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Public support for novel interventions to protect, restore, and accelerate adaptation to climate change in the Great Barrier Reef

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ABSTRACT

Novel technological interventions are under development to build the resilience of ecosystems by providing short-term protection from climate extremes, enhancing recovery from disturbance, and accelerating adaptation to changed climate states. Drawing on surveys of Australian residents ($n = 5320$) conducted in 2018 and 2022, this paper investigates support for the development and deployment of six novel interventions on the Great Barrier Reef (marine cloud brightening, fogging, rubble stabilization, coral seeding, natural breeding for heat tolerance, and genetic engineering) and how support varies across time, social groups, perception of climate risk, and approach to intervention. It finds strong support for research and small-scale trials of all six interventions although support was highest for coral seeding, followed by rubble stabilization, fogging, natural breeding, marine cloud brightening, and genetic engineering. Reflecting their early stage of development, support for large-scale deployment of novel interventions across the Great Barrier Reef moderated, with respondents indicating strongest support for deployment of coral seeding, rubble stabilization, and fogging and lower support for natural breeding, marine cloud brightening, and genetic engineering. Trust in science to deliver solutions was a consistently strong predictor of support for both intervention R&D and large-scale deployment. The perceived ability to identify and test environmental impacts was a strong predictor of support for scaled deployment. Perceived climate threat, trust in the Reef's management authority, and ethics were also consistently associated with support for intervention R&D and implementation. With the vast majority of Australian residents supporting strong action to protect and restore coral reefs the maintenance of trust in scientists and scientific institutions stands out as critical to support for the implementation of novel interventions at scale, including the ability of researchers to identify and assess the environmental risks of these interventions.

1. Introduction

Novel interventions are of increasing interest around the world to protect and restore ecosystems and to accelerate their adaptation to anthropogenic climate change (Boström-Einarsson et al., 2020; Hobbs and Cramer, 2008; Malhi et al., 2020). Global warming has led to unprecedented global environmental problems, including hotter temperatures, more severe storms, increased drought and rising sea levels leading, in turn, to species loss and biodiversity decline (Intergovernmental Panel on Climate Change, 2023). Habitat deterioration threatens global ecological functions and can lead to significant loss of economic and social values (Powers and Jetz, 2019). To minimize the impact of global warming on biodiversity and other values, rapid and deep mitigation of greenhouse gas emissions is essential. Scientists are also exploring how a better understanding of ecological processes, combined with traditional ecosystem management practices and new management options, can be used to increase ecosystems' resilience to those impacts that can no longer be avoided (Anthony et al., 2020; Mcleod et al., 2019). Novel interventions to increase ecosystem resilience include (but are not restricted to) measures to protect ecosystems from climate extremes by manipulating environmental conditions at a local or regional scale, to enhance recovery from disturbance through

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more efficient and effective active restoration practices, and to accelerate adaptation to climate change through genetic selection, species translocation, etc. (Anthony et al., 2020; Bay et al., 2019b; Mcleod et al., 2019; Twardek et al., 2023).

Concerns over the ability of coral reef ecosystems, more specifically, to recover between bleaching and other disturbance events have seen active restoration projects and research into novel intervention options become increasingly common (Boström-Einarsson et al., 2020; McLeod et al., 2022). Possibly the largest intervention research initiative, Australia's Reef Restoration and Adaptation Program (RRAP),[1] [2] aims to develop a suite of ecologically effective, socially acceptable, and economically viable options for intervening at scale on the Great Barrier Reef (GBR) (Gibbs et al., 2021). Spanning over 2300 km (km), home to 70 First Nations, and valued at approximately AUD$56 billion, the GBR is of global social, economic and ecological importance (Commonwealth of Australia, 2024; Deloitte Access Economics, 2017). Its condition, however, like all tropical coral reefs around the world, has deteriorated due to climate change, land-based run-off, illegal fishing, crown-of-thorns starfish outbreaks, and marine debris. Extensive coral bleaching in March 2024 – a consequence of climate change-induced marine heatwaves – represented the fifth major bleaching event in the last eight years.

Following a two-year pre-feasibility assessment of 160 possible interventions (Bay et al., 2019b), RRAP commenced detailed research in 2020 on: (1) protective interventions including two solar radiation management (SRM) techniques – seawater fogging and marine cloud brightening (Butcherine et al., 2023; Harrison, 2024); (2) active restoration interventions including techniques to increase the recruitment of juvenile corals to damaged reefs, stabilize reef substrates to facilitate coral growth, and increase the efficiency of coral aquaculture and outplanting (Kenyon et al., 2023; Lippmann et al., 2023; McLeod et al., 2022); and (3) adaptive interventions including the identification of corals with natural heat resilience traits, selective breeding for heat tolerance within and between coral populations, pre-conditioning of juvenile corals to heat stress, and introduction of heat-evolved strains of algae on which corals rely for photosynthetic production of energy (McLeod et al., 2022; Scharfenstein et al., 2023; Selmoni et al., 2024). Despite strong endorsement by the pre-feasibility study RRAP has not, notably, undertaken research into the potential of genetic engineering (or synthetic biology) to accelerate the development of novel interventions such as corals bred for enhanced heat tolerance.

While meaningful ecological outcomes, which refer to measurable changes in ecosystem health and function such as improvements in coral cover, biodiversity, and ecosystem resilience, are often portrayed as the primary objective, the prospective deployment of novel intervention options for ecosystem management also raises questions concerning the goals and ethics of intervention, the management of risk and uncertainty, the distribution of social and economic risks and benefits, the adequacy of governance and decision-making arrangements, and whether the intervention enjoys broad stakeholder and public support (Fidelman et al., 2019; Le et al., 2022; Minteer and Collins, 2010; Waters, 2022). Numerous scholars note the importance of public support for successful deployment of novel interventions (Hein et al., 2019; Le et al., 2022; Waters, 2022). Understanding public perceptions of novel interventions and how these vary across time, social groups, perception of climate risk, and approaches to intervention, is important not only to mitigate the risk of public opposition to novel interventions but to inform their development and to identify opportunities for public involvement in ecosystem management and restoration.

A substantial body of literature addresses public support for solar radiation management (SRM) (Bellamy and Lezaun, 2017; Burns et al., 2016; Merk et al., 2015; Pidgeon et al., 2012). The dominant focus within this literature on atmospheric aerosol injection and other geoengineering technologies reflects the significant governance and political challenges raised by global-scale climate manipulation (McLaren and Corry, 2021). It also means though that research on support for local- or regional-scale application of SRM for ecosystem protection is limited. A similarly large body of literature addresses public support for active restoration and strategies to involve communities in restoration projects across a diversity of ecosystems (Budiharta et al., 2018; Buijs, 2009; van Oosterzee et al., 2020) including coral reefs (Le et al., 2022; Sebastian et al., 2024; Trialfhianty and Suadi, 2017). Meanwhile the literature on public support for adaptation-focused interventions is dominated by studies of terrestrial species translocation and genetic manipulation (Hajjar and Kozak, 2015; Moshofsky et al., 2019) with only a small number, again, addressing support for the assisted adaptation of coral reef ecosystems. In addition, most studies of public acceptance rely on: (1) cross-sectional designs, investigating the views of a single community; (2) at one point in time; and (3) evaluate only one type of intervention (Burns et al., 2016; Klaus et al., 2020). A more extensive literature review of the factors influencing public support for novel ecosystem protection, restoration, and adaptation interventions is provided in Appendix A.

To bridge these gaps and better understand the potential acceptability of novel protection, restoration and adaptation interventions in the GBR this manuscript aims to: (1) quantify public support for research, trials and implementation of novel interventions; and (2) examine how public support is influenced by factors such as scale, geographic location, and temporal context. Thus, we explore differences in perceptions based on the type of intervention and the scale of deployment (from funding research through to large-scale deployment). Moreover, we examine whether differences in levels of support exist between people living in proximity to the Reef versus the broader Australian public, and whether support changes over time. Finally, we identify the primary determinants of public support for novel interventions and whether these determinants differ across intervention types.

2. Methodology

Data reported in this manuscript were collected through a larger study of community attitudes toward existing and prospective management interventions in the Great Barrier Reef. Surveys were conducted in 2018 and 2022 with over 8000 Australian residents in total to explore support both for current management practices, and the potential introduction of novel management practices designed to accelerate coral adaptation to climate change and/or recovery from disturbance. This manuscript draws on a subsample of 5320 surveys focused on six interventions, five of which are currently being explored through the Reef Restoration and Adaptation Program (RRAP) and one, genetic engineering, which is not under active development. The remaining surveys that we did not include in our analysis focused on interventions that have been excluded from further RRAP R&D (shading using surface films and coral recovery using human-made reef structures, both included only in the 2018 survey), and pest control which has been dealt with elsewhere (Lockie et al., 2024b). In the quasi-experimental design, each respondent had the opportunity to respond to a specific intervention (scenario) rather than comparing the

[1] The Reef Restoration and Adaptation Program (RRAP) is funded through a partnership between the Australian Government's Reef Trust and the Great Barrier Reef Foundation. Partners include the Australian Institute of Marine Science, CSIRO, James Cook University, Queensland University of Technology, the University of Queensland and Southern Cross University. The surveys on which this manuscript draws were conducted as part of RRAP's Stakeholder and Traditional Owner Engagement Subprogram. They aim to provide a longitudinal understanding of Australian attitudes toward the development and deployment of novel reef restoration and adaptation options, along with the factors that influence attitudes toward restoration and adaptation.

[2] Other programs include Saudi Arabia's KAUST Reefscape Restoration Initiative and Australia's Coral Nurture Program.

full suite of interventions.

2.1. Sampling

A stratified sampling strategy was used targeting two primary groups.

1. Australian residents across all states and territories (national sample).
2. Residents located within 50 km of the GBR coastline (resident sample).

Although the GBR is important nationally and internationally, marine conservation challenges or changes to the condition of ecosystem condition due to climate impacts or due to changes that arise from management interventions are more likely to directly and materially impact respondents living closest to the Reef. In both years, online surveys were distributed via a market research company using online panels.[3] Representativeness was maintained by using Australian census data quotas (based on gender, age, and location, with a mix of urban and rural respondents) for the national sample and soft quotas for Queensland as a guide for the resident sample. Detailed information on the sampling strategy is available in Appendix B.

2.2. Novel interventions

We classified the six interventions included in our study into: (1) protective interventions to help protect the Reef from climate extremes; (2) restorative interventions to help support the recovery of degraded reefs; and (3) adaptive interventions to help corals adapt to changing climate conditions. Within each category, we included two specific interventions. Each intervention was introduced to the participant in one paragraph, which included a description of the method used, its aims, and potential benefits and risks. Descriptions of each intervention were developed with scientists and engineers working directly on them to ensure accuracy. Most of the respondents felt that the description of their intervention was neutrally framed, and neutral responses were relatively similar across interventions with no statistical differences found (Appendix B). Moreover, the respondent's perception of description bias did not meaningfully affect support levels for any of the interventions (see Table 1).

For protective interventions, we included marine *cloud brightening* (2018 and 2022 surveys) and *fogging* (2022 survey only), described to survey respondents as follows:

> One approach is to help cool and **shade** the waters of the Reef by enhancing the clouds above it to reflect more sunlight and heat. This is known as **Marine Cloud Brightening**. To achieve this, very small seawater droplets are sprayed into the atmosphere using devices similar to snow making cannons placed on boats, pontoons or permanent structures in the marine environment. **Potential benefits** include cooling and shading the reef during stressful conditions that can lead to coral bleaching. Cloud brightening can be used when bleaching conditions are predicted. It can also be used only when it is required (i.e., it can be 'turned off'). **Potential risks** could include small changes to local weather patterns such as altered rainfall. Further research is required to understand the atmospheric conditions over the Reef, the ability of this technology to be scaled up and the impacts to local weather.

> One approach aims to **shade** areas of the reef using artificially generated sea mist or fog**.** This mist reduces the amount of sunlight and heat reaching the sea surface and the coral reefs beneath. **Potential benefits** include cooling and shading the reef, which prevents damage to coral and other organisms. Fogging could be deployed when coral bleaching conditions (i.e., extreme heat events) are predicted. Fogging could be effective in protecting targeted areas over short critical periods (days to weeks). It can also be used only when it is required (i.e., it can be 'turned off'). **Potential risks** include over-shading which may slow coral growth. It would be ineffective during strong wind; however, bleaching is most likely to occur during calm conditions.

For restorative interventions, we included *rubble stabilization* (2018 and 2022 surveys) and *coral seeding* (2022 survey only). These approaches were described to survey respondents as follows:

> One approach aims to help **stabilize dead coral rubble so that new corals can grow.** Mesh structures or the application of binding agents can be used to prevent movement of the coral rubble. New coral can then naturally establish themselves and grow on this material. **Potential benefits** include providing a stable habitat to promote coral settlement and growth. This approach requires minimal human labour to maintain and would work most effectively at a local scale. **Potential risks** could include changes to natural conditions such as ocean currents, water quality, and impacts on other reef species. Further research is required to understand the effect of this technology. Similar methods are currently used overseas to fix coral reefs damaged by ships.

> One approach – known as **coral seeding -** involves capturing natural, wild coral spawn/larval slicks in tanks and floating pools and then transporting them for release to help re-seed local or regional high-priority reefs. **Potential benefits** include speeding up the return of coral cover to a disturbed or damaged reef by increasing the number of available coral babies (larvae) that can settle and grow into new corals. Harvesting wild coral larval slicks is likely to have a minimal negative impact on Reef ecology, as the mortality rate of the larvae in a slick is typically high. **Potential risks** include introduced and relocated corals impacting the local coral population ecosystem. More research is needed to develop effective and efficient collection and transfer and delivery techniques.

For adaptive interventions, we included *enhancing heat resistance – natural breeding* (2018 and 2022 surveys) and *enhancing heat resistance – genetic engineering* (2018 and 2022 surveys). These approaches were described to survey respondents as follows:

> One approach aims to enhance the **heat resistance of corals** through the selective breeding and spread of **naturally more heat resistant corals**. This can help corals become more resilient to ocean warming and improve the overall health of coral reefs. **Potential benefits** include helping corals to become more tolerant to marine heatwaves and environmental change. **Potential risks** could include possible changes in local coral structures and species interactions. Further research is required to understand the effect of this technology. This approach may involve breeding corals in land-based nurseries, an approach that is already used in aquaculture.

> One potential approach could enhance the **heat resistance of corals** using **genetic engineering**. Genetic engineering includes methods that allow very precise changes to be made to the genetic material of corals, or algae that lives in corals, to increase their ability to cope with heat stress. **Potential benefits** include helping corals to resist, repair and recover from bleaching events by improving their tolerance to heat stress. **Potential risks** could include possible disruptions to the ecosystem and spread of modified algae to other organisms. This technology is not yet sufficiently developed to be applied to corals. Further research is required to understand the effect of this technology. Similar methods have been used to genetically modify food crops including maize and canola.

[3] The final survey in 2018 was launched on 7 August 2018 and remained open until 14 September 2018. The final survey in 2022 was launched on 14 February 2022 and remained open until 28 February 2022.

Table 1
Factors influencing social acceptance for small-scale outdoor trials and large-scale outdoor use of different novel interventions.

Variable	Description	Unit of measurement
Demographics		
Reef proximity	Distance of respondent's residence from the GBR	(0) More than 50 km from GBR (1) Within 50 km from GBR
Gender[a]	Gender of respondent	(0) Female (1) Male
Age Group	Respondent's age group; initially measured using six levels	(0) Below 50 years (1) 50 years and older
First Nations people	Respondent identified as Aboriginal and/or Torres Strait Islander	(0) No (1) Yes
Education	Respondent had an undergraduate and/or postgraduate degree; initially measured using five levels	(0) No (1) Yes
Employment	Respondent had a full-time employment status at the time of the survey	(0) No (1) Yes
Visitation (ever)[b]	Respondent had ever visited the GBR	(0) No (1) Yes
Knowledge (GBR)[b]	Respondent's self-rated knowledge about the GBR.	From 1 'know very little' to 10 'know a lot'
Values and threats		
National asset (intrinsic value) Personal importance (intrinsic value) Climate threat	Respondent's level of agreement with the statement that: - The GBR is an important national asset - The GBR is personally important to me - Climate change is negatively affecting the health of the GBR	7-scale Likert: (1) strongly disagree (2) disagree (3) slightly disagree (4) neither agree or disagree (5) slightly agree (6) agree (7) strongly agree
Institutions and management		
Trust in the Great Barrier Reef Management Authority (GBRMPA) Trust in Federal Government Trust in science to provide solutions[c]	Respondent's level of agreement with the statement that: - I trust the Great Barrier Reef Marine Park Authority to act in the best interests of society - I trust the Federal Government to act in the best interests of society - Scientific research can provide solutions to help prevent *or* repair damage to the GBR	7-scale Likert: (1) strongly disagree (2) disagree (3) slightly disagree (4) neither agree or disagree (5) slightly agree (6) agree (7) strongly agree
Intervention-specific		
Description bias[b]	Respondent felt the intervention description was biased [...] towards the intervention.	(1) Against (2) Neutral (3) Favourably
Awareness[b]	Respondent had heard about the intervention before	(0) No (1) Yes
Understanding	Respondent's self-rated knowledge about the intervention	From 1 'know very little' to 10 'know a lot'
Promising Ethical Cost-effective Testable impacts	Respondent's level of agreement with the statement that intervention: - Looks like a promising option to help the Reef - Is ethical in use - Is likely to be cost-effective when fully developed - Has environmental impacts that can be identified and tested	7-point Likert scale from statement representing highest potential risk (1) to most benefit (7)

[a] In five out of our 5320 surveys the respondents selected the 'other/prefer not to say' gender option. These five surveys were too few for a dedicated gender category and they were consequently excluded from our analysis.

[b] Four variables were excluded from our final analysis because they did not significantly affect support levels for any of the six interventions across the two deployment levels for which we did a regression analysis.

[c] We used only one of the '*trust in scientific solutions'* variables as predictor, depending on the type of intervention. We used trust in scientific solutions to *prevent* damage to the GBR for the two adaptive and two protective interventions, and trust in scientific solutions to *repair* damage to the GBR for the two restorative interventions.

2.3. Levels of support

We used survey participants' stated support for different interventions with regards to four stages of development of increasingly larger scale using the respondents' level of agreement with the following statements.

1. I support the funding of research into this intervention.
2. I support indoor lab research into this intervention.
3. I support small-scale outdoor trials of this intervention in selected parts of the GBR.
4. I support large-scale outdoor use of this intervention across the GBR.

The level of agreement was measured using a 7-point Likert scale including (1) strongly disagree; (2) disagree; (3) slightly disagree; (4) neither agree or disagree; (5) slightly agree; (6) agree; and (7) strongly agree.

2.4. Determinants of public support

We used four different groups of predictors to test which determinants were most strongly associated with support for the deployment of novel Reef interventions (Table 1). The four groups of predictors included demographics, values and threats, institutions and management, and intervention-specific factors. For interventions measured across two time periods (2018 and 2022) we also include the survey year as a binary predictor to test whether public support changed over time. We initially included past GBR visitation and self-rated knowledge about the GBR as predictors within the demographic group, but these variables were not included in the final models because they did not significantly affect support for any of the interventions regardless at any stage of development.

Broader values act as guiding principles underpinning beliefs and attitudes, and studies have shown that environmental values influence emotions, perceived risks, benefits, and overall support for climate change mitigation options (Merk and Pönitzsch, 2017). Past studies have also identified reef related values or benefits as important antecedents to explain attitudes or support for reef management (Marshall et al., 2017). Values/benefits of the GBR were developed using past studies as a guide (Moffat et al., 2014, 2018). Perceived threats to the GBR and their views on the effect of a decline of the GBR were also examined. This can create issue salience (Yang et al., 2014) or threat appraisal that can influence attitudes toward restoration options.

A series of statements asked respondents about their understanding of the current management of the GBR. Questions were also asked regarding the prospects of scientific research to help repair and restore the Reef.

Finally, respondents were asked about their understanding of the intervention based on the scenario and their knowledge level associated with the intervention, by asking if they had heard of it prior to the information presented in the survey, and if so, how much knowledge they had. We also measured respondents' perceptions of whether they believed the intervention looks promising, ethical, cost-effective, and is perceived as having identifiable and testable environmental impacts.

2.5. Analysis

We started our analyses by providing descriptive results on the distribution of answers in our surveys regarding support for six interventions at four stages of development. For the last two stages of development (small-scale outdoor trials and large-scale outdoor use), we ran a regression model for each intervention including the predictor variables as described in Table 1. Models were fit using R modelling software (R Core Team, 2013), version 4.2.2. Because all our outcome variables were measured on a 7-point Likert scale, we used ordinal logistic regression models which were implemented using the MASS package in R (Ripley et al., 2013).

All non-binary predictors in the models were scaled using z-scores to reduce multicollinearity and to make effect sizes directly comparable (Abelson, 1995). We tested for multicollinearity through variance inflation factors using the performance package in R (Lüdecke et al., 2021). All predictors in the models had a variance inflation factor below 3, indicating low collinearity. We reported pseudo-R-squared values that were derived by using the DescTools package, specifically the Nagelkerke (Cragg and Uhler) value, which represents the proportion of the total variability in the outcome variable that is accounted for by the model.

3. Results

3.1. Sample description

We sampled a total of 5320 Australian residents, of which 2020 in 2018 and 3300 in 2022. About a third (31%) of our sample consisted of survey participants that lived in close proximity (<50 km) to the Great Barrier Reef, and we had a relatively even balance in terms of age and gender (Appendix C, Table 3). Eight percent of our sample consisted of participants that classified themselves as Aboriginal and/or Torres Strait Islander. About two-thirds (62%) of the participants had ever visited the Reef and the average self-reported knowledge about the GBR was 5.2 on

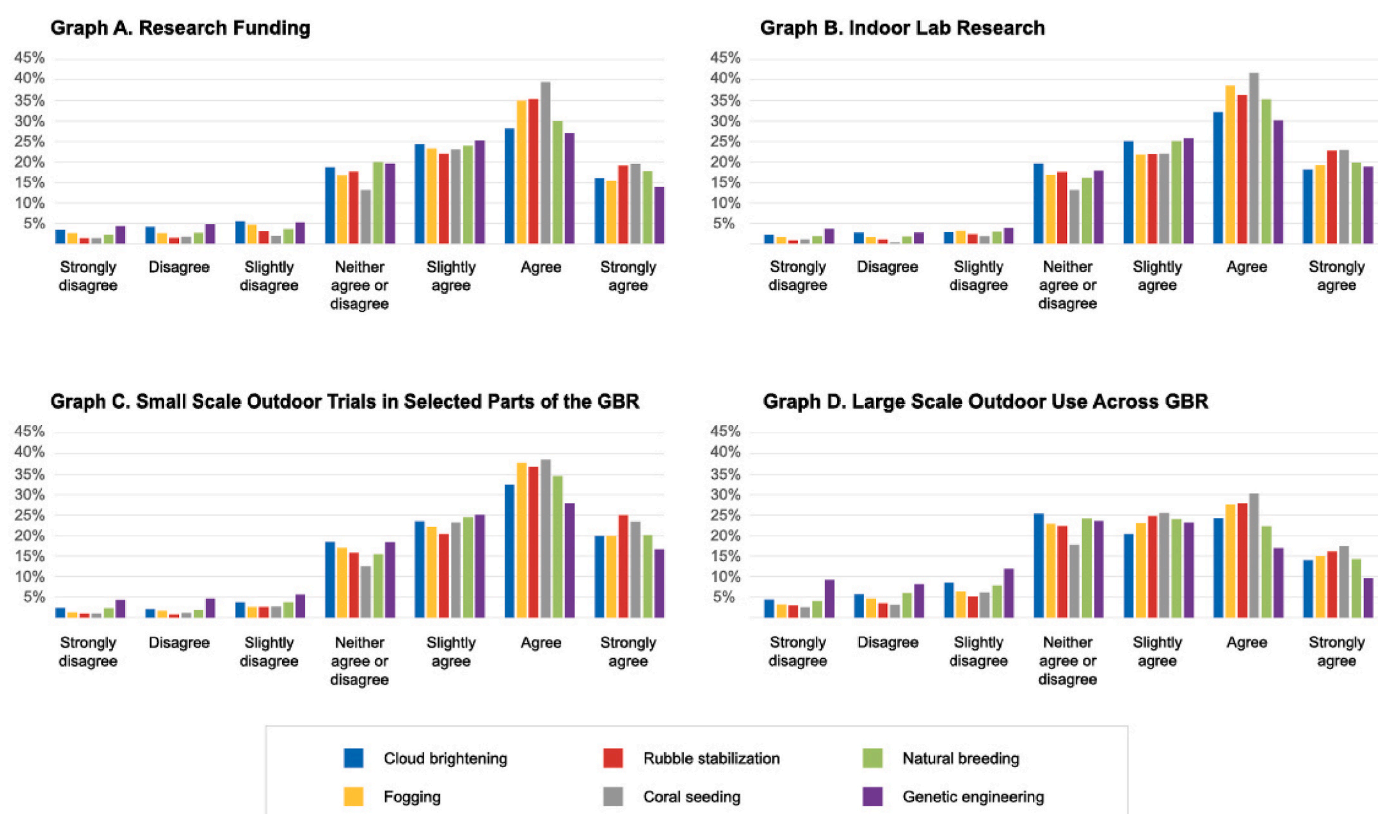

Fig. 1. Level of agreement on the support for research funding (Graph A), indoor lab research (Graph B), small scale outdoor trials in selected parts of the GBR (Graph C), and large-scale outdoor use across GBR (Graph D), by intervention.
Note: Data were collected through surveys in the year 2018 and 2022 (Australian residents, $n = 5320$) except for the *coral seeding* and *fogging* technologies, which were only included in the 2022 survey.

a ten-point scale.

3.2. Public support for novel reef management interventions

Our results indicate that support levels for the first three stages of development (research funding, indoor lab research, and small-scale outdoor trials) were relatively similar, with overall high support levels, while support levels for the fourth stage (large scale outdoor use) was more skewed towards neutral and slight agreement (Fig. 1). In terms of support for small scale outdoor trials in selected parts of the GBR, respondents showed relatively high support for all six interventions, i.e., for all approaches most survey respondents “agreed” with small scale

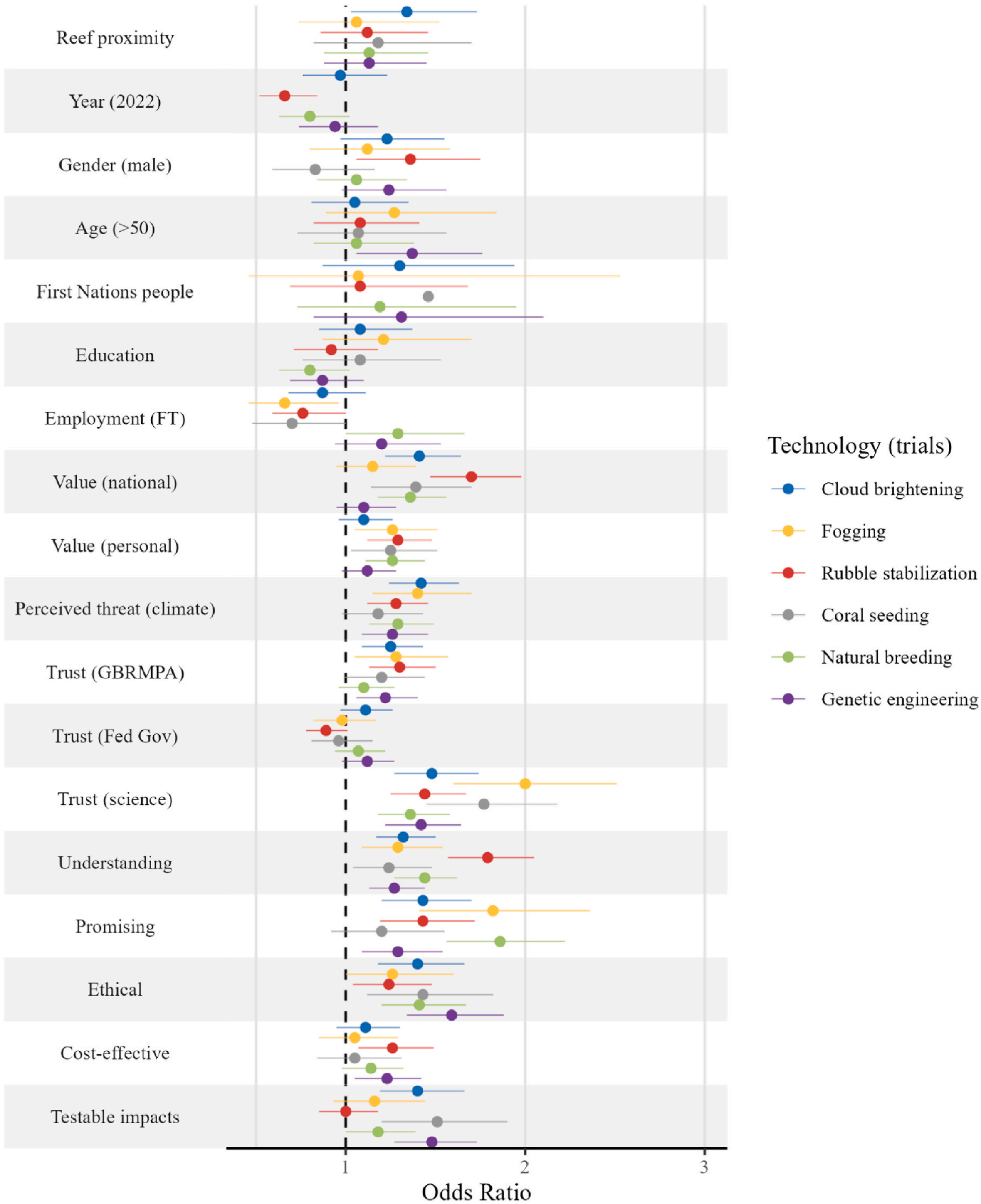

Fig. 2. Regression statistics (odds ratios at 95% confidence intervals) for ordinal logistic regression model outcomes associated with support for small-scale outdoor trials of each intervention in selected parts of the GBR. Note: Outcomes are on a 7-point Likert scale (Fig. 1). Significant predictors are those that do not cross the dotted ‘1’ line. Non-binary predictors (all predictors below *Employment (FT)*) were standardized using z-scores. Effect sizes shown in this Figure and discussed in the text can be de-standardized by multiplying with the standard deviation of the respective indicator (Appendix C, Table 3). Because of the wide confidence interval range for the effect of the *First Nations people* predictor on support for the *coral seeding* intervention (0.57–3.87, mean effect size of 1.46), we included only the mean effect size in the Figure for visualization purposes.

outdoor trials. The median response was also "agreed" for all interventions, except for genetic engineering which had a median response of "slightly agreed" (Appendix D, Table 5). Respondents were overall most agreeable, in terms of small-scale outdoor trials, with the restorative interventions (coral seeding and rubble stabilization), and slightly less agreeable about genetic engineering (adaptative intervention) and cloud brightening (protective intervention).

In terms of support for large-scale outdoor use of novel interventions across the GBR, respondents showed relatively less enthusiasm as compared to small-scale outdoor trials, although most respondents were still overall in support (Fig. 1). Most survey respondents "agreed" with the large-scale outdoor use of rubble stabilization, coral seeding, and fogging. For cloud brightening, natural breeding, and genetic engineering, on the other hand, most respondents revealed neutral responses regarding their large-scale outdoor use across the GBR. The median response was "slightly agreed" for all interventions, except for genetic engineering which had a median response of "neither agree or disagree" (Appendix D, Table 5).

3.3. Determinants of public support for small-scale outdoor trials of technological interventions

As shown in Fig. 2, residents located within 50 km of the GBR coastline were significantly more likely than Australian residents across all states and territories to support cloud brightening (mean odds ratio = 1.34, p-value = 0.028). Support for rubble stabilization was significantly lower in 2022 compared to 2018 (mean odds ratio = 0.66, p-value = 0.001). Demographically, male respondents were significantly more likely to support rubble stabilization (mean odds ratio = 1.36, p-value = 0.017), while older respondents were significantly more likely to support genetic engineering (mean odds ratio = 1.37, p-value = 0.015). We found no significant effect size for First Nations respondents and education levels. Respondents who had a fulltime employment status at the time of the survey were significantly more likely to support natural breeding (mean odds ratio = 1.29, p-value = 0.047), while they were significantly less likely to support fogging (mean odds ratio = 0.66, p-value = 0.027) and rubble stabilization (mean odds ratio = 0.76, p-value = 0.045).

Whether respondents valued the Reef and whether they believed the Reef is under threat from climate change generally had a positive effect size on support for *outdoor trials.* The perceived value of the GBR as a national asset had the strongest effect size for rubble stabilization (standardized mean odds ratio = 1.70, p-value <0.001), while it was not a significant determinant of support for genetic engineering or fogging. Whether respondents felt the GBR is personally important to them was a significant determinant of support for all interventions except genetic engineering and cloud brightening. The perceived threat of climate change on the Reef was positively associated with all interventions, with the protective interventions (cloud brightening and fogging) having the strongest (standardized) mean effect sizes, respectively 1.41 (p-value <0.001) and 1.40 (p-value = 0.001). In terms of trust in institutions and Reef management, trust in scientific solutions to help *prevent* or *repair* damage to the Reef was a strong determinant of support for all interventions, with the standardized mean effect sizes ranging from 1.36 (p-value <0.001) for natural breeding to 2.00 for fogging (p-value <0.001). Trust in GBRMPA was a significant determinant of support for all interventions except natural breeding and coral seeding, although the effect sizes were less strong compared to those of trust in science, in the range of 1.22 (genetic engineering) to 1.30 (rubble stabilization). Trust in the Federal Government had no significant effect sizes in terms of support for *outdoor trials*.

Intervention-specific factors had strong effect sizes associated with support for all interventions. First, respondents' self-rated knowledge about the intervention was a significantly positive determinant of support for all interventions, with the strongest effect size for rubble stabilization (standardized mean odds ratio = 1.79, p-value <0.001), followed by natural breeding (standardized mean odds ratio = 1.44, p-value <0.001). Whether respondents agreed an intervention looked like a promising option to help the Reef had a significantly positive effect size for all interventions except for coral seeding, with the highest reported effect sizes for natural breeding (standardized mean odds ratio = 1.86, p-value <0.001) and fogging (standardized mean odds ratio = 1.82, p-value <0.001). Whether an intervention was perceived as being ethical in use was a significant predictor for all interventions, with the strongest effect size for genetic engineering (standardized mean odds ratio = 1.59, p-value <0.001). Whether an intervention was perceived as likely to be cost-effective when fully developed only significantly affected support for rubble stabilization (standardized mean odds ratio = 1.26, p-value = 0.005) and genetic engineering (standardized mean odds ratio = 1.23, p-value = 0.008). Finally, whether respondents felt that the intervention has environmental impacts that can be identified and tested was a strong determinant of support for outdoor trials for coral seeding (standardized mean odds ratio = 1.51, p-value <0.001), genetic engineering (standardized mean odds ratio = 1.48, p-value <0.001), and cloud brightening (standardized mean odds ratio = 1.40, p-value <0.001), while a lower effect size was found for natural breeding (standardized mean odds ratio = 1.18, p-value = 0.046).

Overall, our models explained between 42% and 52% of the total variance in the support levels for *outdoor trials,* with respective of R-squared values of 46% for natural breeding, 42% for genetic engineering, 46% for cloud brightening, 52% for fogging, 51% for rubble stabilization, and 46% for coral seeding.

3.4. Determinants of public support for large-scale deployment of novel interventions

As shown in Fig. 3, residents located within 50 km of the GBR coastline were significantly less likely than other Australian residents to support coral seeding (mean odds ratio = 0.57, p-value = 0.002). Support levels did not change significantly between 2018 and 2022. Demographically, male respondents were significantly more likely to support cloud brightening (mean odds ratio = 1.37, p-value = 0.007) and rubble stabilization (mean odds ratio = 1.30, p-value = 0.028), while older respondents were significantly less likely to support cloud brightening (mean odds ratio = 0.77, p-value = 0.035), fogging (mean odds ratio = 0.64, p-value = 0.012), and natural breeding (mean odds ratio = 0.66, p-value = 0.002). First Nations respondents were significantly more likely to support coral seeding (mean odds ratio = 3.11, p-value = 0.017) and natural breeding (mean odds ratio = 2.55, p-value <0.001). Respondents with higher education levels were significantly less likely to support natural breeding (mean odds ratio = 0.77, p-value = 0.034), while we did not find significant effect sizes associated with employment status.

Like support levels for small scale *outdoor trials,* support for larger scale deployment was generally positively associated with whether respondents felt the GBR is personally important to them. Unlike support levels for *outdoor trials,* however, the perceived value of the GBR as a national asset was not a determinant of support for scaled deployment, and it was significantly negatively associated with support for genetic engineering (standardized mean odds ratio = 0.77, p-value = 0.001). The perceived threat of climate change on the Reef was positively associated with all interventions, with the protective interventions (cloud brightening and fogging) having the strongest (standardized) mean effect sizes, respectively 1.41 (p-value <0.001) and 1.61 (p-value <0.001). Trust in scientific solutions to help *prevent* or *repair* damage to the Reef was a strong determinant of support for technologies, although the effect size was lower compared to support for *outdoor trials,* and became insignificant for the fogging intervention, which had the strongest effect size for this predictor for *outdoor trials* (Fig. 2). Trust in GBRMPA was a significant determinant of support for all interventions except natural breeding, and the effect size was the largest for rubble stabilization (standardized mean odds ratio = 1.45, p-value <0.001).

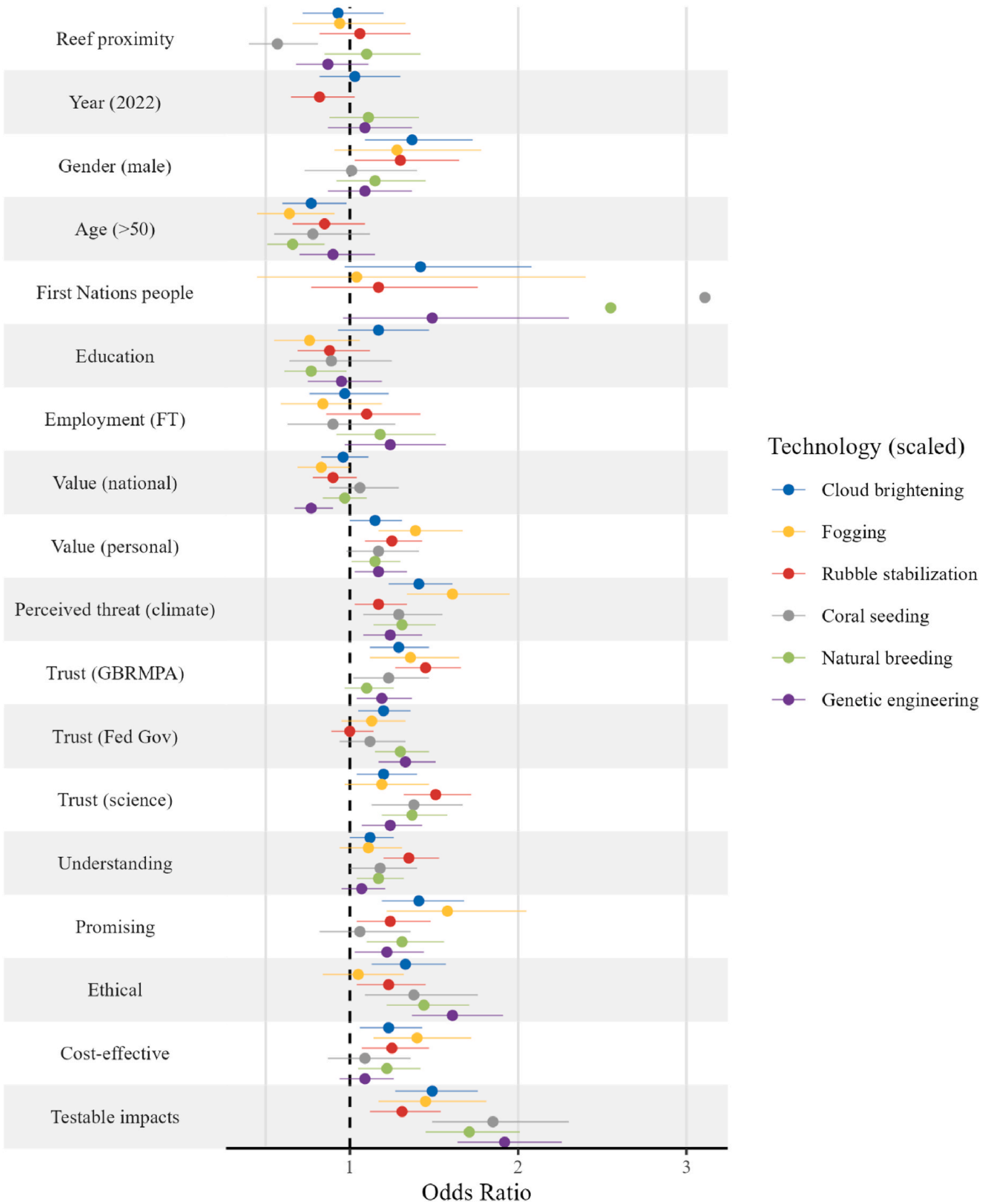

Fig. 3. Regression statistics (odds ratios at 95% confidence intervals) for ordinal logistic regression model outcomes associated with support for large-scale outdoor use of each intervention across the GBR.Note: Outcomes are on a 7-point Likert scale (Fig. 1). Significant predictors are those that do not cross the dotted '1' line. Non-binary predictors (all predictors below *Employment (FT)*) were standardized using z-scores. Effect sizes shown in this Figure and discussed in the text can be de-standardized by multiplying with the standard deviation of the respective indicator (Appendix C, Table 3). Because of the wide confidence interval range for the effect of the *First Nations people* predictor on support for the *coral seeding* (1.22–7.98, mean effect size of 3.11) and *natural breeding* (1.57–4.17, mean effect size of 2.55) technologies, we included only the mean effect size in the Figure for visualization purposes.

Unlike *outdoor trials,* trust in the Federal Government became a significant predictor of support for the *scaled deployment* of cloud brightening (standardized mean odds ratio = 1.20, p-value = 0.006), natural breeding (standardized mean odds ratio = 1.30, p-value <0.001), and genetic engineering (standardized mean odds ratio = 1.33, p-value <0.001).

Intervention-specific factors (see Table 1) had strong effect sizes associated with support for all interventions. Unlike support for *outdoor trials,* the respondent's self-rated knowledge about the intervention had a lower effect size on all interventions and became insignificant for all interventions except rubble stabilization (standardized mean odds ratio = 1.35, p-value <0.001) and natural breeding (standardized mean odds ratio = 1.17, *p*-value = 0.009). Whether respondents agreed an intervention looked like a promising option to help the Reef had a significantly positive effect size for all interventions except for coral seeding, with the highest reported effect sizes for protective interventions, cloud brightening (standardized mean odds ratio = 1.41, *p*-value <0.001) and fogging (standardized mean odds ratio = 1.58, *p*-value = 0.001). Whether an intervention was perceived as being ethical in use was a significant predictor for all interventions except fogging, with the strongest effect size for genetic engineering (standardized mean odds ratio = 1.61, *p*-value <0.001). Compared to support for *outdoor trials,* perceptions of a intervention's cost-effectiveness became a much stronger predictor for cloud brightening (standardized mean odds ratio = 1.23, *p*-value = 0.007) and fogging (standardized mean odds ratio = 1.40, *p*-value = 0.002), while for genetic engineering the effect size became insignificant. Finally, whether respondents felt that the intervention has environmental impacts that can be identified and tested became a stronger predictor of support, compared to support for *outdoor trials,* for all interventions, with the strongest effect sizes for genetic engineering (standardized mean odds ratio = 1.92, *p*-value <0.001), coral seeding (standardized mean odds ratio = 1.85, *p*-value <0.001), and natural breeding (standardized mean odds ratio = 1.71, *p*-value <0.001).

Overall, our models explained between 37% and 43% of the total variance in the support levels for *scaled deployment,* with respective of R-squared values of 43% for natural breeding, 43% for genetic engineering, 38% for cloud brightening, 42% for fogging, 37% for rubble stabilization, and 37% for coral seeding.

4. Discussion

4.1. Patterns of support across interventions

The pattern evident across our data of high support for intervention research and trials and slightly more muted support for large-scale deployment makes intuitive sense considering the relative novelty of these interventions. It is also consistent with past research demonstrating that while people support research on climate interventions such as stratospheric aerosol injection this does not necessarily lead to their endorsement of full-scale deployment (Baum et al., 2024; Macnaghten and Szerszynski, 2013; Pidgeon et al., 2013). Bearing in mind that five of our own six intervention descriptions advised respondents that more research was needed to understand their effects, and all qualified their outline of benefits and risks as "potential," it would not be unreasonable for respondents to conclude interventions are not sufficiently mature for large-scale deployment but deserving nonetheless of further research and development.

Support did, of course, vary across the interventions, being highest for coral-seeding across all stages of development from research to deployment (Fig. 1). Speculatively, this might be explained by early applications of this intervention receiving positive media coverage using language such as 'coral babies' and 'coral IVF' - language evocative of nurturing and care (Taylor et al., 2019, app. E). It is also possible coral-seeding, by helping improve the recruitment of wild coral juveniles to degraded reefs, was perceived as more natural than the other interventions we examined. Particularly strong support for coral-seeding would thus be consistent with studies showing that nature-based climate solutions such as afforestation and soil carbon sequestration attract more support and are perceived to have fewer risks than technology-based alternatives such as space-based geoengineering (Bertram and Merk, 2020; Jobin and Siegrist, 2020; Wolske et al., 2019).

For three reef interventions – coral seeding, rubble stabilization, and shading by fogging – tentative support was already evident for large-scale deployment. In fact, support for these interventions was comparable to those of an existing Reef management practice – the manual control (or culling) of crown-of-thorns starfish (COTS) – with 71%, 67%, and 64% of respondents at least slightly agreeing with the scaled deployment of coral seeding, rubble stabilization, and fogging respectively, compared with 68% for manual COTS control (Lockie et al., 2024b).

At the other end of the scale, genetic engineering attracted the lowest support at all stages of development. However, with only 14% of respondents disagreeing to any extent with small-scale trials of genetic engineering and 29% disagreeing to any extent with scaled deployment it is clear there is no widespread opposition to investigating the potential of this technology to assist reef restoration and adaptation. Older respondents especially showed higher preference for enhancing heat resistant corals through genetic engineering, indicating greater trust in technological solutions and novel approaches to enhance reef recovery. Similar findings are reported by Hobman et al. (2022; Mankad et al., 2021) who found that 59% of Australians support the use of genetic engineering to enhance coral resilience.

4.2. Determinants of support

The perceived threat of climate change was consistently associated with support for intervention trials and deployment. It was most strongly associated with trials and deployment of protective interventions, suggesting people may become more open to solar radiation management interventions, such as cloud brightening and fogging, as climate threats intensify. This might be related to the possibility of protective interventions having the most immediate impact by reducing water temperatures above reefs (Condie et al., 2021). Studies of public attitudes to the use of genetically modified organisms for the purposes of environmental management or restoration have found that the idea of 'thresholds of environmental damage' are influential in public acceptance of novel and contentious technologies. Hobman et al.'s (2022) study of public opinion on the use of genetically modified coral shows that at certain rates of coral mortality from bleaching, people believe the use of this technology increasingly justified.

The perceived promise (is this likely to work?), ability to identify and test impacts (can risks be managed?), understanding (what do I know?), and ethics (is it right to use?) of interventions were consistently strong predictors of support for both trials and large-scale deployment. The perceived cost-effectiveness of interventions, meanwhile, had limited influence. While all these findings make intuitive sense it is important to note their consistency with other studies of technological intervention. Of particular note are findings reported by Hobman and colleagues' suggesting people are particularly receptive to the idea of applying genetic engineering when benefits are clearly communicated and the techniques themselves prove more effective than other approaches (Hobman et al., 2022; Mankad et al., 2021). In our results, understanding of interventions became less important as a predictor of support for scaled deployment while the ability to identify and test environmental impacts became the major determinant – especially for the coral-focused interventions (Fig. 3). This underscores the importance for reef managers of conducting comprehensive risk assessment and of transparently communicating the findings of such assessments to the public in an easy-to-understand manner.

Trust in science to provide solutions and trust in the Great Barrier Reef Marine Park Authority to act in the best interests of society were also consistently strong predictors of support for both trials and deployment. It is well known that trust in scientists and management institutions influences support for potentially controversial interventions such as gene technology (Barnett et al., 2007) and solar radiation management (Merk and Pönitzsch, 2017). In essence, trustworthy scientific and management institutions provide confidence that meaningful action to address threats will be taken and risks associated with that action managed appropriately.

In contrast with the importance of trust in science and trust in GBRMPA, trust in the Federal Government had little influence on support. This may reflect public understanding of GBRMPA's lead role as manager and regulator of the marine park charged with protecting its

Outstanding Universal Value under World Heritage listing. For coral-breeding interventions, however, and to a lesser extent for cloud brightening, trust in the Federal Government became an important driver of support levels. This could indicate respondents perceive a need for more active Federal Government involvement in decisions about scaled deployment of more technology-based and potentially higher risk interventions. It could also indicate that public expectations of regulatory oversight might differ between interventions with those perceived as more familiar or nature-based regulated through existing management and permit arrangements in the marine park and those perceived as more novel or risky requiring oversight at the national level. Trust in regulators have been found to influence public's perceptions of the benefits and risks of novel technologies including carbon capture and storage (Midden and Huijts, 2009) and gene technology (Siegrist, 2000).

Respondents living in proximity of the Reef (<50 km) showed more support for trials of cloud seeding and lower support for scaled deployment of coral seeding than did residents of the rest of Australia. For all other interventions, proximity to the Reef had no significant effect on support for either trials or scaled deployment. Two potential explanations for these findings (i.e., that Reef residents have a higher understanding of these specific interventions or perceive them as more environmentally risky) can be excluded because these explanations were included in the regression model. Any remaining effect size from Reef proximity requires an alternative explanation and further research, especially because the coral seeding intervention was overall the novel intervention with the highest support rates. Possibly the most important point to note is that, for the most part, people living within 50 kms of the GBR coast do not have markedly different views to their fellow Australians. To the extent that place values (the economic, biodiversity, cultural and/or recreational values people associate with a place) influence support for intervention in the GBR (Le et al., 2022; Scholte et al., 2016) they appear widely shared among Australian residents.

Other demographic characteristics had similarly limited bearing on support for interventions. First Nations status was the one possible exception to this generalization (showing much higher support levels for the scaled deployment of coral seeding and natural breeding interventions (Fig. 3)). However, there is considerable variance in the responses provided by First Nation respondents due to the relatively small sample (especially for coral seeding which was only measured in the 2022 survey (Appendix C, Table 3)) and more focused inquiry will be needed. For the most part, it seems, concern about the condition of the GBR and belief more should be done to address climate threats (Lockie et al., 2024a) is sufficiently widespread to override most demographic differences.

The perceived value of the GBR as a national asset was positively and meaningfully associated with support for outdoor trials but not with support for scaled deployment. Given almost all respondents were in high agreement that the GBR is a major national asset (Appendix C, Table 3), this suggests many feel that while something must be done (funded, researched, and trialled) to protect the intrinsic value of the GBR, interventions should not be deployed prematurely and place those same values at risk. This finding highlights the need both for careful risk assessment of intervention deployments and for more public engagement, deliberation, and, in lay terms, difficult conversations about the trade-offs between intervening and not-intervening in response to global environmental change. Informing and engaging the public to address public's concerns about the risks novel management intervention can have on the GBR or to people's everyday lives is needed to create consensus (Vella et al., 2021).

5. Conclusion

Australian residents, including those living in proximity to the GBR, offered broad support for research and development of novel interventions to help protect, restore and support adaption of the GBR. The level of support they expressed did vary across types of intervention and, as proposed interventions moved through stages of development from laboratory testing to small field trials, to larger scale deployments, support moderated. Despite variability in support for the six interventions, however, it is important to note that the broad trend of strong support for R&D and moderate support for large-scale implementation was just as evident of those technologies which have proven controversial in other contexts (i.e., genetic engineering and solar radiation management through marine cloud brightening and fogging) as it was of others included in this study. Indeed, there was little evidence of opposition among Australian residents to the development and eventual use of any novel intervention included in this study on the GBR.

At face value, this suggests that from the perspective of public opinion: (1) no interventions should be considered 'off the table' for research and development; and (2) scientists and management authorities can be trusted to guide interventions into deployment. While people are generally more supportive of interventions they perceive as natural and familiar they become more open to novel technology-based solutions as climate threats and impacts escalate. For many members of the Australian public, our results suggest, that time is now.

Some caveats, however, need to be placed around this conclusion. First, it should be borne in mind that while surveys of the kind we have reported here are useful in understanding attitudes and perspectives at a population level they are not democratic instruments. They can inform, but not replace, democratic dialogue over the management of climate threats in the GBR and other ecosystems. Such dialogue must be particularly cognizant of the rights and authority of First Nations in the GBR, the interests of stakeholders including local communities, and the potential distribution of social and economic impacts arising from intervention. Second, we have investigated six novel interventions, five of which are subject to active R&D through the RRAP and one which is not. While consistency between our results and other research provides confidence, we cannot discount the possibility that had we used different descriptions within the survey or asked about different interventions we may have recorded different results. A significant number of candidate interventions were reviewed and rejected in the 2018 feasibility phase for the RRAP (Anthony et al., 2019; Bay et al., 2019a). That a considerable number of potential interventions were not included in this study suggests the possibility that both technical scrutiny and public scrutiny may lead to further interventions being rejected in the future.

This study highlights the critical influence of public understanding of threats to the reef, such as climate related impacts, and the expectation of the public that appropriate and rigorous regulatory and management oversight by relevant authorities tasked with protecting the GBR is part of the process of intervention development and deployment in the World Heritage Listed marine park. That trust in science to deliver solutions and the ability to identify and test environmental impacts were identified as critical to public support for implementation of novel interventions – along with perceived climate threat, trust in the Reef's management authority, and ethics – presents a strong case, we believe, for transparency and, wherever possible, direct First Nations, public and stakeholder involvement in both R&D and implementation.

CRediT authorship contribution statement

Henry A. Bartelet: Writing – review & editing, Writing – original draft, Visualization, Formal analysis. **Stewart Lockie:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Funding acquisition, Conceptualization. **Csilla Demeter:** Writing – review & editing, Writing – original draft. **Lintje Sie:** Writing – review & editing, Project administration, Methodology, Investigation, Data curation. **Bruce Taylor:** Writing – original draft, Supervision, Methodology, Funding acquisition, Conceptualization, Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization.

Research ethics

This research adheres to the National Statement on Ethical Conduct in Human Research. Human ethics approval was granted prior to data collection by the University of Queensland Human Research Ethics Committee (ref: 2018/HE001183 and 2021/HE002586). Reciprocal approval was granted by the James Cook University Human Research Ethics Committee (ref: H9172).

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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. Extended Literature Review: Factors influencing public support for novel ecosystem protection, restoration, and adaptation interventions

Escalating climate impacts and risks have stimulated calls among scientists for resilience-based approaches to ecosystem management that support natural processes of resistance and recovery (Lam et al., 2017; Mcleod et al., 2019). Resilience-based management builds on the integrated, multi-scalar approach to social and ecological objectives characteristic of ecosystem-based adaptation (Nalau et al., 2018) through increased focus on the active management of ecosystem processes to maintain desired values in the face of large-scale social and ecological change (Mcleod et al., 2019). Resilience-based management calls for improvement in the execution and targeting of traditional management practices such as the protected area designations, invasive species control, water quality regulations, etc. (Mcleod et al., 2019). However, resilience-based management also requires innovation to dramatically upscale ecosystem restoration (Gibbs et al., 2021) and develop new options for ecosystem protection and adaptation. While novel protection, restoration and adaptation interventions for coral reef ecosystems are at varying stages of development (Boström-Einarsson et al., 2020; McLeod et al., 2022), none are sufficiently mature for deployment at a regional or whole-of-ecosystem scale. It is just as relevant, consequently, to ask what is known about public support for research and field trials as it is to ask what is known about support for widespread deployment.

Solar radiation management (SRM) refers to a suite of technologies designed to control how much solar energy reaches the Earth's surface (Sovacool, 2021). SRM is generally classified as a type of geoengineering; that is, a deliberate intervention in the climate system to minimize the impacts of climate change (Sovacool, 2021). It is important to note, however, that SRM can be applied at a diversity of scales (the surface-level fogging and marine cloud brightening under investigation through RRAP intended for deployment at much smaller scales than technologies such as stratospheric aerosol injection and space mirrors) and has little in common with greenhouse gas removal technologies (e.g. carbon capture and storage (CCS)) other than categorization as a form of geoengineering. Care must be taken when interpreting the results of public perception research concerning SRM and geoengineering to ensure their implications for different technological approaches and scales of application are not confused.

The type of intervention and the scale of implementation, it turns out, both influence public support. Multiple studies find geoengineering interventions perceived to be more natural (interventions such as afforestation and soil-based CO_2 storage) receive greater support than those considered artificial (Baum et al., 2024; Burns et al., 2016; Jobin and Siegrist, 2020; Sweet et al., 2021; Vella et al., 2021). Multiple studies also show that support is higher for laboratory research and small-scale field trials than it is for large-scale field deployment (Baum et al., 2024; Macnaghten and Szerszynski, 2013; Pidgeon et al., 2013).

In the only published study to assess a variety of SRM techniques specifically, however, Baum et al. (2024) found little difference in support for marine cloud brightening, stratospheric aerosol injection, and space-based geoengineering. Respondents from the Global North were best described as ambivalent toward SRM while respondents from the Global South were significantly more supportive – a difference best explained by the younger age, higher perceived urgency of dealing with climate change, and greater vulnerability to climate impacts among respondents from the Global South (Baum et al., 2024). Both cohorts perceived less benefit and more risk from SRM relative to both engineered and ecosystem-based CO_2 removal, but respondents from the Global South evinced significantly higher levels of trust in international organizations to set standards and provide oversight of SRM, scientific agencies to start testing and development, information and engagement campaigns, and national regulation of SRM technology. Trust in scientists and relevant management institutions has been found to play a role in assessing support in a number of other sectors including gene technology (Barnett et al., 2007), hydroelectric power (Siegrist et al., 2000), nuclear power (Visschers and Siegrist, 2013), stratospheric aerosol injection (Merk and Pönitzsch, 2017) and CCS (Terwel et al., 2009).

Traditionally defined simply as the process of assisting recovery in degraded or destroyed ecosystems, understandings of *ecosystem restoration* are increasingly attuned to the diversity of goals relevant to restoration projects (Martin, 2017) including, importantly, the provision of socially beneficial ecosystem services and planning for future climate resilience (Ren and Coffman, 2023). Active coral reef restoration initiatives are burgeoning in response to global declines in coral cover and recognition of escalating climate threats (Hein et al., 2017) but historically they have, in fact, been rare (Boström-Einarsson et al., 2020; McLeod et al., 2022). Coral restoration practices are in an embryonic stage of development when compared with those available for terrestrial and coastal environments (Hein et al., 2017) and suitable for application only at very small scales (Gibbs, 2021). While the imperative to scale-up restoration practices drives the logic of research programs like RRAP, public support for increased restoration effort in marine ecosystems cannot be assumed (McLeod et al., 2022). Even at relatively small scales, research suggests that support for coral restoration can vary depending on context, culture, time, demographics, knowledge levels, values and beliefs (Le et al., 2022).

How members of the public perceive risks, benefits, costs and opportunities associated with coral reef restoration projects can vary based on people's place values (Le et al., 2022; Thiault et al., 2021). Place value – how people value a place, in terms of its economic, biodiversity, cultural or recreational value – plays an important role in the decision-making process of supporting restoration and conservation efforts (Le et al., 2022; Scholte et al., 2016). Past studies show for example, that local stakeholders perceive greater value in sociocultural benefits as opposed to ecological ones (Hein et al., 2019).

Knowledge and understanding of environmental management has been found to reduce perceived risks and increase the perceived benefits of coral reef restoration in Bali, Indonesia (Trialfhianty and Suadi, 2017). Knowledge was found to be an important element in increasing acceptance of reef restoration technologies in their early stages of development in Australia (Ritchie et al., 2022) while elsewhere in Bali, where support for coral restoration was already high, knowledge was linked to a range of subsidiary social benefits associated with increased participation in restoration (Sebastian et al., 2024). The relationship between knowledge levels and support for ecosystem restoration more generally is mixed, however, with findings showing that increased knowledge does not always translate into support (Vella et al., 2021). One potential explanation may be that shifts in attitudes towards new technologies are influenced by factors like misinterpretation of information, political affiliation, or selectively scrutinizing information (McFadden and Lusk, 2015).

Understanding the values and motivations of publics creates opportunities for aligning the goals of restoration and increasing the likelihood of public support (Scholte et al., 2016). Noting attitudes are formed through experiences as well as the rational appraisal of information, Scholte et al. (2016) argue that involving people directly in restoration, where possible, will also increase support. Elsewhere, trust in institutions has been found to indirectly increase public support for ecosystem restoration in riverine environments, by reducing perceptions of environmental risks and increasing beliefs in the benefits of environmental interventions (Metcalf et al., 2015).

Assisted ecosystem adaptation interventions are intended to accelerate the evolutionary responses of species or ecosystems to anthropogenic pressures associated with global environmental change (Lockie, 2024; Vella et al., 2021). Prospective interventions include assisted species migration, managed or selective breeding, pre-conditioning seed- or brood-stock to changed environmental conditions, and genetic engineering (Hobman et al., 2022; McLeod et al., 2022). Such interventions may be implemented in parallel with ecosystem restoration projects to maximize opportunities for long-term climate resilience (Vella et al., 2021).

Mankad et al. (2021; Hobman et al., 2022) investigate correlates of support for the genetic engineering (GE) of corals on the Great Barrier Reef for heat tolerance. While neither RRAP nor any other research program are actively engaged in genetic engineering research in the GBR, this study provides useful insight into prospective support for what many scientists will intuitively believe (in light of social conflict over genetically engineered food) is potentially one of the most controversial adaptation intervention options (Hobman et al., 2022). Despite low self-reported knowledge of gene editing of coral, respondents expressed moderate to strong support for this technology, a result consistent with prior research suggesting positive sentiment to synthetic biology applications for environmental or social benefit (Hobman et al., 2022). Respondents perceived coral reef loss as a significant threat, and believed it was particularly important to find a viable solution for reef conservation (Mankad et al., 2021). The main correlate of support consequently was the perceived efficacy of genetic engineering relative to other intervention and management options.

Furthermore, research on adaptation and mitigation shows that public responses may also largely depend on their perceptions of risk/threats from climate change, people's "beliefs about the existence and characteristics of a natural hazard" (Nigg and Mileti, 2002, p. 280). In other words, support for novel technologies can be influenced by people's perceptions associated with the potential threats, the degree of exposure to climate change. Perceived threats can create issue salience or threat appraisal that can influence attitudes towards restoration interventions (Yang et al., 2014).

In sum, while current advances in reef protection, restoration and adaptation technologies continue to be developed and tested in laboratory settings, there is a lack of understanding of stakeholder and public perspectives on reef restoration interventions and the factors that influence support for novel technologies (Mankad et al., 2021). Many of the factors identified to influence support levels of emerging technologies in general in past studies, however, appear broadly applicable to reef restoration and adaptation interventions. Public support may differ, for example, based on the type of technology proposed, or the scale of deployment. Attitudes may vary depending on the understanding of the technological interventions, with public support often influenced by the scientific consensus related to the urgency and effectiveness of proposed interventions (Vella et al., 2021). Levels of support could be also influenced by the perceived relative benefits, risks, including unforeseen outcomes or costs associated with specific technologies (Mankad et al., 2021; Vella et al., 2021). Furthermore, public support may be affected by the level of trust in related scientific and management institutions.

Appendix B. Detailed methodological description

Sampling

The market research company utilised diverse online panels to include participants from different income levels, reducing the likelihood of over-representing affluent individuals. The market research company also directly managed and distributed incentives to all participants, regardless of income level. These incentives were designed to appeal to a wide audience, encouraging participation from various socio-economic strata and helping to balance the sample. The survey was designed to require participants to complete all questions. The survey platform was set up to remind participants of any unanswered questions, and they were unable to progress to the next question unless the previous ones were fully completed.

This design ensured that we collected a complete dataset from each participant, eliminating the issue of missing data and allowing us to include all responses in our analysis without the need for imputation or deletion methods. Data were cleaned by removing surveys that were either not completed in full (submissions before all sections were finalized) or that were completed in a time not considered feasible in order to maintain quality (i.e. by "speeders"). For the 2018 survey, a total of 1978 surveys were removed and for the 2022 survey, a total of 2113 surveys were removed. The 2018 survey amounted to a total of 4036 *useable* surveys (2743 from the national sample and 1293 from the resident sample). The 2022 survey amounted to a total of 4410 *useable* surveys (3082 from the national sample and 1328 from the resident sample). Where applicable, questions were randomised to reduce priming effects. This randomisation was managed by the survey platform, ensuring each participant received a unique question sequence.

Intervention bias

We tested for potential bias in our written framing of each intervention because the survey presented detailed descriptions of a range of interventions to a largely non-scientific audience.

Table 1
Overview of whether survey respondents felt that description of the intervention was written in way that was biased, neutral, or in favour of the intervention.

Technology	Biased against intervention	Neutral regarding intervention	Biased in favour of intervention
Cloud brightening	53 (5%)	725 (69%)	278 (26%)
Fogging	34 (6%)	381 (69%)	140 (25%)
Rubble stabilization	54 (5%)	742 (70%)	257 (24%)
Coral seeding	26 (5%)	375 (69%)	141 (26%)
Natural breeding	71 (7%)	695 (66%)	295 (28%)
Genetic engineering	87 (8%)	737 (70%)	229 (22%)

Appendix C. Sample description

Table 3
Sample description.

Indicator	Level	Frequency (fraction)		
		2018	2022	Total
Surveys	#	2020 (38%)	3300 (62%)	5320 (100%)
Reef proximity	>50 km from the GBR	1373 (68%)	2304 (70%)	3677 (69%)
	<50 km from the GBR	647 (32%)	996 (30%)	1643 (31%)
Gender	Female	1082 (54%)	1742 (53%)	2824 (53%)
	Male	934 (46%)	1557 (47%)	2491 (47%)
Age group	<50 years	1137 (56%)	1762 (53%)	2899 (54%)
	>50 years	883 (44%)	1538 (47%)	2421 (46%)
First Nations people	No	1730 (86%)	3177 (96%)	4907 (92%)
	Yes	284 (14%)	123 (4%)	407 (8%)
Education (graduate degree)	No	1252 (62%)	1781 (54%)	3033 (57%)
	Yes	762 (38%)	1519 (46%)	2281 (43%)
Employment (full-time)	No	1239 (62%)	1880 (57%)	3119 (59%)
	Yes	775 (38%)	1420 (43%)	2195 (41%)
Reef visitation	No	753 (37%)	1289 (39%)	2042 (38%)
	Yes	1267 (63%)	2011 (61%)	3278 (62%)
GBR knowledge	μ (10-scale Likert)	5.50	5.02	5.20
	σ	2.12	2.16	2.16
Value (national asset)	μ (7-scale Likert)	6.08	6.34	6.24
	σ	1.11	0.99	1.05
Value (personal)	μ (7-scale Likert)	5.24	5.29	5.27
	σ	1.41	1.36	1.38
Perceived threat (climate)	μ (7-scale Likert)	5.30	5.52	5.44
	σ	1.55	1.57	1.56
Trust in GBRMPA	μ (7-scale Likert)	4.82	5.32	5.13
	σ	1.36	1.34	1.37
Trust in Federal Government	μ (7-scale Likert)	3.79	3.81	3.80
	σ	1.62	1.60	1.61
Trust in scientific solutions to repair damage GBR	μ (7-scale Likert)	5.42	5.67	5.58
	σ	1.18	1.15	1.17
Trust in scientific solutions to prevent damage to GBR	μ (7-scale Likert)	5.45	5.73	5.62
	σ	1.18	1.14	1.16
Awareness (technology)	No	1476 (73%)	819 (25%)	2295 (43%)
	Yes	544 (27%)	2481 (75%)	3025 (57%)
Understanding (technology)	μ (10-scale Likert)	4.73	4.78	4.76
	σ	1.45	1.42	1.43

Appendix D. Support for interventions, summary statistics

Table 4
Australian residents' ($n = 5320$) expressed levels of agreement with statements about support for small-scale outdoor trials and large-scale outdoor use of different interventions across the GBR. Summary statistics. ">4" reflects fraction of total respondents that at least "slightly agreed (5)".

	Funding of research			Indoor lab research		
	Modus	Median	>4	Modus	Median	>4
Cloud brightening	6	5	68%	6	5	74%
Fogging	6	6	74%	6	6	78%

(continued on next page)

Table 4 (*continued*)

	Funding of research			Indoor lab research		
	Modus	Median	>4	Modus	Median	>4
Rubble stabilization	6	6	77%	6	6	79%
Coral seeding	6	6	82%	6	6	85%
Natural breeding	6	5	72%	6	6	78%
Genetic engineering	6	5	66%	6	5	73%

Table 5
Australian residents' ($n = 5320$) expressed levels of agreement with statements about support for small-scale outdoor trials and large-scale outdoor use of different interventions across the GBR. Summary statistics. ">4" reflects fraction of total respondents that at least "slightly agreed (5)".

	Small-scale outdoor trials			Large-scale outdoor use		
	Modus	Median	>4	Modus	Median	>4
Cloud brightening	6	6	74%	4	5	57%
Fogging	6	6	78%	6	5	64%
Rubble stabilization	6	6	80%	6	5	67%
Coral seeding	6	6	83%	6	5	71%
Natural breeding	6	6	77%	4	5	59%
Genetic engineering	6	5	68%	4	4	48%

Appendix E. RRAP Survey Introductory information for participants

Dear Survey Respondents:

We are undertaking a study to find out your thoughts about the Great Barrier Reef and its management, including potential options for (future) interventions to sustain the Reef. An understanding of your attitudes will help to inform strategies and actions to help the Great Barrier Reef (GBR). This research is funded by the Australian Government through the Reef Restoration and Adaptation Program (RRAP). This study is being conducted by a consortium of research organizations including The University of Queensland.

The survey will take approximately 20–25 min to complete. We appreciate your time. By hitting the next button below, you will agree to have read and understood the nature of the research as described at the bottom of this page and thus provided informed consent to participate.

If you participate in this study, you will not be identified in the study or final report. All responses will be coded and will be pooled and aggregated so no individual responses will be identifiable or made available. The information will be stored in a secure environment and will only be accessible to members of the research team. Your responses will be confidential and any information provided will only be used for the purposes of this research. Please understand that you are under no obligation to participate and may withdraw at any time without penalty. The findings of this project will be provided on the UQ Business School website http://www.uq.edu.au/business at the conclusion of the study.

This study adheres to the Guidelines of the ethical review process of The University of Queensland and the National Statement on Ethical Conduct in Human Research (#2021/HE002586). Whilst you are free to discuss your participation in this study with project staff (contactable on 07 3346 7308), if you would like to speak to an officer of the University not involved in the study, you may contact the Ethics Coordinator on 3365 4584 or on humanethics@research.uq.edu.au.

Data availability

The data that has been used is confidential.

References

Abelson, R.P., 1995. Statistics as Principled Argument. Lawrence Erlbaum Associates, Publishers, Hillsdale, NJ.

Anthony, K., Bowen, J., Mead, D., Hardisty, P.E., 2019. Reef Restoration and Adaptation Program: Intervention Analysis and Recommendations. A report provided to the Australian Government by the Reef Restoration and Adaptation Program.

Anthony, K.R.N., Helmstedt, K.J., Bay, L.K., Fidelman, P., Hussey, K.E., Lundgren, P., Mead, D., McLeod, I.M., Mumby, P.J., Newlands, M., Schaffelke, B., Wilson, K.A., Hardisty, P.E., 2020. Interventions to help coral reefs under global change—a complex decision challenge. PLoS One 15, e0236399. https://doi.org/10.1371/journal.pone.0236399.

Barnett, J., Cooper, H., Senior, V., 2007. Belief in public efficacy, trust, and attitudes toward modern genetic science. Risk Anal. 27, 921–933. https://doi.org/10.1111/j.1539-6924.2007.00932.x.

Baum, C.M., Fritz, L., Low, S., Sovacool, B.K., 2024. Public perceptions and support of climate intervention technologies across the Global North and Global South. Nat. Commun. 15, 2060. https://doi.org/10.1038/s41467-024-46341-5.

Bay, L.K., Mead, D., Boström-Einarsson, L., 2019a. Reef Restoration and Adaptation Program: Intervention Summary. A report provided to the Australian Government by the Reef Restoration and Adaptation Program.

Bay, L.K., Rocker, M., Boström-Einarsson, L., Babcock, R., Buerger, P., Cleves, P., Harrison, D., Negri, A., Quigley, K., Randall, C.J., van Oppen, M.J.H., Webster, N., 2019b. Reef Restoration and Adaptation Program: Intervention Technical Summary. A Report provided to the Australian Government by the Reef Restoration and Adaptation Program. Australian Institute of Marine Science (AIMS).

Bellamy, R., Lezaun, J., 2017. Crafting a public for geoengineering. Publ. Understand. Sci. 26, 402–417. https://doi.org/10.1177/0963662515600965.

Bertram, C., Merk, C., 2020. Public Perceptions of Ocean-Based Carbon Dioxide Removal: the Nature-Engineering Divide? Front. Clim., vol. 2. https://doi.org/10.3389/fclim.2020.594194.

Boström-Einarsson, L., Babcock, R.C., Bayraktarov, E., Ceccarelli, D., Cook, N., Ferse, S.C.A., Hancock, B., Harrison, P., Hein, M., Shaver, E., Smith, A., Suggett, D., Stewart-Sinclair, P.J., Vardi, T., McLeod, I.M., 2020. Coral restoration – a systematic review of current methods, successes, failures and future directions. PLoS One 15, e0226631. https://doi.org/10.1371/journal.pone.0226631.

Budiharta, S., Meijaard, E., Gaveau, D.L.A., Struebig, M.J., Wilting, A., Kramer-Schadt, S., Niedballa, J., Raes, N., Maron, M., Wilson, K.A., 2018. Restoration to offset the impacts of developments at a landscape scale reveals opportunities, challenges and tough choices. Global Environ. Change 52, 152–161. https://doi.org/10.1016/j.gloenvcha.2018.07.008.

Buijs, A.E., 2009. Public support for river restoration. A mixed-method study into local residents' support for and framing of river management and ecological restoration in the Dutch floodplains. J. Environ. Manag. 90, 2680–2689. https://doi.org/10.1016/j.jenvman.2009.02.006.

Burns, E.T., Flegal, J.A., Keith, D.W., Mahajan, A., Tingley, D., Wagner, G., 2016. What do people think when they think about solar geoengineering? A review of empirical social science literature, and prospects for future research. Earth's Future 4, 536–542. https://doi.org/10.1002/2016EF000461.

Butcherine, P., Tagliafico, A., Ellis, S.L., Kelaher, B.P., Hendrickson, C., Harrison, D., 2023. Intermittent shading can moderate coral bleaching on shallow reefs. Front. Mar. Sci. 10. https://doi.org/10.3389/fmars.2023.1162896.

Commonwealth of Australia, 2024. Great Barrier Reef Progress Report to UNESCO World Heritage Centre - February 2024. Commonwealth of Australia, Canberra.
Condie, S.A., Anthony, K.R.N., Babcock, R.C., Baird, M.E., Beeden, R., Fletcher, C.S., Gorton, R., Harrison, D., Hobday, A.J., Plagányi, É.E., Westcott, D.A., 2021. Large-scale interventions may delay decline of the Great Barrier Reef. R. Soc. Open Sci. 8, 201296. https://doi.org/10.1098/rsos.201296.
Deloitte Access Economics, 2017. At what Price? the Economic, Social and Icon Value of the Great Barrier Reef. Deloitte, Brisbane, Australia.
Fidelman, P., McGrath, C., Newlands, M., Dobbs, K., Jago, B., Hussey, K., 2019. Regulatory implications of coral reef restoration and adaptation under a changing climate. Environ. Sci. Pol. 100, 221–229. https://doi.org/10.1016/j.envsci.2019.04.016.
Gibbs, M.T., 2021. Technology requirements, and social impacts of technology for at-scale coral reef restoration. Technol. Soc. 66, 101622. https://doi.org/10.1016/j.techsoc.2021.101622.
Gibbs, M.T., Gibbs, B.L., Newlands, M., Ivey, J., 2021. Scaling up the global reef restoration activity: avoiding ecological imperialism and ongoing colonialism. PLoS One 16, e0250870. https://doi.org/10.1371/journal.pone.0250870.
Hajjar, R., Kozak, R.A., 2015. Exploring public perceptions of forest adaptation strategies in Western Canada: implications for policy-makers. For. Pol. Econ. 61, 59–69. https://doi.org/10.1016/j.forpol.2015.08.004.
Harrison, D.P., 2024. An Overview of environmental engineering methods for reducing coral bleaching stress. In: Oceanographic Processes of Coral Reefs. CRC Press.
Hein, M.Y., Birtles, A., Willis, B.L., Gardiner, N., Beeden, R., Marshall, N.A., 2019. Coral restoration: socio-ecological perspectives of benefits and limitations. Biol. Conserv. 229, 14–25. https://doi.org/10.1016/j.biocon.2018.11.014.
Hein, M.Y., Willis, B.L., Beeden, R., Birtles, A., 2017. The need for broader ecological and socioeconomic tools to evaluate the effectiveness of coral restoration programs. Restor. Ecol. 25, 873–883. https://doi.org/10.1111/rec.12580.
Hobbs, R.J., Cramer, V.A., 2008. Restoration ecology: interventionist approaches for restoring and maintaining ecosystem function in the face of rapid environmental change. Annu. Rev. Environ. Resour. 33, 39–61. https://doi.org/10.1146/annurev.environ.33.020107.113631.
Hobman, E.V., Mankad, A., Carter, L., Ruttley, C., 2022. Genetically engineered heat-resistant coral: an initial analysis of public opinion. PLoS One 17, e0252739. https://doi.org/10.1371/journal.pone.0252739.
Intergovernmental Panel on Climate Change (IPCC), 2023. Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge. https://doi.org/10.1017/9781009325844.
Jobin, M., Siegrist, M., 2020. Support for the deployment of climate engineering: a comparison of ten different technologies. Risk Anal. 40, 1058–1078. https://doi.org/10.1111/risa.13462.
Kenyon, T.M., Harris, D., Baldock, T., Callaghan, D., Doropoulos, C., Webb, G., Newman, S.P., Mumby, P.J., 2023. Mobilisation thresholds for coral rubble and consequences for windows of reef recovery. Biogeosciences 20, 4339–4357. https://doi.org/10.5194/bg-20-4339-2023.
Klaus, G., Ernst, A., Oswald, L., 2020. Psychological factors influencing laypersons' acceptance of climate engineering, climate change mitigation and business as usual scenarios. Technol. Soc. 60, 101222. https://doi.org/10.1016/j.techsoc.2019.101222.
Lam, V.Y.Y., Doropoulos, C., Mumby, P.J., 2017. The influence of resilience-based management on coral reef monitoring: a systematic review. PLoS One 12, e0172064. https://doi.org/10.1371/journal.pone.0172064.
Le, (Jenny) Dung, Becken, S., Curnock, M., 2022. Gaining public engagement to restore coral reef ecosystems in the face of acute crisis. Global Environ. Change 74, 102513. https://doi.org/10.1016/j.gloenvcha.2022.102513.
Lippmann, R.B., Helmstedt, K.J., Gibbs, M.T., Corry, P., 2023. Optimizing facility location, sizing, and growth time for a cultivated resource: a case study in coral aquaculture. PLoS One 18, e0282668. https://doi.org/10.1371/journal.pone.0282668.
Lockie, S., 2024. Climate adaptation. In: Elgar Encyclopedia of Environmental Sociology. Edward Elgar Publishing, pp. 53–58.
Lockie, S., Bartelet, H.A., Ritchie, B.W., Demeter, C., Taylor, B., Sie, L., 2024a. Australians support multi-pronged action to build ecosystem resilience in the Great Barrier Reef. Biol. Conserv. https://doi.org/10.1016/j.biocon.2024.110789.
Lockie, S., Bartelet, H.A., Ritchie, B.W., Sie, L.S., Paxton, G., 2024b. Quantifying public support for culling crown-of-thorns starfish (Acanthaster spp.) on the Great Barrier Reef. Conservation Science and Practice 6. https://doi.org/10.1111/csp2.13252.
Lüdecke, D., Ben-Shachar, M.S., Patil, I., Waggoner, P., Makowski, D., 2021. Performance: an R package for assessment, comparison and testing of statistical models. J. Open Source Softw. 6, 3139. https://doi.org/10.21105/joss.03139.
Macnaghten, P., Szerszynski, B., 2013. Living the global social experiment: an analysis of public discourse on solar radiation management and its implications for governance. Global Environ. Change 23, 465–474. https://doi.org/10.1016/j.gloenvcha.2012.12.008.
Malhi, Y., Franklin, J., Seddon, N., Solan, M., Turner, M.G., Field, C.B., Knowlton, N., 2020. Climate change and ecosystems: threats, opportunities and solutions. Phil. Trans. Biol. Sci. 375, 20190104. https://doi.org/10.1098/rstb.2019.0104.
Mankad, A., Hobman, E.V., Carter, L., 2021. Genetically engineering coral for conservation: psychological correlates of public acceptability. Front. Mar. Sci. 8.
Marshall, N.A., Curnock, M.I., Goldberg, J., Gooch, M., Marshall, P.A., Pert, P.L., Tobin, R.C., 2017. The dependency of people on the Great barrier reef, Australia. Coast. Manag. 45, 505–518. https://doi.org/10.1080/08920753.2017.1373454.
Martin, D.M., 2017. Ecological restoration should be redefined for the twenty-first century. Restor. Ecol. 25, 668–673. https://doi.org/10.1111/rec.12554.
McFadden, B.R., Lusk, J.L., 2015. Cognitive biases in the assimilation of scientific information on global warming and genetically modified food. Food Pol. 54, 35–43. https://doi.org/10.1016/j.foodpol.2015.04.010.
McLaren, D., Corry, O., 2021. The politics and governance of research into solar geoengineering. WIREs Climate Change 12, e707. https://doi.org/10.1002/wcc.707.
Mcleod, E., Anthony, K.R.N., Mumby, P.J., Maynard, J., Beeden, R., Graham, N.A.J., Heron, S.F., Hoegh-Guldberg, O., Jupiter, S., MacGowan, P., Mangubhai, S., Marshall, N., Marshall, P.A., McClanahan, T.R., Mcleod, K., Nyström, M., Obura, D., Parker, B., Possingham, H.P., Salm, R.V., Tamelander, J., 2019. The future of resilience-based management in coral reef ecosystems. J. Environ. Manag. 233, 291–301. https://doi.org/10.1016/j.jenvman.2018.11.034.
McLeod, I.M., Hein, M.Y., Babcock, R., Bay, L., Bourne, D.G., Cook, N., Doropoulos, C., Gibbs, M., Harrison, P., Lockie, S., Oppen, M.J.H. van, Mattocks, N., Page, C.A., Randall, C.J., Smith, A., Smith, H.A., Suggett, D.J., Taylor, B., Vella, K.J., Wachenfeld, D., Boström-Einarsson, L., 2022. Coral restoration and adaptation in Australia: the first five years. PLoS One 17, e0273325. https://doi.org/10.1371/journal.pone.0273325.
Merk, C., Pönitzsch, G., 2017. The role of affect in attitude formation toward new technologies: the case of stratospheric aerosol injection. Risk Anal. 37, 2289–2304. https://doi.org/10.1111/risa.12780.
Merk, C., Pönitzsch, G., Kniebes, C., Rehdanz, K., Schmidt, U., 2015. Exploring public perceptions of stratospheric sulfate injection. Climatic Change 130, 299–312. https://doi.org/10.1007/s10584-014-1317-7.
Metcalf, E.C., Mohr, J.J., Yung, L., Metcalf, P., Craig, D., 2015. The role of trust in restoration success: public engagement and temporal and spatial scale in a complex social-ecological system. Restor. Ecol. 23, 315–324. https://doi.org/10.1111/rec.12188.
Midden, C.J.H., Huijts, N.M.A., 2009. The role of trust in the affective evaluation of novel risks: the case of CO2 storage. Risk Anal. 29, 743–751. https://doi.org/10.1111/j.1539-6924.2009.01201.x.
Minteer, B.A., Collins, J.P., 2010. Move it or lose it? The ecological ethics of relocating species under climate change. Ecol. Appl. 20, 1801–1804. https://doi.org/10.1890/10-0318.1.
Moffat, K., Pert, P., McCrea, R., Boughen, N., Rodriguez, S., Lacey, J., 2018. Australian Attitudes toward Mining: Citizen Survey – 2017 Results. CSIRO. https://doi.org/10.4225/08/5a8f0526f2ec8.
Moffat, K., Zhang, A., Boughen, N., 2014. Australian Attitudes toward Mining - Citizen Survey - 2014 Results. CSIRO. https://doi.org/10.4225/08/584ee6f6e15ff.
Moshofsky, M., Gilani, H.R., Kozak, R.A., 2019. Adapting forest ecosystems to climate change by identifying the range of acceptable human interventions in western Canada. Can. J. For. Res. 49, 553–564. https://doi.org/10.1139/cjfr-2018-0076.
Nalau, J., Becken, S., Mackey, B., 2018. Ecosystem-based Adaptation: a review of the constraints. Environ. Sci. Pol. 89, 357–364. https://doi.org/10.1016/j.envsci.2018.08.014.
Nigg, J., Mileti, D., 2002. Natural Hazards and Disasters (Handbook of Environmental Sociology). Greenwood Press, Westport.
Pidgeon, N., Corner, A., Parkhill, K., Spence, A., Butler, C., Poortinga, W., 2012. Exploring early public responses to geoengineering. Phil. Trans. Math. Phys. Eng. Sci. 370, 4176–4196. https://doi.org/10.1098/rsta.2012.0099.
Pidgeon, N., Parkhill, K., Corner, A., Vaughan, N., 2013. Deliberating stratospheric aerosols for climate geoengineering and the SPICE project. Nat. Clim. Change 3, 451–457. https://doi.org/10.1038/nclimate1807.
Powers, R.P., Jetz, W., 2019. Global habitat loss and extinction risk of terrestrial vertebrates under future land-use-change scenarios. Nat. Clim. Change 9, 323–329. https://doi.org/10.1038/s41558-019-0406-z.
R Core Team, 2013. R: A Language and Environment for Statistical Computing.
Ren, J.W.F., Coffman, G.C., 2023. Integrating the resilience concept into ecosystem restoration. Restor. Ecol. 31, e13907. https://doi.org/10.1111/rec.13907.
Ripley, B., Venables, B., Bates, D.M., Hornik, K., Gebhardt, A., Firth, D., 2013. Package 'MASS.'.
Ritchie, B.W., Prideaux, B., Thompson, M., Demeter, C., 2022. Understanding tourists' attitudes toward interventions for the Great Barrier Reef: an extension of the norm activation model. J. Sustain. Tourism 30, 1364–1383. https://doi.org/10.1080/09669582.2021.1948048.
Scharfenstein, H.J., Alvarez-Roa, C., Peplow, L.M., Buerger, P., Chan, W.Y., van Oppen, M.J.H., 2023. Chemical mutagenesis and thermal selection of coral photosymbionts induce adaptation to heat stress with trait trade-offs. Evolutionary Applications 16, 1549–1567. https://doi.org/10.1111/eva.13586.
Scholte, S.S.K., Todorova, M., van Teeffelen, A.J.A., Verburg, P.H., 2016. Public support for wetland restoration: what is the link with ecosystem service values? Wetlands 36, 467–481. https://doi.org/10.1007/s13157-016-0755-6.
Sebastian, P., Sparks, L.D., Resolute, P., Prasetijo, R., 2024. Connecting communities to coral reefs: a socio-ecological perspective on coral restoration programs in a remote marine protected area. J. Coast Conserv. 28, 39. https://doi.org/10.1007/s11852-024-01041-6.
Selmoni, O., Bay, L.K., Exposito-Alonso, M., Cleves, P.A., 2024. Finding genes and pathways that underlie coral adaptation. Trends Genet. 40, 213–227. https://doi.org/10.1016/j.tig.2024.01.003.
Siegrist, M., 2000. The influence of trust and perceptions of risks and benefits on the acceptance of gene technology. Risk Anal. 20, 195–204. https://doi.org/10.1111/0272-4332.202020.
Siegrist, M., Cvetkovich, G., Roth, C., 2000. Salient value similarity, social trust, and risk/benefit perception. Risk Anal. 20, 353–362. https://doi.org/10.1111/0272-4332.203034.

Sovacool, B.K., 2021. Reckless or righteous? Reviewing the sociotechnical benefits and risks of climate change geoengineering. Energy Strategy Rev. 35, 100656. https://doi.org/10.1016/j.esr.2021.100656.

Sweet, S.K., Schuldt, J.P., Lehmann, J., Bossio, D.A., Woolf, D., 2021. Perceptions of naturalness predict US public support for Soil Carbon Storage as a climate solution. Climatic Change 166, 22. https://doi.org/10.1007/s10584-021-03121-0.

Taylor, B., Vella, K., Maclean, K., Newlands, M., Ritchie, B.W., Lockie, S., Baresi, U., Barber, M., Siehoyono Sie, L., Martin, M., Marshall, N., Koopman, D., 2019. Stakeholder, Traditional Owner, and Community Engagement Assessment: A Report provided to the Australian Government by the Reef Restoration and Adaptation Program. Reef Restoration and Adaptation Program, Australia.

Terwel, B.W., Harinck, F., Ellemers, N., Daamen, D.D.L., 2009. Competence-based and integrity-based trust as predictors of acceptance of carbon dioxide capture and storage (CCS). Risk Anal. 29, 1129–1140. https://doi.org/10.1111/j.1539-6924.2009.01256.x.

Thiault, L., Curnock, M.I., Gurney, G.G., Heron, S.F., Marshall, N.A., Bohensky, E., Nakamura, N., Pert, P.L., Claudet, J., 2021. Convergence of stakeholders' environmental threat perceptions following mass coral bleaching of the Great Barrier Reef. Conserv. Biol. 35, 598–609. https://doi.org/10.1111/cobi.13591.

Trialfhianty, T.I., Suadi, 2017. The role of the community in supporting coral reef restoration in Pemuteran, Bali, Indonesia. J. Coast Conserv. 21, 873–882. https://doi.org/10.1007/s11852-017-0553-1.

Twardek, W.M., Taylor, J.J., Rytwinski, T., Aitken, S.N., MacDonald, A.L., Van Bogaert, R., Cooke, S.J., 2023. The application of assisted migration as a climate change adaptation tactic: an evidence map and synthesis. Biol. Conserv. 280, 109932. https://doi.org/10.1016/j.biocon.2023.109932.

van Oosterzee, P., Liu, H., Preece, N.D., 2020. Cost benefits of forest restoration in a tropical grazing landscape: thiaki rainforest restoration project. Global Environ. Change 63, 102105. https://doi.org/10.1016/j.gloenvcha.2020.102105.

Vella, K., Baresi, U., Lockie, S., Taylor, B., 2021. Challenges and opportunities for assisted regional ecosystem adaptation: international experience and implications for adaptation research. PLoS One 16, e0257868. https://doi.org/10.1371/journal.pone.0257868.

Visschers, V.H.M., Siegrist, M., 2013. How a nuclear power plant accident influences acceptance of nuclear power: results of a longitudinal study before and after the fukushima disaster. Risk Anal. 33, 333–347. https://doi.org/10.1111/j.1539-6924.2012.01861.x.

Waters, Y.L., 2022. Establishing a baseline decision context for restoring the Great Barrier Reef - Implications for long-term management. Mar. Pol. 141, 105106. https://doi.org/10.1016/j.marpol.2022.105106.

Wolske, K.S., Raimi, K.T., Campbell-Arvai, V., Hart, P.S., 2019. Public support for carbon dioxide removal strategies: the role of tampering with nature perceptions. Climatic Change 152, 345–361. https://doi.org/10.1007/s10584-019-02375-z.

Yang, Z.J., Kahlor, L., Li, H., 2014. A United States-China comparison of risk information–seeking intentions. Commun. Res. 41, 935–960. https://doi.org/10.1177/0093650213479795.