aspects are being protected?

Interviews were not audio recorded; instead, extensive notes were taken by the first author. Interviews were analysed in Word, where key words and phrases were coded into thematic concepts that could be used as indicators (for example: colour, movement, glistening). The initial list of potential indicators was 184. These 184 terms were condensed into a more manageable list by merging similar themes together. For example words such as shape, texture, composition were merged together into a theme called 'composition'. This iteration occurred two more times until a final list of 12 indicator clusters emerged. It was not an intention to limit the list to 12, but more of a natural outcome. Each of the final clusters of indicators are described in the results section using sentiments described in the interviews.

2.2 A quantitative study: identifying robust indicators of aesthetic value

In this component of the study, our aim was to provide rigorous testing of potential indicators for use in GBR reporting, monitoring and management. We chose the five factors that were both prominent amongst responses and amenable to quantification as part of a monitoring program, and tested for their influence on aesthetic ratings through regression analysis. They included: (i) coral cover, (ii) coral pattern, (iii) coral topography, (iv) fish abundance, and (v) visibility. (Coral pattern is likened to 'coherence' within the field of landscape aesthetics where a harmonious arrangement within a landscape composition, such as unity in colour, shape, or texture exists; Stamps, 2004; Rosley, Rahman, and Lamit, 2014).

We then identified 181 underwater coral reef photographs from those that were publically available (www.gbrmpa.gov.au) or existed in the combined image libraries of the study authors

(see Appendix 1). They represented typical underwater images from the GBR, with a common oblique perspective taken from approximately 5-10 m above a coral substrate. This perspective characterised the image that a person would see as soon as they placed their head beneath the water, and it was similar to the visual perspective used in monitoring surveys conducted by manta-towing at the Australian Institute of Marine Sciences. Some photos were duplicated and placed randomly, and some were modified using photo editing software to manipulate one feature independent of others, for the purposes of 'checking' the consistency and subtleties associated with making aesthetic judgements (see Appendix 1).

Each photo was rated for each of the five factors (on a scale of low, medium, high) by members of the research team with experience in coral reefs (see Appendix 1). Given that there were insufficient photos representing abundant fish and poor visibility, a total of 20 photos were manipulated to enhance or de-emphasise certain factors. These photos ensured that we could attribute differences in aesthetic appeal of each photo to at least one of the five factors. The final set of photos represented realistic coral reef images across all five factors, with a greater representation of images containing moderately high coral cover to capture the nuances across the scale of potential ratings and also to aide engagement during online rating sessions (see Appendix 1).

Once 181 photos were identified and rated for each of the five factors, they were delivered to an online service provider with the ability to reach a large number of random, representative Australians (www.pollinate.com.au). A survey was constructed to collect simple demographic information about each participant, the self-rated level of interest in coral reefs, and aesthetic ratings for each photo on a scale of 1-10 (where 1=extremely unattractive, and 10=extremely attractive) (See Appendix 2). Once an individual agreed to partake in the survey, they were sent a survey with 50 photographs randomly chosen from the pool of 181 photographs. We were concerned that the quality of responses would be affected if more than 50 photos were viewed (where 50 photos represented a ten-minute survey). The style of the survey was not dissimilar from very popular online games in which individuals are asked to rank aesthetic preferences of fashion or interior design items.

A total of 1,417 individuals participated in the study, where each photo was rated at least 380 times on the ten-point scale. Twenty-nine percent of the sample came from Queensland, and 71% were distributed across Australia. Some 62.3% of people came from Metropolitan Australia, whilst 37.7 came from rural/regional Australia. Some 51.4% were female. Participants represented a range of experiences with the Great Barrier Reef, where 7.2% had never visited, and 7.9% did not find coral reefs that interesting. Most participants (99.6%) were not part of a GBR based club or community groups, such as a spear-fishing club. The average age for the sample population was 46.96 (standard error=0.471), and ranged from 16 to 89.

Data were analysed in SPSS version 20, where we obtained the mean and standard error of the aesthetics rating for each photo. In this way we were able to identify the most attractive photo, and each subsequently most attractive photo. We then conducted analyses of co-variance where the dependent variable was the mean aesthetic rating of each photo and each of the following factors were tested in combination for their influence: (i) coral cover, (ii) coral pattern, (iii) coral topography, (iv) fish abundance, and (v) visibility. We also tested for the influence of gender, experience, age and self-reported, 'interest in coral reefs'.

Table 4: Level of experience with the Great Barrier Reef amongst survey participants. Responses to the survey question, “Which of the following statements best applies to you?”

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	I have visited the Great Barrier Reef in the last 12 months	164	11.6	11.6	11.6
	I have visited the Great Barrier Reef – but it was more than 12 months ago	575	40.6	40.7	52.3
	I have never visited the Great Barrier Reef, but I would like to at some stage	572	40.4	40.5	92.8
	I have never visited the Great Barrier Reef, and don't intend to	102	7.2	7.2	100.0
	Total	1413	99.7	100.0	
Missing	System	4	.3		
Total		1417	100.0		

Table 5: Responses to the survey question, ‘How would you best describe your interest in coral reefs?’

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	I generally find coral reefs not that interesting	111	7.8	7.9	7.9
	I generally find coral reefs interesting	767	54.1	54.3	62.1
	I generally find coral reefs really interesting	535	37.8	37.9	100.0
	Total	1413	99.7	100.0	
Missing	System	4	.3		
Total		1417	100.0		

2.3 Relating reef aesthetics to reef health

The concept of health has been long used as a metaphor to represent the condition (state and function) of ecosystems, and is sometimes used synonymously with resilience. In the context of the Great Barrier Reef, an ecosystem is considered healthy “if it can maintain its structure and function in the face of external pressures” (Great Barrier Reef Outlook Report 2009, 2014). Reef health is a core theme in the management and reporting for the Great Barrier Reef Marine Park, which is the statutory responsibility of the Great Barrier Reef Marine Park Authority. It is also a focus for the monitoring programs that support GBR management, such as the Inshore and Long Term Monitoring Programs of the Australian Institute of Marine Science, as well as for citizen science programs such as Reef Check and GBMRPA’s Eye on the Reef.

A wide range of characteristics contribute to overall reef health, but a smaller subset is usually sufficient to provide reliable and practicable indicators for assessment and monitoring. These

tend to focus on the key drivers of reef health and resilience, such as the condition of coral and fish communities, and indicators of stress such as coral health (disease, etc.) and macroalgal cover (often a response to nutrient pollution).

We found that experts involved in reef health assessment and monitoring tend to develop an ability to quickly establish an overall impression of a reef's health through a quick visual evaluation of key drivers of health and resilience. This is further honed through time through comparison and calibration of their visual impressions with the analytical results of survey of reef health using measurements of these indicators. This ability also enables experienced experts to provide consistent assessments of reef health from images of reef habitat. This skill provided the basis for our study, which aimed to derive expert assessments of reef health for our 181 images of coral reef habitat. These assessments are to be used as inputs to a related project task, which aims to compare expert assessments of reef health with non-expert evaluations of aesthetic quality of the same images.

In order to rate the health of the same 181 photographs, we needed to initially decide on criteria (indicators) for rapid visual assessment of the health of reef habitat. We convened a workshop comprising a panel of 8 highly experienced coral reef health assessment and monitoring experts. These included two long-term members of the Australian Institute of Marine Sciences' Inshore and Long Term Monitoring Programs; two members of GBRMPA's Reef 2050 Integrated Monitoring and Reporting Program; three senior experts from Reef Ecologic with extensive experience in coral and fish monitoring; and the regional coordinator of the Reef Check citizen science program. In combination, these experts had over 100 years of experience in the assessment and monitoring of coral reef health.

The experts were first asked to discuss key indicators of reef health, with reference to their experience with rapid visual and quantitative monitoring. There was strong consensus that seven indicators that could be evaluated from visual assessments of images could provide reliable and repeatable estimates of reef health using a simple 5-point scale. The seven characteristics chosen as visual indicators of reef health were; (i) proportion of live coral cover, (ii) coral diversity, (iii) coral size range, (iv) fish abundance, (v) fish size range, (vi) fish diversity, and (vii) presence/absence of macro algae.

The eight experts were shown each of the 181 images on a large screen, one at a time. Through a visual evaluation of the above indicators, the experts were asked to rate the health of the coral reef habitat in each image on a 1-5 scale (where 1=very poor health, 2=poor health, 3=good health, 4=very good health, and 5=excellent health).

An interactive polling tool (keypad and software by Turning Point) was used to facilitate a Delphi method (Dalkey et al. 1963) to establish expert consensus on each reef health assessment. Experts voted upon being shown each image. After each expert had entered their initial rating, the distribution of votes was reviewed by the group. Where votes spanned more than two immediately adjacent rating categories, we facilitated discussion among the experts to explore the basis for differences in evaluations. This was followed by a second round of voting, in which experts could modify or retain their initial rating. No further voting rounds were done, and we noted any images where there remained significant variation (more than three categories) among the experts in their ratings. In most instances, this process lead to greater

consensus, with most images receiving evaluations spanning one or two categories. The final ratings were compiled and used to generate an average health rating for each image.

A Pearson correlation was conducted on the ratings of aesthetics and health using data from all 181 photos. This provided a measure of the strength of correlation between aesthetic judgements and reef health, and to explore the veracity of aesthetic ratings as a high-level proxy for reef health.

3.4 Using reef aesthetics in reef monitoring and management

We presented preliminary results of our study to the Great Barrier Reef Marine Park Authority (GBRMPA) and convened a workshop with senior staff with responsibilities for citizen science programs, integrated monitoring, impact assessment and permits. These engagements and consultations provided an opportunity to explore the feasibility and utility of integrating our aesthetic indicators into GBR management and monitoring programs.

Additionally, we tested the utility of an online tool developed for computational evaluation of coral reef aesthetics (Haas et al. 2015). We submitted ten images representing reef habitats in varying health to test the strength of correlation between computational evaluations of beauty and expert assessments of reef health.

habitat-complexity, structural heterogeneity, design, size and shape. To these respondents, the Great Barrier Reef, both above and below the water represented a visual experience of interesting, stimulating and exciting images. Words such as Feng Shui, balance, and symmetry were used to convey rich meanings into what was important aesthetically. Below the water, the most common descriptors were about a coral reef scene, sometimes with drop-offs or swim-throughs. Above the water, the most common descriptors revolved around the rainforest coming onto the beach.

Clear Water. The clarity of the water was mentioned by nearly all respondents. Most agreed that the visual experience was enhanced by having clear water. For some, the clear water itself was beautiful, particularly with the sun shining through it, and particularly if there were small fish reflecting the sunshine just below the surface. Clarity was important for people describing aesthetics both from below the water as well as from above the water. Some respondents mentioned that they were aware that clear water did not always mean safe water where a cocktail of various toxins could exist within the water but not be visually detectable. Other respondents mentioned that muddy water was sometimes the more natural situation in areas such as Magnetic Island, and that knowing that helped them to appreciate water that was not necessarily clear.

Colour. Colour was identified by many respondents as an important indicator contributing to their interpretation of the aesthetic value of the Great Barrier Reef. Colour could refer to the colour of coral, the colour of coral bleaching, the colour of fish or the combination of colour within a single scene. However, for the most part, people described colour in terms of the blues, greens or turquoises of the water and water/sky and of the whiteness of the sand. White sand through clear/blue water on a sunny day was mentioned several times.

Experience. This category represents words like movement (of fish or waves), connection with nature, destination, smell, sound, touch, taste, and opportunity. These respondents regarded the aesthetics of the Great Barrier Reef in its entire sensory definition. If a coral reef, for example, looked particularly inviting because it had several nooks and crannies, or swim-throughs or fell away to the unknown, it was described as exciting and full of opportunity. The need to explore and adventure was tantalised and the delight of being able to interact and venture into the scene was described as extremely appealing. The word opportunity was also used in reference to aerial perspectives, where some respondents described how aerial images of the Great Barrier Reef with its channels and sea cays and islands made them want to be part of the environment, to explore it, so that they could experience it.

Charisma. This indicator is very much related to 'experience'. Whales, turtles, nesting seabirds, dolphins, big fish, clown fish, seahorses, nudibranchs, and several other charismatic animals were highlighted during the interviews as beautiful. In contrast to the cluster called, 'composition', this cluster was very much focusing in on particular elements of a visual experience. The actual elements were all biological. Some respondents described what it felt like to respond to witnessing a special interaction under the sea (such as a bill fish herding bait fish into a 'ball'), or being able to touch a turtle under water, or swim beside a minke whale. Whilst these descriptions were very much about the personal response to being in nature, they were described as a critical part of their aesthetic experience. One respondent remarked that the intense emotional environment created when interacting with Nature might be misinterpreted as beautiful, when in fact it might not be.

Coral. Coral was described by most people as the ultimate Great Barrier Reef aesthetic experience. Coral epitomised what was so special about the Reef and what was so beautiful. Coral was described in many different ways. Some respondents described it in terms of its composition (shape, topography, colour, texture, interest), whereas others described it in terms of abundance/cover and diversity of species and form. Two respondents made comment that coral reefs were like old growth forests, where massive *Porites* coral bommies represented the slow-growing ancient giants of the system, whilst the staghorns, whilst beautiful, represented the fast-growing weeds or undergrowth of the system, and that both forms together represented aesthetic values, and were together, related to coral reef health.

Fish. Fish, like corals, were described either in terms of their physical presence (movement, colour, size, shape, reflection, sound, schooling), or in terms of their ecological value (fish abundance and fish diversity). Most respondents agreed that fish abundance and diversity in fish size were important contributions to their aesthetic experience below the water. One respondent described how she liked to imagine that there were large schools of various fish on the Reef.

Tiny things. This aspect of aesthetic appreciation relates to below the water, and is closely related to the clusters, experience and charisma. Many respondents liked to describe how they enjoyed interacting with the Reef as part of their aesthetic enjoyment of the Reef. Inevitably, this involved aesthetically appreciating the small invertebrates existing amongst the coral such as the ascidians, nudibranchs, sessile organisms and worms. These tiny organisms were beautiful to look at in their own right, but were also beautiful in their contribution to the conglomerate of what a coral reef represented to them.

Healthy system. Some respondents wanted to describe what they thought what a beautiful experience both above and below the water in terms of words such as healthy, connectivity, whole-of-system, alive, vibrant. Respondents wanted to describe how sometimes it wasn't possible to tell whether a coral system or any other natural system was healthy or not, and that education played an important role in helping people understand what was healthy and what was not. One respondent suggested that it was possible to change one's perspective on what was beautiful simply by informing them on whether it was healthy or not. Bleaching came up frequently as an example of a system that is unhealthy but beautiful. Another respondent wanted to point out that if the whole system was healthy (e.g. inshore, estuarine, coastal, mangroves etc.), then through the channels of connectivity, the best indicator would be a healthy coral reef (with coral, fish, invertebrates etc included). No-one described the role of people in the visual healthy image of a whole of Great Barrier Reef system.

Recreation. Only a few respondents wanted to mention the role of people on the aesthetic of the Great Barrier Reef. This indicator cluster is closely related to the cluster of experience. These people described the image of boats on the water, particularly yachts, as relaxing, inspiring or beautiful. Importantly, they described only a few boats at a time, and sometimes they were described as nestled into bays. People enjoying themselves such as playing on the beach, snorkelling or diving was seen as contributing to the aesthetic experience of these respondents.

Aerial view or spatial considerations. Whilst most respondents were happy to discuss the aesthetic values of the Reef below or above the water, some respondents really wanted to describe the beauty of the reef from an aerial perspective. Several respondents described the appreciation of 'space'. Vast, open areas that are so typical of the region were regarded by some as particularly stunning. This inevitably led to discussions about the various different scales that ought to be considered when one considers the beauty of the Reef. As such, this indicator cluster is closely related to tiny things and experience. The wide open space provided by beaches (Whitehaven and Port Douglas in particular) and the broad vista of the sea from the beach were particularly recognised as part of the aesthetic of the region.

3.2 Quantifiable indicators of aesthetic value

The mean aesthetic rating (on a scale of 1 to 10) for the 181 photos was 6.86 and ranged between 4.35 and 8.34. The mode was 7.42. Whilst many photos were rated along the whole spectrum from 1-10, the standard error was relatively tight (approximately 0.1 on the 1-10 scale). The most highly rated photographs are presented in Table 6.

Results from the ANCOVA suggested that topography, fish abundance and visibility were significant influences on how survey participants rated the aesthetic quality of each of the 181 photos (Table 7).

Table 6: The highest and lowest ranking photos of the survey and their mean and standard error scores.
Note that the fourth and fifth favourite photo have been photo-shopped and are not 'natural'.

Highest ranking photos based on aesthetic rating	Mean score
	8.34 ± .081
	8.25 ± .077

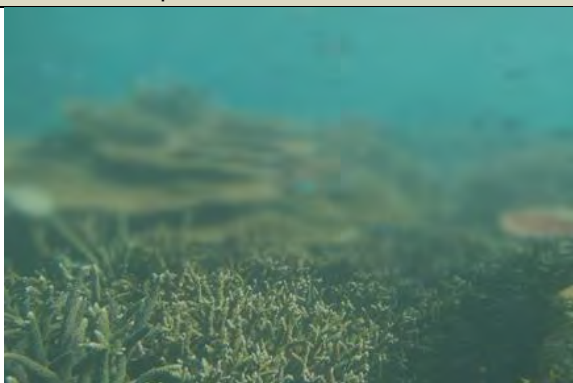
	$8.20 \pm .078$
	$8.18 \pm .08$
	$8.17 \pm .085$
Worst Rated photos	
	$4.36 \pm .124$



Table 7: Results of an Analysis of Co-Variance (ANCOVA) looking at the combined influence of factors on aesthetic ratings. Significance values less than 0.05 were regarded as significant.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	41.332a	5	8.266	20.599	.000
Intercept	49.737	1	49.737	123.941	.000
Coral cover	4.006E-6	1	4.006E-6	.000	.997
Coral pattern	.179	1	.179	.446	.505
Topography	1.751	1	1.751	4.364	.038
Fish abundance	21.751	1	21.751	54.201	.000
Visibility	11.706	1	11.706	29.169	.000
Error	70.227	175	.401		
Total	8626.313	181			
Corrected Total	111.559	181			

a. R Squared = .370 (Adjusted R Squared = .353)

Table 8: Influence of demographics on aesthetics ratings.

	Df	F	p-value
Age	71	1.080	.307
Gender	1	3.983	.046
Visitation	3	1.657	.174
Interest in coral reefs	2	34.244	.000

3.3 Linking Reef aesthetics with Reef Health

3.3.1 Health ratings of coral reef photographs

The averaged health ratings generated by reef health monitoring experts for the 181 images ranged from 1.13 to 5 (on a scale of 1 to 5). The standard deviations calculated from the 8 expert ratings for each image ranged from 0 (full consensus) to a maximum of 0.5. Figure 5 presents the frequency histogram for the 5 rating categories, showing a normal distribution with good (average rating 2.5-3.5) or very good (3.5-4.5) health ratings occurring the most frequently. Ratings below 1 or above 5 were not possible with our rating system.

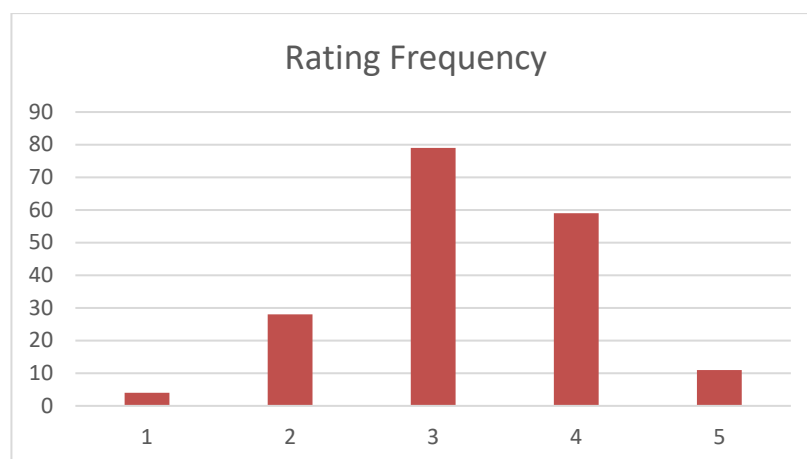


Figure 5: The distribution of health ratings of the 181 photos.

3.3.1 Correlations between Reef health and Reef Aesthetics

A Pearson correlation revealed a highly significant correlation between the aesthetics ratings on the 181 photos and the expert health ratings ($p=0.000$).

Table 9: Results of a Pearson correlation between ratings of reef aesthetics and reef health

		aesthetics	health
aesthetics	Pearson Correlation	1	.259**
	Sig. (2-tailed)		.000
	N	181	181
health	Pearson Correlation	.259**	1
	Sig. (2-tailed)	.000	
	N	181	181

** . Correlation is significant at the 0.01 level (2-tailed).

3.4 Using reef aesthetics in reef monitoring and management

Consultations with GBRMPA and a review of current policies and programs highlighted a range of opportunities for integrating our reef aesthetic indicators into monitoring and management of the GBR. The citizen science program, Eye on the Reef, could incorporate indicators of aesthetic quality alongside the current list of biophysical indicators. Current limitations to the capacity of GBRMPA staff to expand the program and provide necessary training to program participants suggest a more strategic approach to adapting the program is required. However, there is significant potential to use indicators of aesthetics to increase engagement appeal of the program, initiate tracking of aesthetic conditions at frequently monitored sites and to test the utility of aesthetic ratings as an early warning for changes in reef health.

A range of monitoring programs provide information on health of the Reef to GBRMPA and partners, however these are almost exclusively focused on biophysical characteristics, and they are not well integrated as an information system for management. The Reef 2050 Integrated Monitoring and Reporting Program (RIMReP) has been established to integrate these separate monitoring programs and to inform future development of monitoring programs toward meeting the full range of information needed by managers. This creates an opportunity

for incorporating aesthetic indicators into GBR monitoring programs in the future. The results of our study demonstrated to GBRMPA that there is potential to reliably measure reef aesthetics and has encouraged further consideration of structural changes to monitoring programs that would enable them to measure and monitor aesthetics in accord with their responsibilities as the World Heritage site manager.

As part of their management responsibilities, GBRMPA is required to consider potential aesthetic impacts when assessing permit applications. Where relevant to an assessment, this has historically been done through qualitative evaluations, and without the benefit of an analytical framework. The indicators identified in our study demonstrate potential for developing such a framework, and associated assessment guidelines. We intend to continue to work with relevant staff to further scope tools and future research that could lead to tools and guidelines that can support a more structured approach to assessing aesthetic impacts of proposed activities.

There are other current research projects investigating underwater aesthetics including NESP Project 3.2.3 Monitoring aesthetic value of the Great Barrier Reef by using artificial intelligence to score photos and videos with the aim to design a robust basis for automatically measuring aesthetic value of the Great Barrier Reef to be adopted by the Reef 2050 Integrated Monitoring and Reporting Program (RIMReP).

4.0 DISCUSSION

Our scoping study has demonstrated the potential to reliably and repeatedly measure reef aesthetics using a tractable set of indicators, and that these indicators in combination can also provide useful information about coarse changes in reef health. While there is a need for further work to fully resolve all the drivers of reef aesthetics across a range of habitat types, these initial results pave the way for managers of coral reefs to more reliably monitor and report on aesthetic conditions.

We found that coral topography, fish abundance and visibility were reliable predictors of aesthetic quality and are simple to estimate. Topography, whilst classified under 'coral' in the analysis of the qualitative study, maybe also be acting to provoke a response that could be described as the 'potential for experience', or 'opportunity for experience'. The topography of a reef can be described as the three dimensional landscape of a coral reef, which may include a reef slope, flat or lagoon with various shapes and features, or a complex network of 'nooks and crannies', within which large or small marine animals may be hiding. Coral reef topography is thus likely to appeal to people's sense of adventure, exploration, and intrigue (Rosley et al. 2014). It presents uncertainty and mystery and possibly inspires a high degree of inquiry and curiosity in people's minds (Stamps, 2004, Rosley et al. 2014).

Coral cover and coral pattern, whilst important themes distilled from our interviews with key informants, did not reliably correlate with aesthetic ratings in our study. In several instances, observers rated images of reef flats with high coral cover as not beautiful; these images also had low fish abundance or low visibility, suggesting that these latter variables may have a relatively larger influence on aesthetics. Our results suggest that testing for the influence of a larger number of indicators may uncover additional correlates; however, such studies will require a substantially larger statistical design (which was beyond the scope and timeframe for this project).

Fish abundance has been identified by others as a key indicator of aesthetics (see Becken in prep). Of note is that two of the five most aesthetic photos had been manipulated to increase fish abundance, reinforcing findings that fish abundance is a key indicator of reef aesthetics. Fish abundance may represent ecological integrity, completeness or wholesomeness within a seascape. One participant described how a coral reef without fish is like a playground without the laughter, perhaps capturing the important role of this ecological element in the overall aesthetic impression of a reef scene. This is likely to be related also to the dynamic and variable nature of fish communities, which contribute movement and colour, reflection and sound, and a diversity of sizes and shapes. Fish abundance and fish diversity were both important as a potential indicator in the qualitative study. Fish are also an integral component of a healthy reef, suggesting that the role of fish in reef aesthetics warrants further investigation.

Visibility was also an important influence on aesthetic ratings in this study, as in other studies (Völker and Kistemann, 2013, Burmil et al., 1999; Herzog, 1985; Pflüger, Rackham, & Larned, 2010; Yamashita, 2002). Water clarity is a primary concern for people (Farr et al. 2016). Tourists' visual satisfaction with water bodies in tourism fishing ports was positively and strongly influenced by water clarity. Researchers have found that improving water clarity leads

to an increase in visual satisfaction. Water clarity is influenced by water quality (Lee, 2016), so it may be that humans have evolved to associate positive experiences with water condition, where experiences with clear water have been more positive than in less clear water (e.g. health issues, animal encounters).

An important insight from our study is that beauty is not in the 'eye of the beholder' when it comes to assessing underwater coral reef imagery. Whilst people did vary in their judgements of each photo, ratings were surprisingly consistent across observers. Coral health ratings estimated by reef experts were just as likely to vary as aesthetic ratings for two identical photographs placed apart from each other (see Appendix 1). Importantly, age, gender, education, and experience with the Great Barrier Reef did not significantly influence aesthetic judgement. The only social factor that we could detect as being important was the self-reported 'interest in coral reefs', where people who self-proclaimed to be more interested in coral reefs were more likely to rate a photograph higher for its aesthetic appeal.

Our results have identified and tested three factors of aesthetic value in the Great Barrier Reef. Many more indicators need to be tested if comprehensive aesthetic consideration, reporting and monitoring are to occur, and not only within underwater seascapes, but within the variety of landscapes within which coral reef managers and other environmental managers work. Within the Great Barrier Reef, managers increasingly need reliable and objective measures for aesthetic values above the water, and at the water line, such as for beaches, islands and cays, in order to ensure those values are adequately protected. Our study was necessarily limited in scope to a narrow range of visual perspectives (matched to the perspective of a snorkeler looking obliquely toward and over a reef habitat). Replicating our approach on a wider range of perspectives, including aerial, above-water and water line views would provide additional insights that could inform reef management. Further study is also needed to understand the extent to which aesthetic indicators can be incorporated into long-term monitoring. The process of testing and incorporating coral reef aesthetics into reef management is likely to be extensive, but with significant benefits for the management of coral reefs in Australia and internationally.

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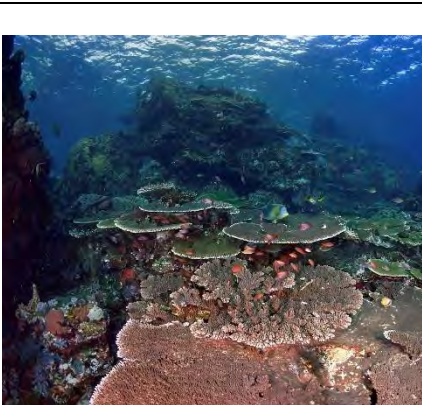
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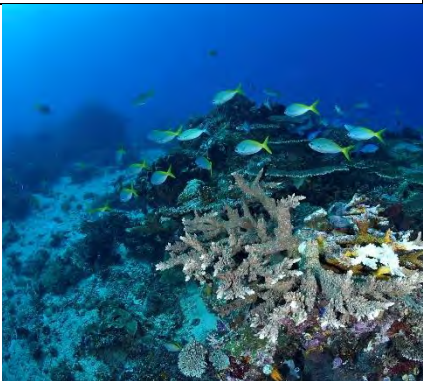
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APPENDIX 1: THE 181 PHOTOS USED IN THE QUANTITATIVE STUDY

All 181 photos and their aesthetics, health and indicator ratings. Aesthetics were rated on a scale of 1-10 (n~400 per photo from a pool of 1,500 participants), (where 1=really, really ugly and 10= really, really beautiful). Health was rated by experts on a scale of 1-5 (where 1=very poor health and 5= excellent health). Indicators were rated by the research team on a scale of 1-3 (1=low, 2=medium, 3=high). Note that some photos are randomly duplicated, and duplicated in tandem. Note also that some photos have been photo-shopped to enhance, or detract, some features (one of the five indicators). Photos copyright Matt Curnock, Paul Marshall, GBRMPA.

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
1.		6.69	.108	4.75	3.00	2.00	2.00	3.00	3.00
2.		6.91	.102	3.13	2.00	2.00	2.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
3.		6.02	.11	2.88	2.00	2.00	1.00	1.00	3.00
4.		7.77	.086	3.25	2.00	1.00	2.00	2.00	3.00
5.		6.62	.104	3.50	3.00	3.00	3.00	3.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
6.		5.60	.118	2.38	3.00	3.00	1.00	1.00	3.00
7.		7.11	.098	2.88	2.00	2.00	2.00	3.00	3.00
8.		6.57	.109	2.38	1.00	1.00	1.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
9.		6.44	.108	3.50	3.00	2.00	1.00	3.00	3.00
10		7.25	.095	4.13	2.00	1.00	1.00	3.00	3.00
11		6.75	.109	2.25	1.00	1.00	1.00	3.00	3.00

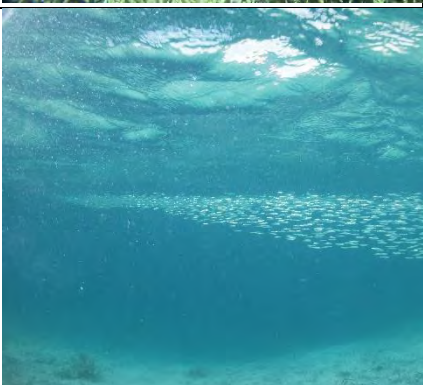
	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
12		7.24	.096	3.75	1.00	1.00	2.00	3.00	3.00
13		6.95	.103	3.75	2.00	2.00	2.00	3.00	3.00
14		6.84	.111	3.75	3.00	3.00	2.00	3.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
15		7.49	.097	4.38	3.00	2.00	1.00	2.00	3.00
16		6.75	.102	4.63	3.00	2.00	1.00	3.00	3.00
17		7.09	.106	3.75	3.00	2.00	1.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
18		7.02	.104	2.50	2.00	2.00	1.00	1.00	3.00
19		7.34	.095	2.25	2.00	2.00	1.00	1.00	3.00
20		6.83	.108	2.75	3.00	1.00	1.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
21		5.62	.111	3.38	3.00	2.00	2.00	1.00	3.00
22		5.45	.116	3.25	3.00	1.00	1.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
23		6.69	.098	3.75	3.00	2.00	1.00	1.00	3.00
24		6.74	.11	3.50	3.00	2.00	1.00	1.00	3.00
25		6.67	.102	4.13	3.00	3.00	1.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
26		6.14	.113	3.63	3.00	3.00	2.00	1.00	3.00
27		6.61	.101	4.25	3.00	3.00	1.00	1.00	3.00
28		6.35	.111	2.38	1.00	2.00	1.00	3.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
29		6.20	.118	2.38	1.00	1.00	1.00	1.00	3.00
30		6.05	.117	2.63	1.00	2.00	1.00	3.00	3.00
31		7.22	.098	3.63	3.00	3.00	2.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
32		8.17	.085	4.13	2.00	2.00	1.00	3.00	3.00
33		7.03	.108	3.50	3.00	3.00	3.00	3.00	3.00
34		7.76	.089	3.38	3.00	3.00	3.00	3.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
35		6.55	.11	2.25	3.00	3.00	3.00	1.00	3.00
36		8.18	.08	3.25	3.00	3.00	1.00	3.00	3.00
37		7.97	.09	2.88	3.00	2.00	1.00	3.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
38		8.02	.086	2.25	1.00	1.00	3.00	3.00	3.00
39		7.47	.101	3.88	3.00	3.00	3.00	3.00	3.00
40		7.79	.098	4.25	3.00	3.00	1.00	3.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
41		4.54	.125	1.25	1.00	1.00	3.00	1.00	3.00
42		8.01	.086	4.75	3.00	3.00	3.00	3.00	3.00
43		7.70	.091	3.88	3.00	3.00	3.00	3.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
44		4.36	.124	3.25	3.00	3.00	2.00	1.00	1.00
45		5.19	.124	2.50	3.00	3.00	2.00	1.00	1.00
46		5.32	.118	3.75	3.00	2.00	1.00	1.00	2.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
47		4.85	.12	3.38	3.00	2.00	1.00	1.00	2.00
48		4.94	.122	4.25	3.00	3.00	1.00	1.00	2.00
49		5.97	.108	3.00	3.00	1.00	1.00	1.00	2.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
50		5.07	.126	2.88	1.00	2.00	2.00	3.00	2.00
51		7.06	.103	3.13	2.00	1.00	2.00	3.00	3.00
52		5.99	.11	3.50	1.00	2.00	1.00	3.00	2.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
53		5.95	.112	3.25	1.00	2.00	1.00	3.00	2.00
54		6.01	.114	3.50	1.00	1.00	2.00	3.00	2.00
55		5.98	.114	3.25	3.00	2.00	2.00	3.00	2.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
56		7.52	.098	3.13	3.00	2.00	2.00	3.00	3.00
57		5.20	.13	1.50	1.00	1.00	1.00	1.00	3.00
58	 Please note: 58, 59, 60 are identical	7.42	.098	4.75	3.00	3.00	2.00	3.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
59		7.42	.093	4.63	3.00	3.00	2.00	3.00	3.00
60		7.34	.099	4.75	3.00	3.00	2.00	3.00	3.00
61		6.49	.109	4.50	3.00	2.00	2.00	2.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
62		6.92	.113	2.38	1.00	1.00	1.00	1.00	3.00
63		8.01	.086	4.25	3.00	3.00	3.00	1.00	3.00
64		6.45	.109	3.13	3.00	2.00	3.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
65		7.46	.092	2.50	2.00	1.00	1.00	2.00	3.00
66		8.15	.078	4.25	3.00	3.00	3.00	1.00	3.00
67		7.20	.101	4.13	3.00	3.00	3.00	3.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
68		5.47	.122	2.75	2.00	3.00	1.00	1.00	3.00
69		7.01	.105	3.25	2.00	2.00	2.00	1.00	3.00
70		8.20	.078	3.13	3.00	3.00	3.00	3.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
71		7.92	.078	3.75	3.00	3.00	2.00	3.00	3.00
72		7.82	.099	2.25	1.00	1.00	1.00	1.00	3.00
73		7.04	.103	3.38	1.00	2.00	1.00	3.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
74		8.34	.081	3.63	3.00	3.00	3.00	2.00	3.00
75		6.12	.109	1.88	3.00	3.00	2.00	2.00	3.00
76		5.76	.115	1.50	3.00	3.00	2.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
77		6.12	.114	3.38	3.00	3.00	1.00	1.00	3.00
78		7.68	.093	3.50	3.00	3.00	2.00	3.00	3.00
79		7.86	.083	3.50	3.00	3.00	2.00	3.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
80		7.80	.086	3.75	3.00	3.00	2.00	3.00	3.00
81		7.42	.094	4.00	3.00	3.00	3.00	2.00	3.00
82		7.23	.096	3.63	3.00	2.00	1.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
83		7.86	.092	3.38	2.00	1.00	2.00	3.00	3.00
84		6.55	.107	4.00	2.00	1.00	2.00	2.00	2.00
85		6.86	.101	3.75	3.00	2.00	1.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
86		5.78	.109	3.50	3.00	3.00	2.00	1.00	3.00
87		5.91	.113	3.88	3.00	3.00	1.00	1.00	3.00
88		6.89	.101	4.25	3.00	3.00	1.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
89		6.75	.103	4.00	3.00	3.00	3.00	2.00	3.00
90		6.16	.107	3.75	3.00	3.00	3.00	1.00	3.00
91		6.24	.107	3.63	3.00	3.00	3.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
92		7.73	.092	3.63	2.00	2.00	2.00	2.00	3.00
93		7.95	.082	3.25	3.00	3.00	3.00	3.00	3.00
94		6.66	.108	3.38	3.00	3.00	3.00	2.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
95		7.12	.098	3.25	3.00	3.00	3.00	2.00	3.00
96		7.34	.104	3.75	1.00	2.00	1.00	3.00	3.00
97		6.39	.114	3.50	3.00	3.00	1.00	2.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
98		7.68	.092	3.63	1.00	1.00	1.00	3.00	3.00
99		7.37	.093	2.13	2.00	1.00	1.00	3.00	3.00
10		6.98	.11	3.00	1.00	1.00	1.00	2.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
10		8.25	.077	2.00	2.00	3.00	2.00	3.00	3.00
10		6.28	.107	3.13	3.00	3.00	2.00	1.00	3.00
10		6.39	.108	4.13	3.00	2.00	1.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
10		6.29	.107	4.00	3.00	2.00	1.00	2.00	3.00
10		6.23	.106	3.38	3.00	3.00	1.00	1.00	3.00
10		5.87	.112	3.50	3.00	3.00	1.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
10		6.36	.104	3.50	3.00	2.00	1.00	1.00	3.00
10		7.15	.097	4.13	3.00	3.00	1.00	1.00	3.00
10		6.33	.109	4.75	3.00	3.00	1.00	2.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
11		7.08	.095	5.00	3.00	3.00	1.00	3.00	3.00
11		6.53	.105	4.00	3.00	3.00	3.00	3.00	3.00
11		6.86	.101	3.75	3.00	3.00	3.00	3.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
11		7.26	.093	4.63	3.00	3.00	2.00	2.00	3.00
11		7.42	.103	3.50	3.00	3.00	2.00	1.00	3.00
11		7.49	.101	2.75	2.00	2.00	1.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
11		6.92	.102	3.38	2.00	1.00	1.00	1.00	3.00
11		6.20	.124	3.63	3.00	3.00	1.00	1.00	3.00
11		6.84	.100	3.25	2.00	2.00	1.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
11		6.98	.103	3.25	2.00	1.00	1.00	1.00	3.00
12		5.81	.113	3.63	1.00	1.00	1.00	1.00	2.00
12		6.68	.11	3.25	2.00	1.00	2.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
12		6.70	.108	2.63	3.00	2.00	1.00	1.00	3.00
12		7.04	.102	4.13	3.00	1.00	1.00	1.00	3.00
12		7.13	.104	4.25	3.00	1.00	1.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
12		6.88	.10	3.75	3.00	3.00	1.00	2.00	3.00
12		7.64	.09	4.25	3.00	1.00	1.00	1.00	3.00
12		6.39	.11	3.13	3.00	3.00	2.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
12		6.74	.10	4.38	3.00	3.00	1.00	2.00	3.00
12		6.93	.094	3.88	2.00	1.00	1.00	2.00	2.00
13		5.90	.113	2.38	2.00	1.00	2.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
13		6.28	.11	2.25	2.00	1.00	1.00	1.00	3.00
13		5.78	.117	2.63	2.00	1.00	1.00	2.00	3.00
13		6.73	.106	3.25	2.00	2.00	1.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
13		6.70	.103	3.00	1.00	1.00	1.00	2.00	3.00
13		5.13	.132	1.13	1.00	1.00	1.00	1.00	3.00
13		7.08	.102	3.63	3.00	3.00	2.00	2.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
13		7.99	.087	4.13	3.00	3.00	2.00	3.00	3.00
13		6.49	.107	3.75	3.00	3.00	2.00	2.00	3.00
13		7.69	.091	4.63	3.00	3.00	2.00	3.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
14		7.21	.095	5.00	3.00	3.00	3.00	3.00	3.00
14		7.79	.087	2.50	2.00	1.00	2.00	3.00	2.00
14		7.04	.105	2.25	1.00	2.00	2.00	3.00	2.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
14		7.20	.102	2.13	1.00	2.00	2.00	3.00	2.00
14		6.93	.101	3.38	3.00	2.00	1.00	3.00	3.00
14		6.78	.107	3.38	3.00	2.00	1.00	3.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
14		6.14	.118	2.88	3.00	1.00	1.00	2.00	3.00
14		8.03	.081	4.25	3.00	3.00	3.00	2.00	3.00
14		6.40	.113	3.13	3.00	3.00	1.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
14		6.55	.111	2.50	1.00	1.00	1.00	1.00	3.00
15		6.92	.104	2.88	2.00	1.00	1.00	1.00	3.00
15		6.62	.111	2.63	2.00	1.00	1.00	1.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
15		7.05	.095	2.63	1.00	1.00	2.00	3.00	2.00
15		6.23	.11	3.50	2.00	1.00	1.00	1.00	2.00
15		6.84	.102	2.88	2.00	1.00	2.00	2.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
15		6.81	.106	3.25	1.00	2.00	1.00	3.00	2.00
15		7.41	.101	3.25	1.00	2.00	1.00	3.00	2.00
15		7.12	.105	3.13	1.00	1.00	1.00	3.00	2.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
15		7.55	.095	3.25	1.00	2.00	1.00	3.00	2.00
15		7.67	.09	3.50	2.00	1.00	3.00	3.00	2.00
16		7.85	.089	3.88	1.00	1.00	3.00	3.00	2.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
16		7.53	.09	3.38	1.00	2.00	1.00	3.00	3.00
16		7.40	.093	2.50	1.00	2.00	2.00	3.00	2.00
16		7.31	.095	2.38	1.00	2.00	2.00	3.00	2.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
16		7.25	.094	2.63	1.00	2.00	1.00	3.00	2.00
16		7.65	.1	3.13	1.00	1.00	2.00	3.00	3.00
16		6.59	.098	2.50	1.00	1.00	1.00	3.00	2.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
16		7.48	.096	4.25	1.00	1.00	2.00	3.00	3.00
16		7.44	.092	2.88	1.00	2.00	2.00	3.00	3.00
16		7.40	.092	2.25	1.00	1.00	2.00	3.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
17		7.43	.102	3.75	3.00	1.00	2.00	3.00	3.00
17		5.92	.111	3.38	3.00	1.00	2.00	1.00	2.00
17		5.79	.11	3.25	2.00	1.00	1.00	3.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
17		7.96	.088	3.38	1.00	2.00	2.00	3.00	3.00
17		7.22	.091	3.00	1.00	1.00	2.00	3.00	3.00
17		7.35	.093	3.88	2.00	1.00	1.00	3.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
17		6.60	.112	2.75	3.00	1.00	1.00	1.00	3.00
17		7.28	.095	3.25	1.00	1.00	2.00	3.00	2.00
17		7.89	.079	3.88	2.00	2.00	2.00	3.00	3.00

	Photograph	Aesthetic ratings (1-10)	Standard error (aesthetic ratings)	Expert health ratings (1-5)	Indicator: Coral cover (1-3)	Indicator: Coral pattern (1-3)	Indicator: Topography (1-3)	Indicator: Fish abundance (1-3)	Indicator: Visibility (1-3)
17		6.79	.107	4.00	3.00	2.00	3.00	2.00	3.00
18		7.40	.094	2.38	3.00	3.00	3.00	3.00	3.00
18		7.43	.102	3.75	3.00	1.00	2.00	3.00	3.00

APPENDIX 2: THE SURVEY USED IN THE STUDY

ASK ALL

A1	Firstly, just some demographic questions to ensure we're speaking to a wide range of people. Are you...		National sample	QLD boost
SR	Male	1	488	195
	Female	2	512	205
	Gender diverse (NOTE: only show this option for CLIENT-SUPPLIED SURVEY)	3	-	-

ASK ALL

A2	What is your age?			
OE NUM				
HA2	HIDDEN QUESTION CODED TO PUNCH AGE CATEGORIES BELOW		National sample	QLD boost
	15 or younger	1	CLOSE	CLOSE
	16-24	2	144	59
	25-34	3	181	69
	35-44	4	168	68
	45-54	5	165	68
	55-64	6	147	59
	65-74	7	111	45
	75 or older	8	85	32

ASK ALL

A3	WORDING IF PANEL SAMPLE: What is your current post code? WORDING IF CLIENT-SUPPLIED SAMPLE: What is your current Australian postcode? If you don't live in Australia, please tick the box below. NUMERIC OPEN TEXT BOX LIMIT TO 4 DIGITS (FOR CLIENT-SAMPLE, INCLUDE A TICK-BOX 'I don't live in Australia')			
OE				
HA3	HIDDEN QUESTION CODED TO PUNCH STATE USING THE STANDARD POST CODE LIST; TERMINATE ANYONE OUTSIDE OF STANDARD LIST		National sample (ideally even gender split)	QLD boost
SR	Sydney metropolitan [NSW]	1	207	-
	NSW (not Sydney) [NSW]	2	113	-

Melbourne metropolitan [VIC]	3	193	-	
Victoria (not Melbourne) [VIC]	4	62	-	
Brisbane metropolitan [QLD]	5	96	193	
Queensland (not Brisbane) [QLD]	6	103	207	
Adelaide metropolitan [SA]	7	57	-	
South Australia (not Adelaide) [SA]	8	16	-	
Perth metropolitan [WA]	9	83	-	
Western Australia (not Perth) [WA]	10	22	-	
Hobart metropolitan [TAS]	11	10	-	
Tasmania (not Hobart) [TAS]	12	12	-	
Darwin metropolitan [NT]	13	6	-	
Northern Territory (not Darwin) [NT]	14	3	-	
Australian Capital Territory [ACT]	15	17	-	
Outside Australia	16	CLOSE	CLOSE	

ASK ALL

ASK ALL

A4	Which of the following statements best applies to you?	
	When we refer to "the Great Barrier Reef" or "GBR" for short, we mean all land and water from the beaches on the coast, the bays and creeks, the islands, the shoals and seafloor, the open waters, and of course the coral reefs.	
SR	I have visited the Great Barrier Reef in the last 12 months	1
	I have visited the Great Barrier Reef – but it was more than 12 months ago	2
	I have never visited the Great Barrier Reef, but I would like to at some stage	3
	I have never visited the Great Barrier Reef, and don't intend to	4

ASK ALL

A5	How would you best describe your interest in coral reefs?	
SR	I generally find coral reefs not that interesting	1
	I generally find coral reefs interesting	2
	I generally find coral reefs really interesting	3

Asking these 2 questions before the proper introduction, so as not to bias their responses

SECTION B: MAIN SECTION

PROPER INTRODUCTION

In this survey, we would like to identify which images of the Great Barrier Reef are most beautiful to you and why. Knowing these aspects will really help decision makers manage for aesthetic impacts. All images are likely images of coral reefs that you would see if you were to pop your head under the surface of the water. We have tried to choose photos that are similar in 'type', but you will notice that they are obviously different in their detail. Having said this, we do not need to you to spend much time looking at the detail in each photo – we are keen to receive your initial impressions only.

Please rate the beauty of each of the following photos on a scale of 1-10, where 1= a really, really UGLY photo, and 10= a really, really BEAUTIFUL photo. Please spend less than 8 seconds on any photo, and record the first number that comes into your head. You will be presented with 50 photographs, along with some other questions to help with our analysis. The survey should take less than 10 minutes to complete. All results will be aggregated so that it will not be possible to identity individual ratings.

If you would like additional information about the survey or the project, please contact Dr. Nadine Marshall from CSIRO Land and Water, Townsville, at nadine.marshall@csiro.au or on 07 4753 8537

PROGRAMMER NOTE:

THE FOLLOWING SURVEY WILL BE MAINLY IMAGE BASED – i.e. RESPONDENTS EVALUATING IMAGES, ONE BY ONE ON A 10-point scale

AS THIS CAN GET QUITE REPETITIVE, WE HAVE INSERTED A FEW OTHER CLOSED-ENDED QUESTIONS THROUGHOUT

THERE ARE ABOUT 181 POSSIBLE IMAGES, HOWEVER EACH PERSON SHOULD ONLY SEE A RANDOM SELECTION OF 50 IMAGES. (BY THE END OF FIELDWORK EACH IMAGE SHOULD HAVE BEEN SHOWN TO ROUGHLY THE SAME NUMBER OF PEOPLE).

WE HAVE ORGANISED THE SURVEY SO THAT PEOPLE EVALUATE IMAGES IN 5 BLOCKS/CHUNKS OF 10 IMAGES EACH.

BLOCK 1:

ASK ALL

B1	Please rate the beauty of the photo below on a scale of 1-10, where 1 = a really, really UGLY photo, and 10 = a really, really BEAUTIFUL photo.									
										
SR	1 = really, really UGLY	2	3	4	5	6	7	8	9	10 = really, really BEAUTIFUL

REPEAT FOR 9 OTHER PHOTOS

ASK ALL

B2	How would you best describe your experience with coral reefs?	
SR	I have no experience with coral reefs	1
	I have dived/snorkelled once on coral reefs	2
	I have dived/snorkelled 2-10 times on coral reefs	3
	I have dived/snorkelled 11-100 times on coral reefs	4
	I have dived/snorkelled more than 100 times on coral reefs	5

BLOCK 2:

ASK ALL

B3	Please rate the beauty of the photo below on a scale of 1-10, where 1 = a really, really UGLY photo, and 10 = a really, really BEAUTIFUL photo.									
										
SR	1 = really, really UGLY	2	3	4	5	6	7	8	9	10 = really, really BEAUTIFUL

REPEAT FOR 9 OTHER PHOTOS

ASK ALL

B4	Are you part of a Great Barrier Reef based club or community group such as a spear-fishing club in your region?	
SR	No	1
	Yes, please specify the name of your club/group: _____	2

BLOCK 3:

ASK ALL

B5	Please rate the beauty of the photo below on a scale of 1-10, where 1 = a really, really UGLY photo, and 10 = a really, really BEAUTIFUL photo. 									
SR	1 = really, really UGLY	2	3	4	5	6	7	8	9	10 = really, really BEAUTIFUL

REPEAT FOR 9 OTHER PHOTOS

BLOCK 4:

ASK ALL

B7	Please rate the beauty of the photo below on a scale of 1-10, where 1 = a really, really UGLY photo, and 10 = a really, really BEAUTIFUL photo.									
										
SR	1 = really, really UGLY	2	3	4	5	6	7	8	9	10 = really, really BEAUTIFUL

REPEAT FOR 9 OTHER PHOTOS

ASK ALL

B8	Please list the first 5 words or phrases that come to mind when you think of the Great Barrier Reef. Please type in one idea per text box.	
	SHOW 5 TEXT BOXES	
OE	1	
	2	
	3	
	4	
	5	

BLOCK 5:

ASK ALL

B9	Please rate the beauty of the photo below on a scale of 1-10, where 1 = a really, really UGLY photo, and 10 = a really, really BEAUTIFUL photo.									
										
SR	1 = really, really UGLY	2	3	4	5	6	7	8	9	10 = really, really BEAUTIFUL

REPEAT FOR 9 OTHER PHOTOS

ASK ALL

B10	And finally, would you like to make any comments about the survey, or coral reefs more generally? Please feel welcome.
OE	

THANK AND CLOSE

