Full length article

Perceived need for management interventions in the Great Barrier Reef

Aditi Mankad [a],[*],[1] , Elizabeth V. Hobman [a],[2] , Matt Curnock [b],[3] , Michelle Dyer [c],[4] ,
Petina Pert [b],[5]

[a] *CSIRO Environment,GPO Box 2583, Brisbane, QLD 4001, Australia*
[b] *CSIRO Environment, James Cook University,Bebegu Yumba Campus, ATSIP Building 145, Townsville, QLD 4811, Australia*
[c] *Great Barrier Reef Marine Park Authority, PO Box 1379, Townsville, QLD 4810, Australia*

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ABSTRACT

The health of coral reef ecosystems is critically threatened by global warming, a fact well-recognized by reef managers and conservation specialists. However, this awareness does not necessarily extend to the broader public, potentially creating an epistemological disparity between expert understanding of necessary environmental management interventions and public perceptions of the need to intervene. This study examines the Great Barrier Reef (GBR; the Reef) as a case example to explore predictors of the perceived need for environmental management interventions in the Reef. Drawing on risk perception literature and public attitudes towards novel environmental solutions, it was hypothesised that the perceived need for intervention would be associated with: (a) perception of the problem (e.g., threats to the Reef); and (b) personal benefits derived from, and emotional responses to, the GBR environment (e.g., wellbeing, economic benefits, positive and negative emotions). A quantitative survey of 2048 GBR residents was conducted to measure public attitudes. The results revealed a robust multivariate regression model ($R^2 = 0.67$), identifying emotional reactions to reef damage, perceived threat of climate change to the GBR, and personal pride in the GBR as a World Heritage Area as the most influential predictors of perceived need for intervention. This study underscores key individual factors that are likely to be significant for residents when considering the necessity of future interventions in the GBR, providing valuable insights for reef managers and decision-makers.

1. Introduction

Global reef ecosystems, in particular coral reefs, provide significant economic value through tourism and fisheries; as well as essential coastal protection services [46]. Estimates indicate that almost half a billion people depend on reef ecosystems worldwide for food, income and protection [44,52]. However, coral reefs around the world are under threat from climate change with rising sea surface temperatures causing frequent and severe marine heatwaves, resulting in mass coral bleaching, coral mortality, and degraded ecological health [17,19]. The cumulative and compounding nature of climate change impacts on reefs are such that a combination of management interventions and environmental policy tools are needed to help coral reefs survive and adapt

to warming oceans; these include marine zoning, selective breeding of heat-tolerant corals, cooling and shading infrastructure, stronger fishing regulations and carbon emission reduction policies laws [27,48,55,60].

Reef managers and environmental management specialists recognize the essential ecosystem functions and services provided by coral reefs, as well as their intrinsic values, which justifies investments in their protection. The ecosystem services generated by coral reefs benefit both those directly dependent on reefs as well as those indirectly reliant on the broader reef context, encompassing economic, wellbeing, and existence values. Notably, many individuals who do not directly benefit from coral reefs still value their existence and feel an emotional connection, such as pride [20]. However, public perceptions of threats to reef ecosystems such as climate change and human activities vary;

* Correspondence to: 41 Boggo Road, Dutton Park QLD 4101, GPO Box 2583, Brisbane, QLD 4001, Australia.
E-mail address: aditi.mankad@csiro.au (A. Mankad).
[1] ORCID ID: 0000–0001-7441–4634
[2] ORCID ID: 0000-0002-2011-7279
[3] ORCID ID: 0000-0002-2365-810X
[4] ORCID ID: 0000-0001-7291-5339
[5] ORCID ID: 0000-0002-7738-7691

and, not everyone agrees with the need to intervene in a natural system [7,33,38]. It is argued that this variability in opinion, and possible mismatch with expert sentiment, influences public support for, and engagement with, reef interventions. This study addresses the question: *How do perceptions of environmental threats, personal relevance, and emotions influence reef catchment residents' perceived need for reef interventions?*

1.1. Psychological predictors of environmental intervention

1.1.1. Emotion

The environmental psychology literature highlights the role of threat perception and emotion in shaping public acceptability of environmental solutions for conservation (e.g. [9,30,54,61]). There is also ongoing debate within the broader literature regarding whether fear- and threat-based messaging about climate change leads to maladaptive emotional responses (e.g., avoidance, denial) compared to hope-based messaging, which may have a more motivational effect [2,3]. Brosch [2] reviewed the literature and concluded that both positive and negative emotions (affect) are major drivers of climate change perception and can promote sustainable pro-environmental intentions and behaviours. However, positive affect is associated with more sustained behaviour change [2]. Among these, emotions such as pride in living near or within a place of significant natural value such as a World Heritage Area, can elicit psychological benefits and opportunities for being "unique". This type of reflected appraisal and sense of distinctiveness can be a powerful motivator for behaviour [36,37,41]. Positive emotions such as pride, hope, or awe can reinforce a sense of identity around pro-environmental behaviour, particularly when these emotions are triggered through positive narratives that increase a sense of connectedness with nature [29,63].

This interplay between emotional valence and behavioural motivation becomes even more apparent when considering individuals' emotional bonds with specific ecosystems. In Australia, research on climate messaging has found that negative emotional content emphasizing climate change threats increases perceived risk and intention to act, compared to low-threat conditions [21,24]. In a reef context, Waters et al. [62] found that negative emotions (i.e., sadness, worry, anxiety) rather than positive emotions (i.e., hopefulness, encouragement, optimism) elicited in response to messaging about climate change impacts on reef ecosystems motivate climate-related behaviours. Overall, empirical evidence suggests that both positive and negative emotions in response to climate change threats drive behavioural intentions. However, in the reef context, messaging that evokes negative emotions may have a greater motivational effect.

Personal factors, such as emotional connections to coral reef ecosystems, have been implicated in motivating individuals to protect reef ecosystems and engage in climate change action. For example, Marshall et al. [38] examined individuals' emotional responses to coral bleaching and mortality in the Reef, and whether these responses varied based on the different meanings and values people attach to the Reef. The key emotional response measured was 'reef grief'—defined as the emotional suffering associated with losses to valued species, ecosystems, and landscapes due to climate change [6]. Marshall et al. [39] found that significant 'reef grief' (i.e., feeling depressed when thinking about coral bleaching) was experienced by approximately half of coastal residents. They suggested that this grief may motivate residents to protect the reef ecosystem as a consequence of their mourning for the iconic landscape. A complementary study by Curnock et al. [7] argued that climate icons, such as the Great Barrier Reef, hold affective appeal that could stimulate/induce higher engagement with climate change. Curnock et al. found that after notable climate impacts to the GBR (i.e., mass coral bleaching in 2016 and 2017), there was a clear increase in grief-related negative emotions (e.g., sadness, anger and fear) expressed among tourists when asked about the meanings they attach to the GBR [13]. While a causal link between emotions and support for action cannot be

made due to the cross-sectional nature of the study, other environmental research has found that negative emotions in response to environmental damage can effectively drive support for both behavioural and policy action [11,42].

1.1.2. Threat perception

Perceived threats can be understood through the social science literature on coral reef ecosystems and the broader psychological understanding of threat appraisal in environmental disasters [22,35,53]. The threat literature describes how individual motivation and intention to protect against an environmental hazard are influenced by an individual's appraisal of the likelihood and severity of a threatening event (e.g. [22,40,58]). In the reef context, motivation for protective action could be influenced by many identified problems, such as damage to coral reefs and general coral health decline, and the associated threats to reef ecosystems such as overfishing, sediment run-off from agricultural practices, coastal development, pest predation and climate change impacts such as rising sea surface temperatures (which contribute to marine heatwaves), ocean acidification, and an increase in the frequency of high intensity tropical cyclones [19]. The literature suggests that motivation to adopt new or innovative protective actions depends on the value proposition offered by a recommended behaviour or solution (e.g., will a new technological tool effectively remove the threat?), as well as the perceived need for protection from the threat.

Perceived threat as a motivator for action in reef ecosystems has been demonstrated in past social science research examining public support for various strategies designed to help make reef ecosystems more resilient. For example, Lockie, Bartelet, et al. [32] found that most Australians were generally supportive of technological coral reef interventions aimed at mitigating the perceived threat posed by climate change. In their study, the perceived threat of climate change was strongly related to concern regarding the condition of the GBR, which, in turn, was strongly related to the belief that more should be done to save the GBR. Similarly, Mankad et al. [35] found that most people believed coral reef loss was a significant problem, and these views were positively associated with support for a novel genetic intervention to help restore coral reef environments. Suess et al. [54] applied a protection motivation framework to explore how threat messaging about coral reef health outcomes influenced emotional and behavioural responses to reef threats, measured via stated intention to donate to coral restoration efforts. The authors found that while higher levels of threat messaging increased emotional arousal and negative affect, a combination of threat and reassurance messaging stimulated the strongest emotional arousal and was associated with higher stated donations. These case studies collectively demonstrate how individual motivation to protect reef ecosystems is influenced by threat perception and emotional responses to hazards such as coral bleaching, driving the perceived need for intervention in an environmental context.

1.2. Case study context: Australia's Great Barrier Reef

Australia's Great Barrier Reef (GBR; the Reef) is the world's most extensive coral reef system, highly valued by Australians and people all over the world and listed by UNESCO as a World Heritage site of Outstanding Universal Value in 1981 [15,59]. The GBR is estimated to contribute more than AUD\$56 billion to Australia's economy, supporting over 60,000 jobs across various marine industries [12]. The ecological integrity of the Reef, however, is threatened by the persistent and worsening effects of climate driven disturbances such as marine heatwaves, and extreme weather events combined with land-based run-off causing poor water quality, outbreaks of crown-of-thorns starfish (COTS) and human activity causing pollution and overfishing [19].

1.2.1. Interventions in the GBR

Until recently, the main approach to protecting the GBR was management of direct uses (e.g. fishing, recreation, tourism), as well as

efforts to improve land management practices in the Reef's catchments to reduce harmful runoff [5,18,34]. However, since consecutive summers in which mass coral bleaching occurred in 2016 and 2017, there has been an additional investment into direct technological interventions[2] that aim to bolster coral reef resilience and accelerate recovery from disturbance events. There has also been continued investments in reducing land-based runoff, along with research and development of novel coral restoration techniques [16,18].

Technological interventions to mitigate climate change impacts on the Great Barrier Reef (GBR) include shading, cloud brightening, rubble stabilization, enhanced heat resistance through coral seeding, natural breeding, genetic engineering, and an expanded COTS control program [51,57]. Established in 2015, the Australian Government's Reef 2050 Long-Term Sustainability Plan (Reef 2050 Plan) outlines broader climate policies, such as reducing carbon emissions, improving water quality, and integrated coastal zone management [4,47]. Industry initiatives, such as sustainable tourism and agricultural stewardship, further support these efforts [14].

Public support for protective initiatives has been a growing research interest, particularly with the development and piloting of novel Reef interventions [23,31,32,35,57]. Findings indicate that support varies by stakeholder group and intervention type, with strong support for technological interventions like coral seeding, rubble stabilization, and fogging, and lower support for biological solutions such as natural breeding and genetic engineering. The perceived necessity of interventions is likely to influence their implementation [35,56,58]. Thus, while GBR managers and environmentalists may be acutely aware of the need for enhanced resilience of the Reef, understanding what drives public urgency for Reef interventions can encourage timely action. Government and research institutions are more likely to invest in solutions when there is public advocacy for urgent action.

1.3. Present study

Using Australia's GBR as the case context, this study sought to examine underlying psychological predictors of GBR catchment residents' perceived need for intervention in the Reef. It was hypothesised that two groups of factors would influence perceived need for intervention: 1) personal relevance of the GBR to individuals (e.g. individual benefits, personal impacts, emotions), where stronger negative emotions towards damage to the GBR and higher personal relevance of the Reef would predict greater perceived need; and 2) perceptions of coral health and threats, including climate change, coastal development, poor water quality, illegal fishing and pests, where higher perceived threat and poor coral health would predict higher perceived need. The GBR Outlook Reports [17,19] served as the basis for selecting and examining specific threats.

The study sought to model individual factors that may (or may not) drive the need for intervening in a natural system, as perceived by those living within the borders of the GBR catchment. Such a model could serve to highlight which of the most serious threats identified by Reef managers, are influencing perceptions of the need for intervention amongst residents. The findings may be used to understand potential drivers of public decision-making for the adoption of novel environmental interventions. This is relevant not just in the GBR, but also in other nature reserve areas and World Heritage sites negatively affected by extreme climate and environmental stress, and where citizen consultation will play a significant role in the successful implementation of protective environmental initiatives [45].

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[2] Note that 'intervention' in this manuscript refers to tangible actions or behaviours designed to reduce vulnerability to climate change or mitigate the effects of climate-based and other environmental threats

2. Methods

2.1. Participants

A representative sample for age and gender, based on Australian Bureau of Statistics data for the GBR regions, was sought for this study [1]. Eligible participants included residents living in the GBR catchment zones (Fig. 1), aged 18 years and over, and who had visited the GBR at least once in their lifetime (*N* = 2048). Age was categorised in approximately 5-year increments (e.g. 18–24, 25–29, 30–34, 35–49, …, 90–94); a majority (~55 %) of participants were aged between 50 and 74 years of age, with 39 % of the sample younger than 50 years and 6 % aged 75 + years (*Mode* = 60–64 years). Participants were also asked to describe their gender (i.e. man or male, woman or female, non-binary, a different term, or prefer not to say); approximately 56 % of the sample were females, 43 % were males, and 1 % did not disclose their gender or used another term (e.g. non-binary). Approximately 3 % of the sample identified as Aboriginal and/or Torres Strait Islander. A range of educational levels (21 % Bachelor's degree, 18 % Advanced Diploma/Diploma, 17 % Certificate) and household income categories (*Mode* = AUD$100,001-$200,000 household income per year) were represented. Participants had lived in the GBR region for an average of 28 years (SD=18.4 years, range from 0 to 80 years).

2.2. Measures

For this survey, the Great Barrier Reef (GBR) was defined as comprising 'the beaches on the coast, the bays and creeks, the islands, the shoals and seafloor, the open waters, and of course the coral reefs'. This definition was provided to participants at the beginning of the survey and participants were asked to keep this definition in mind when responding to questions relevant to the GBR catchment/region.

Note: For all multi-item subscales, item scores were summed and then averaged to produce a single score for the variable.

2.2.1. Personal factors

Personal factors (Table 1) were those which reflected individual relevance to the GBR, such as individual benefits derived from reef visitation, pride in the GBR, potential personal economic impacts of a declining GBR, and emotions associated with damage to the GBR.

2.2.2. Threat and health perceptions

Items in this category included questions relating to perceptions of the overall health of the GBR and the extent to which loss of coral cover was a problem in the GBR (Table 2). Items also included an assessment of the main threats to the Reef, that may negatively affect GBR health [17,19]: climate change, coastal development, land-based runoff (affecting water quality), illegal fishing and Crown of Thorns Starfish (COTS; a native pest that feeds on coral). On average, all threats were rated as representing a 'serious' threat to the GBR.

2.2.3. Dependent variable

In setting up measurement of the dependent variable, *perceived need for intervention* in the GBR, participants were introduced to a list of possible initiatives/interventions for managing the GBR Table 3. Participants rated their perceived importance for each of these initiatives (1 = not at all important – 10 = extremely important); there was also an "I don't know/I am unsure" response option for those who were not confident to answer.

This list of initiatives was followed by a single item: "*I think adopting additional interventions (such as the ones just described) to manage the GBR is…*"; this item served as the dependent variable. The five response options were: 1 = Not needed at all, 2 = Somewhat needed, 3 = Moderately needed, 4 = Greatly needed, and 5 = Critically needed; participants were asked to choose one (*M* = 3.90, *SD* = 1.13). Scores were combined into a single 'perceived need for intervention' score.
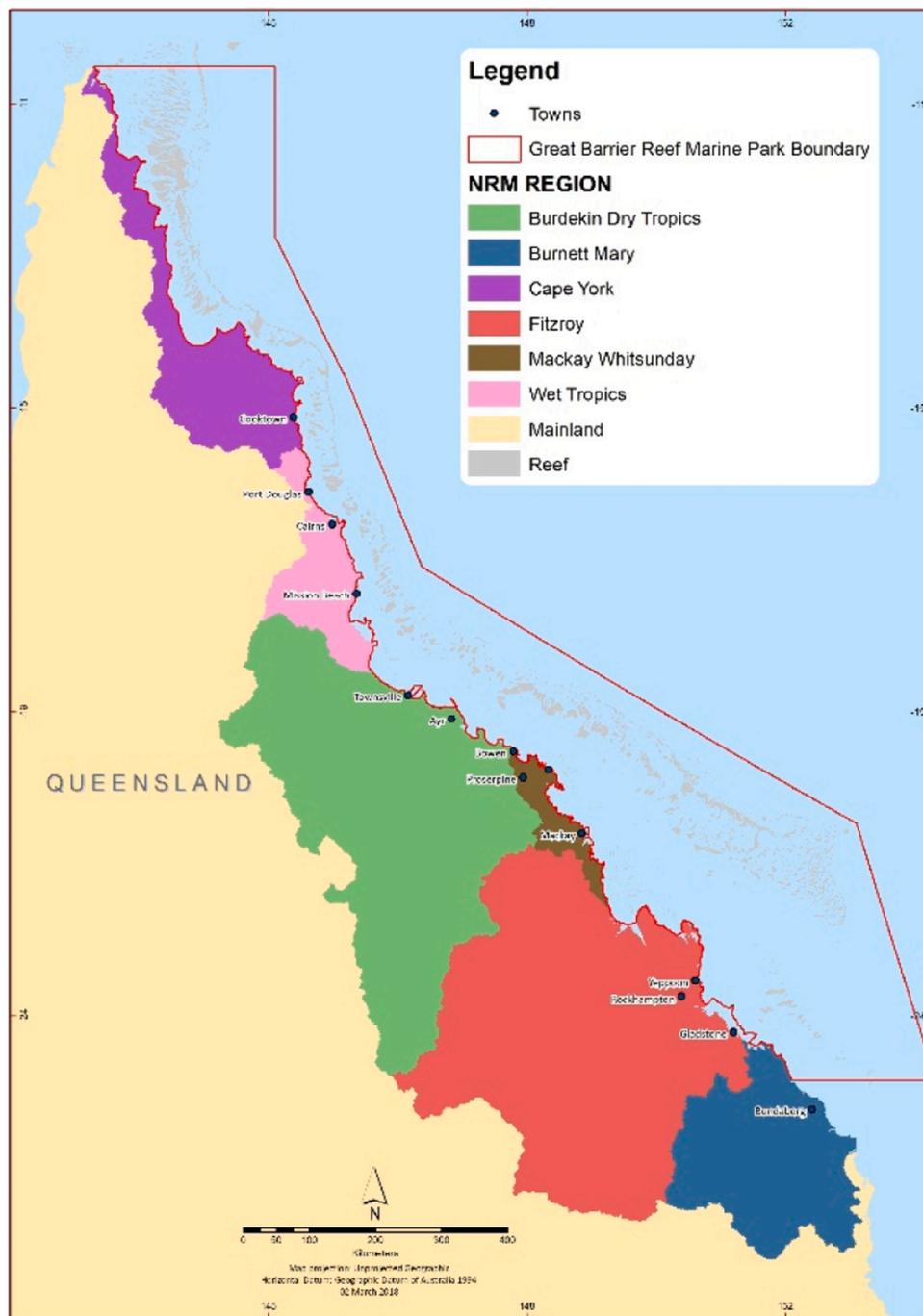
Fig. 1. Great Barrier Reef Marine Park boundary,[31] highlighting distinct Natural Resource Management (NRM) regions surveyed in this study (N = 2048)..

2.3. Procedure

This study was conducted in June/July 2021 and involved the administration of a survey[4] to residents living in the GBR catchment areas, east of the Great Dividing Range from Bundaberg to Cape York,

Queensland. To maximise the reach of the survey, participants were recruited via three channels: (1) a third-party online survey panel provider (*n* = 1182); (2) Facebook paid advertisements and partner agency Facebook posts, which disseminated a link to the online survey (*n* = 639); and (3) a third-party telephone survey provider (*n* = 227). Online survey participants recruited via the panel provider received an initial email invitation, with an embedded link to launch the online survey. Participants recruited via Facebook paid advertisements and partner agency social media posts were presented with a promotional advertisement entitled 'What does the Great Barrier Reef mean to you? (Fig. 2). Clicking on the advertisement took participants directly to the online survey. Telephone survey participants were selected through random digit dialling in designated postcodes of 5 local council areas (identified as hard-to-reach from previous research). Prior to completing

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[4] This study analyses a subset of data obtained via a larger regional survey, which included a broad range of questions assessing individual's attitudes, perceptions, and beliefs as they relate to the GBR. Example content of the larger survey includes canvassing: GBR use and dependency, value placed on GBR's ecosystem services, Reef best practices and stewardship, perceptions of threats and problems, and GBR management practices. Curnock et al., [8]; https://doi.org/10.25919/v7ff-zb64].

Table 1
List of 'personal factors' included in the survey.

Variable	Items	Response Scale	Mean (SD)
Individual benefits α = 0.94	Thinking about your visits to the GBR in general, please rate your level of agreement with the following statements… …Visiting the GBR makes me feel better physically …Visiting the GBR helps me unwind and de-stress …After visiting the GBR, I feel restored and relaxed …I feel more alert and able to concentrate when I visit the GBR …Visiting the GBR is a way of clearing and clarifying my thoughts	1 = Very strongly disagree 10 = Very strongly agree	7.42 (1.99)
Pride (derived from [15, 37])	I feel proud that the GBR is a World Heritage Area	1 = Very strongly disagree 10 = Very strongly agree	8.67 (2.08)
Personal impacts α = 0.83	If the health of the GBR significantly declined… …living in the GBR region would become undesirable to me …I would take steps to relocate out of the GBR region …my employment prospects would be reduced …my financial situation would be negatively affected …my lifestyle would be negatively affected	1 = Very strongly disagree 10 = Very strongly agree	3.87 (2.20)
Emotions α = 0.93	When you hear about damage to the GBR (e.g., from cyclones, coral bleaching), to what extent does it make you feel… …sad …angry …afraid …helpless …disappointed	1 =Not at all 2 =A little bit 3 =Somewhat 4 =Quite a bit 5 =A great deal	3.32 (1.22)

Table 2
List of 'threat perception' measures included in the survey.

Variable	Items	Response Scale	Mean (SD)
GBR health	Of the places you have visited in the GBR, how would you rate the health of the coral reefs?	1 =Very poor 2 =Poor 3 =Fair 4 =Good 5 =Excellent ☐ Not applicable (have not visited) 9 =I don't know	3.45 (1.21)
Problem – loss of coral	In your opinion, how problematic [*is the loss of coral cover*] in the GBR?	1 =Not a problem at all 2 =A small problem 3 =A moderate problem 4 =A big problem 5 =A very big problem ☐ I don't know	4.02 (1.17)
Threat	For the following list of issues – please rate the extent to which you think they represent a threat to the GBR:	1 =Does not represent a threat at all 2 =A minor threat 3 =A moderately serious threat 4 =A serious threat 5 =Represents an extremely serious threat ☐ I don't know	
	…Climate change		3.83 (1.40)
	…Coastal development		3.87 (1.09)
	…Land-based runoff		3.90 (1.39)
	…Illegal fishing		4.04 (0.98)
	…Crown of thorns starfish		3.92 (1.03)

Table 3
List of potential interventions in the Great Barrier Reef (GBR), ranked from most important to least important (response scale: 1 = not important at all – 10 = extremely important). Note: these summary statistics exclude participants who responded, "I don't know/I am unsure"; proportions of these non-responses are reported below.

Item	Mean (SD)	% I don't know/ I am unsure
Efforts to reduce rubbish and plastics from urban areas entering GBR waters	9.14 (1.51)	1 %
Increased compliance to reduce illegal fishing (e.g. poaching in protected Marine Park zones)	8.52 (1.97)	1 %
Improved land management to improve GBR water quality (i.e., efforts to reduce sediments, nutrients and pollution flowing into the sea)	8.25 (2.33)	1 %
Culling Crown of Thorns Starfish (a sea star that feeds on coral) to protect corals on reefs	8.25 (2.18)	4 %
Efforts to improve on-water practices by recreational users and tourists (e.g., reducing coral damage from anchors and human contact)	8.23 (2.06)	1 %
Marine Park zoning to restrict certain activities (e.g. fishing, collecting) in some areas of the GBR	8.16 (2.26)	1 %
Community and citizen science programs that involve local people in reef monitoring, clean-ups, and coral restoration	8.09 (2.05)	2 %
"Coral restoration" (i.e. assisted propagation or "gardening" of corals) to replenish damaged reefs	8.06 (2.43)	2 %
Government and industry initiatives to reduce carbon emissions and tackle climate change	7.64 (3.04)	3 %
Assisted coral "adaptation" to increasing sea temperatures (e.g., through selective breeding and moving of heat-tolerant corals)	7.56 (2.62)	8 %
Improving Indigenous Traditional Owner co-management and custodianship of the GBR	6.35 (3.12)	4 %

the survey, participants were provided (or read) standard information (e.g., study purpose, confidentiality of data) in keeping with the requirements of the overseeing research ethics committee (who granted ethical approval, number: 069/021).

2.4. Data analysis

Data were analysed using IBM® SPSS® Statistics Version 25 program [28]. Descriptive statistics, correlations, and internal consistency metrics were calculated after standard preliminary assumption checks were performed; no multicollinearity between variables was detected, based on the accepted correlation coefficient threshold of 0.8 [50]. Analyses of variance (ANOVAs) were conducted to examine differences in mean scores across variables of interest. A linear multiple regression was conducted to model how the explanatory variables (grouped as

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³ NRM boundaries are from the Australian Bureau of Statistics (ABS): https: //www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/ 1270.0.55.003~July%202016~Main%20Features~Natural%20Resource% 20Management%20Regions%20(NRMR)~11Copyright Commonwealth of Australia administered by the ABS. Content is licensed under a Creative Commons Attribution 2.5 Australia licence.**1270.0.55.003 - Australian Statistical Geography Standard (ASGS): Volume 3 - Non ABS Structures, July 2016**
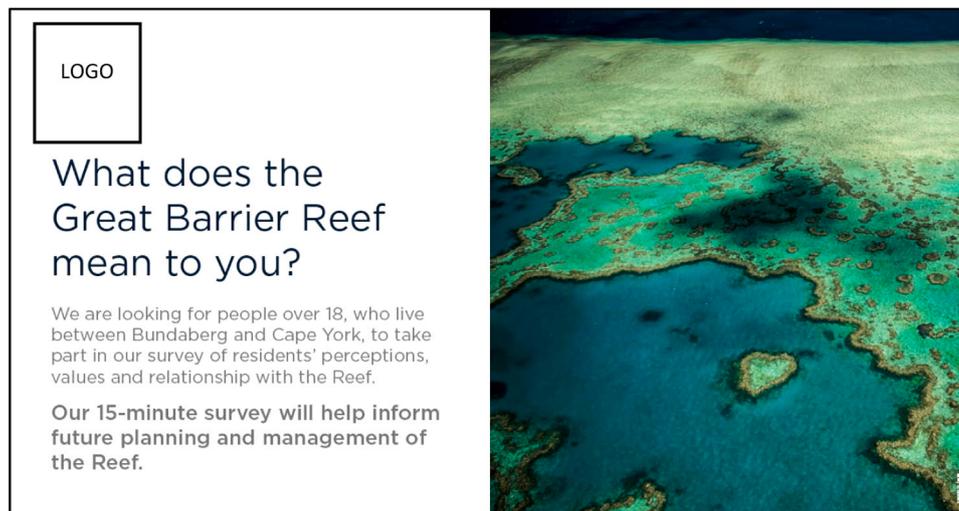
Fig. 2. Example of social media paid advertisement for survey recruitment.

demographics, personal factors, threat and health perceptions) predicted variance in the dependent variable ('*need for intervention*'). Demographic measures of age and sex were included in the regression model as control variables.

3. Results

3.1. Descriptives

Mean scores and standard deviations for the predictor variables are provided in Table 1 and Table 2, to help understand the nature of the variables being measured. Results of the Pearson correlation (Table 4) indicated that the *need for intervention* was significantly and positively correlated with all variables, except for *age* and *perceived coral health* which both had significant negative correlations with perceived *need for intervention*. The strongest correlations were between the *need for intervention* and perceived *threat of climate change*, *emotions*, and perceived *threat of land-based runoff*. Variables that correlated weakly with perceived *need for intervention* were the demographic factors of *age* and *gender*, as well as *individual benefits* and *personal impacts*.

3.1.1. Age and gender differences

A one-way between-groups analysis of variance showed a statistically significant difference in perceived need for intervention amongst the different age groups ($F_{14, 2033}$ = 4.47, p < 0.001). Generally, older participants (in particular, participants aged 75–79) perceived significantly lower need for intervention when compared to those aged between 18 and 44. Despite reaching statistical significance, the real difference in mean scores between age groups was considered a small effect (eta squared = 0.03; see Table S1 for the full table of post hoc comparisons).

An independent-samples *t*-test was performed to compare perceived *need for intervention* between males and females only.[5] Results showed that females (M = 4.19, SD = 0.95) had a higher mean score for perceived *need for intervention* in the GBR when compared to males (M = 3.54, SD = 1.23). Calculation of effect size[6] showed a small to moderate

effect for gender ($t_{1686.45}$ = −13.02, $p < 0.001$, eta squared = 0.08).

3.1.2. Initiatives for managing the GBR

Descriptive analyses measuring relative importance of various Reef initiatives and interventions for managing the GBR (presented in Table 3) showed a spread of stated importance across the activities listed. All scores were above the midpoint, suggesting that participants rated all initiatives as being at least moderately important in the Reef ($F_{(6.77,1190.50)}$ = 287.10, p < 0.001; eta squared= 0.14). The means and standard deviations are presented in Table 3 and the full table of pairwise comparisons can be found in Table S2. Overall, participants rated 'efforts to reduce rubbish and plastics' as the most important way in which action could be taken to assist Reef managers. Other actions that were rated as highly important were reducing illegal fishing through increased compliance in protected Marine Park zones, improved land management practices to reduce nutrient/sediment runoff into the GBR and improve water quality, and culling COTS to reduce predation on corals.

3.2. Regression model: need for management interventions in the GBR

Results of the multiple linear regression indicated that there was a statistically significant relationship between *need for intervention* (dependent variable) and selected predictor variables ($F_{(13, 1812)}$ = 280.01, p < 0.001, R^2 = 0.67). Standardised beta coefficients for individual predictors (see Fig. 3) indicated that the most influential predictor of perceived *need for intervention* was individuals' perceived *threat of climate change* (β = 0.28) and experiencing negative *emotions* when hearing about damage to the GBR (e.g., from cyclones, coral bleaching; β = 0.21). Other influential factors in the model were *pride* in knowing that the GBR was a World Heritage Area (β = 0.13), perceived *threat of coastal development* and *land-based runoff* (β = 0.09), and poor *health of coral reefs* (β = −0.09).

Variables in the model that were found to be statistically significant but weak predictors of perceived need for intervention included personal impacts if the health of the GBR significantly declined (e.g. negative impacts on employment, lifestyle), as well as the threat of COTS and illegal fishing. Age, gender and individual benefits derived from the Reef (e.g. recreation, relaxation, stress reduction) were not significant explanatory variables in the model.

4. Discussion

The influence of personal and environmental threat factors on

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[5] Due to the small number of participants who did not declare their gender or identified as non-binary (1 % of the sample), gender analyses focused on males and females. While this is a potential limitation for generalisability of results, the large sample size mitigates its impact on the overall interpretation of the data.

[6] Eta squared interpretation guidelines proposed by Cohen (1988; pp. 284–7) are: 0.01 =small effect; 0.06 =moderate effect; 0.14 =large effect

Table 4
Correlation matrix for the dependent variable (DV: need for intervention) and predictor variables.

	DV: Need for intervention	Age	Gender	Individual benefits	Pride	Personal impacts	Emotions	GBR Health: coral	Problem: coral loss	Threat: climate change	Threat: coastal develop	Threat: land-based runoff	Threat: illegal fishing	Threat: COTS
DV: Need for intervention	1	−0.15***	0.28***	0.24***	0.48***	0.30***	0.71***	−0.46***	0.64***	0.73***	0.59***	0.65***	0.36***	0.41***
Age		1	−0.17***	−0.11***	−0.03	−0.28***	−0.20***	0.12***	−0.16***	−0.20***	−0.06**	−0.12***	−0.06**	0.03
Gender			1	0.13***	0.21***	0.06***	0.33***	−0.14***	0.21***	0.27***	0.25***	0.23***	0.20***	0.15***
Individual benefits				1	0.35***	0.32***	0.28***	0.03	0.17***	0.17***	0.18***	0.19***	0.18***	0.08***
Pride					1	0.16***	0.44***	−0.17***	0.41***	0.39***	0.32***	0.41***	0.26***	0.30***
Personal impacts						1	0.37***	−0.18***	0.23***	0.29***	0.24***	0.26***	0.09***	0.05*
Emotions							1	−0.44***	0.64***	0.71***	0.57***	0.64***	0.35***	0.39***
GBR Health: coral								1	−0.4***4	−0.48***	−0.35***	−0.42***	−0.15***	−0.18***
Problem: coral loss									1	0.68***	0.55***	0.65***	0.38***	0.43***
Threat: climate change										1	0.58***	0.65***	0.29***	0.36***
Threat: coastal develop											1	0.66***	0.40***	0.34***
Threat: land-based runoff												1	0.38***	0.41***
Threat: illegal fishing													1	0.37***
Threat: COTS														1

* $p \leq 0.05$
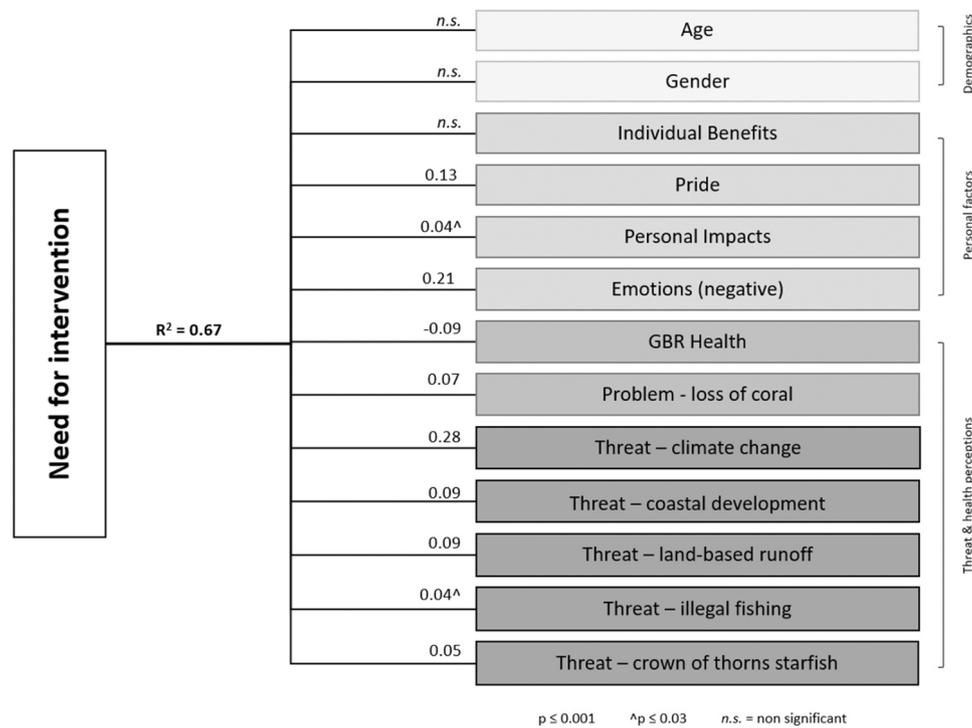** $p \leq 0.01$
*** $p \leq 0.001$

Fig. 3. Regression model with standardised beta weights included for each variable; larger beta values indicate greater explanatory influence of the variable within the regression model.

perceived need for environmental intervention was modelled in this paper, using Australia's Great Barrier Reef (GBR) as the case study context. The results provide insights into what shapes individuals' perception of the need to implement management interventions to help protect the GBR. We found that among residents living in the GBR region, the perceived need for a range of Reef protection initiatives was strongly influenced by residents' negative emotional reactions towards damage to the GBR (e.g., from cyclones, coral bleaching) and how seriously they perceived the threat of climate change to the GBR. Other significant influences on perceived need for intervention included feeling proud that the GBR is a World Heritage Area, seriousness of threat perceptions of coastal development and land-based runoff, and individual ratings of coral reef health. These results underscore the value of applying a psychosocial lens to understanding drivers for public support of environmental management strategies, to better predict public support and engagement. This study shows that the sense of urgency a person feels for Reef protection is driven by both their emotions (including pride) towards the GBR, as well as their evaluation of the severity of certain environmental threats to the GBR and the current condition of coral reefs (see Fig. 3).

The strength of negative emotions in driving perceived need for protective action supports previous research in the GBR and other environmental contexts (e.g. [2,43]). Fear-based appeals have been shown to be effective in encouraging residents to protect against environmental hazards and, in the current study, feelings of sadness, anger, helplessness and fear were the main motivators for intervening. Interestingly, individual benefits derived from the Reef (i.e. relaxation and restoration) and the potential personal economic consequences of its significant decline (e.g. changes in employment status, need for relocation), seemed to have had minimal to no influence on perceived need for intervention (see Fig. 3). This finding may be attributed to the possibility that living and working in proximity to the GBR is perceived as distinct from the existential threats facing the environmental ecosystem. That is, individuals may rationalise that alternative means of relaxation and employment are available, whereas the GBR is unique and irreplaceable. It is also possible that such personal factors were more distal

in their effects, such that when they were included with all other variables, their effects were overshadowed. Certainly, correlations showed that a statistically significant, positive relationship existed between both individual benefits, and personal impacts from declining GBR health, and perceived need for intervention.

The only personal benefit seemingly driving one's need for intervention was *pride* in the GBR as a World Heritage Area. Pride, operationalised as a positive affective sentiment in this study, has been examined in the environmental protection literature before, and in particular in the context of the GBR. For example, Marshall et al. viewed pride as a positive cultural value associated with resource dependency, suggesting pride was closely related to identity. It was seen as a way of receiving psychological benefits and opportunities from living in such a valued, unique and exceptional place [36,37]. Thus, while other more direct personal benefits were not important predictors of respondents' perceived need to intervene, the reflected appraisal afforded to citizens by living and working near a World Heritage Area did explain individuals' desire for intervention in the Reef to some extent.

Perceiving climate change as a serious threat to the GBR was the main driver of respondents' perceived need to intervene to protect the Reef. In the presence of this strong relationship, one might expect that respondents would rate 'government and industry initiatives to reduce carbon emissions and tackle climate change' as extremely important. However, the activities that participants identified as most important to action in the Reef tended to be less, or not, directly related to climate change. These activities included efforts to reduce rubbish/plastics entering waterways, reducing illegal fishing through compliance measures, and improving land management for better water quality. This points to a potential disconnect in understanding between threats and mitigation measures for Reef health in the face of climate change. Dean et al. [10], in an Australia-wide study, found that while most respondents expressed concern for the GBR only a small percentage (4.1 %) mentioned the need for climate change mitigation measures to help the GBR. Reducing plastic pollution to help the GBR was the most common response in the Dean et al. study. A defining feature of the Dean et al. [10] study was that respondents were not offered a list of potential

actions to choose from to help the Reef but were asked to self-generate suggestions. The authors concluded that Australians "have poor capacity to identify individual climate-related actions as helpful for reef protection" [10]. Similarly, research by Hornsey et al. Hornsey et al., [25,26], suggests that beliefs about climate change and the threat it poses is perhaps not strongly related to support for climate-friendly actions. Instead, Hornsey at al. suggested that the association can be stronger if climate-friendly action is described simply and specifically – like reducing waste and recycling – rather than referring to more complex and amorphous environmental policies such as reducing carbon emissions or setting emissions targets. The studies by Hornsey et al. Hornsey et al., [25,26] and Dean et al. [10] both suggest that an effective way to promote climate-friendly behaviour is to increase people's belief that their actions can make a difference, which can be accomplished by setting achievable, small-scale activities such as localised individual behaviours (e.g., reducing home energy consumption, food waste).

Relatedly, the importance of comparatively 'lower tech' behavioural-type interventions (e.g. reducing rubbish and plastic from urban areas or increasing compliance of fishers) over more advanced gene-based solutions, such as assisted breeding or the development of heat tolerant corals (e.g. [51]), is consistent with previous research (e.g. [31]) which indicates greater place-based support for more conventional or manual interventions. The lower ascribed importance for selective breeding and heat tolerant corals, as well as more complex government and industry initiatives to reduce carbon emissions and improving Indigenous co-management of the Reef, seems to suggest that public support for interventions on the Reef are likely influenced by the perceived immediacy and tangibility of threats. Conventional and manual interventions are preferred, likely due to their lower perceived risk and more direct impact, and possibly due to being more familiar and understandable. This preference may also reflect a broader psychological response to climate change that is emerging in the literature akin to learned helplessness, whereby individuals may feel that large-scale interventions are beyond their control or comprehension, leading them to favour more localised and practical actions that feel achievable [49]. Furthermore, the significant influence of coastal development and land-based runoff on public perception underscores the importance of addressing these specific threats through targeted policies and practices.

Overall, the findings from this research provide Marine Park and catchment managers with valuable insights, revealing how key messaging levers, such as negative reactions to reef damage or the threat of climate change, enhance the perceived need for interventions on the GBR. Conversely, other threats like illegal fishing, COTS management, and land-based runoff, although considered as serious threats to the GBR by participants, were less effective in driving perceived need for action. This highlights the importance of prioritizing and framing certain threats in communication efforts. By leveraging these insights, it is possible to develop communication strategies that resonate better with local publics and garner greater attentional appeal and impact for conservation messaging.

4.1. Conclusions and limitations

Amongst people living within the GBR region, there is a strong sense of pride in their natural environment. While people report experiencing individual benefits when visiting the GBR (e.g. restorative effects) and express a desire to stay in the area despite any potential personal impacts brought about by a declining GBR, these factors were not key to influencing perceptions of need for intervention in the Reef. The tipping point for believing that intervention was necessary in the Reef, amongst people living in the region, was a perception that climate change represented a serious threat to the GBR, and the extent to which people were negatively emotionally affected when they heard about damage to the GBR.

While the GBR was used as the case study context for this research, many global reef ecosystems share similarities with the GBR in terms of

potential threats – such as the overarching threat of climate change, pollution and agricultural runoff, and unsustainable fishing practices. The results from our 'perceived need for intervention' model demonstrate that those living within reef catchments can be negatively emotionally affected when hearing about damage to the GBR, and these feelings can positively influence their support for management interventions in a reef ecosystem. The interaction between potential interventions and perceptions of other regional activities (e.g., coastal development, agriculture, fishing) may also affect the public's appetite for change, and provide insights into additional factors that individuals perceive as impacting the health of the GBR. From the model presented in this study, it could also be argued that the high public ratings of threats to the Reef are broadly indicative of support for protective measures. That is, stronger perceived threat can be seen as a potential lever to catalyse public desire or need to act, or indeed general support for protective action, in the GBR.

CRediT authorship contribution statement

Aditi Mankad: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Hobman Elizabeth V:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Petina Pert:** Writing – review & editing, Writing – original draft, Visualization, Investigation, Data curation. **Matt Curnock:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Investigation, Funding acquisition, Conceptualization. **Michelle Dyer:** Writing – review & editing, Writing – original draft, Resources, Funding acquisition.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2025.106796.

Data availability

I have shared the link to relevant data within the manuscript

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