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RESEARCH ARTICLE

Immersive citizen science experiences and their role in changing perceptions of coastal wetlands

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Abstract

1. Citizen, or community, science initiatives are increasingly recognised as an effective strategy to connect society with nature, science and environmental issues. However, different approaches to the delivery of the programmes can have different impacts on participant awareness, perceptions and behaviour change—especially when working with ecosystems perceived as less popular or uncharismatic, such as coastal wetlands, mangroves and saltmarshes.
2. Using the HSBC Blue Carbon Citizen Science Programme as a case study, we compared two groups of corporate employees from Australia and New Zealand ($N=89$) who participated in either: (a) a short duration citizen science experience including educational workshops and fieldwork in a local wetland; or (b) in educational workshops-only. Questionnaires assessed the impact on participants' knowledge and perception towards wetlands, as well as their likelihood of adopting sustainable behaviours.
3. Results revealed that participants' knowledge and understanding of environmental concepts increased, independent of the type of experience attended. However, the citizen science experience was more effective at fostering participants' intentions to make behaviour changes, with 64% of citizen science participants implementing sustainable changes at home or work, compared to 45% of workshop-only participants.
4. Our results highlight the importance of immersive citizen science experiences that, even of short duration, can have a valuable role enhancing participant knowledge, perception, and importantly, intention to make long-term behaviour changes.
5. With the increasing challenges faced by coastal systems globally, incorporating hands-on, immersive experiences into educational programmes can be a strategic solution to improve ocean and climate literacy, while facilitating the actions required for a sustainable future.

KEYWORDS
behaviour change, citizen science, environmental stewardship, marine social sciences, natural capital, public perceptions, tidal marshes

1 | INTRODUCTION

Globally, coastlines are experiencing large-scale and unprecedented rates of change and degradation due to increasing anthropogenic pressures (e.g. changes in land and water use and coastal development), coupled with an increasingly complex mix of users and a correspondingly complicated governance landscape. These pressures have already resulted in a 50% loss of global wetlands, with degradation rates increasing progressively over the last centuries (Davidson, 2014). Efforts to address these global challenges are increasingly turning to the social science community to improve our understanding of how society interacts with and perceives different environmental systems. Recent years have witnessed a growing recognition of the importance of understanding public perceptions, and the value this can have in developing effective management strategies, supporting and delivering on policy and decision-making, and in engendering a stronger connection to nature resulting in increased pro-environmental behaviours (Bennett et al., 2017; Dean et al., 2016; Jefferson et al., 2015, 2021).

Coastal wetlands (including saltmarshes, seagrass beds and mangroves) provide a diverse and vital set of ecosystem services and benefits, including fisheries enhancement, climate change mitigation, coastal resilience, habitat provisioning and nutrient cycling, as well as supporting recreational and cultural activities that enhance society's health and well-being (McKinley et al., 2018). Despite all these services, there is increasing dialogue around the disbenefits that individuals might experience or perceive to be associated with these ecosystems (Rendón et al., 2019). As a result, amidst global efforts to restore and expand wetlands to address multiple environmental challenges (e.g. increasing carbon sequestration, enhancing ecosystem function and biodiversity, mitigating climate change), it is important to recognise such proposals may be met with concern and trepidation (Rendón et al., 2019). In some regions, such as New Zealand, there has been a historical opposition from local communities to the natural expansion of mangrove habitats due to the perception that coastal vegetation limits people's access to waterways and increases the accumulation of sediments (Lundquist et al., 2014). In response, since 2013, Auckland Council has allowed mangrove clearings (back to the extent that existed in 1996) to reinstate the navigation, access and amenity values (Auckland Council, 2013). This highlights the complexity and heterogeneity that is inherent within societal relationships with coastal wetlands. Perceptions and values can vary across space and time, are context-specific, and crucially, we require comprehensive understanding of how these might change and what this may mean for engagement in coastal issues, such as coastal habitat restoration programmes (Foley et al., 2020; McKinley, Pages, et al., 2020; Roberts et al., 2020).

Defined as 'the practice of engaging the public in a scientific project…that produces reliable data and information usable by scientists, decision makers or the public and that is open to the same system of peer review that applies to conventional science' (McKinley et al., 2017, p. 16), the concept of citizen or community science is not new (Bonney et al., 2014; McKinley et al., 2017). However, as global efforts to address the challenge of climate change and sustainability continue, the role of citizen science programmes as a mechanism of engaging a range of societal audiences and understanding public attitudes and values, towards environmental issues continues to grow (Agnew et al., 2022; Cigliano et al., 2015; Dickinson et al., 2012). While not a 'catch all' solution, citizen science has been found to be a valuable tool, achieving numerous objectives: (1) contributing to scientific knowledge; (2) enhancing participants awareness, concern and knowledge about natural systems; (3) positioning society as part of the solution to global environmental challenges, with the ultimate goal of engendering a greater sense of environmental stewardship towards nature; and (4) actively supporting conservation of the global environment (Cigliano et al., 2015; McKinley et al., 2017; Toomey & Domroese, 2013; Turrini et al., 2018; Vann-Sander et al., 2016). By providing a number of mechanisms for individuals from any part of society to be involved in scientific discovery, ranging from involvement in short- and long-term nature-based citizen science experiences to independent submissions of data through Apps and social media sites, citizen science programmes can provide a bridge between science and society by bringing research to life (Edwards et al., 2021; Turrini et al., 2018). In the context of marine and coastal environments, the number of citizen science programmes continues to grow (Garcia-Soto et al., 2021; Kelly et al., 2020), although projects frequently focus on charismatic species (e.g. Project Seahorse, Project Manta, TurtleWatch) or the health of popular ecosystems such as coral reefs (e.g. CoralWatch, ReefCheck). Fewer programmes concentrate on ecosystems perceived as being less charismatic or less valued—Project Seagrass and MangroveWatch being some of the exceptions (McKinley et al., 2017). Despite this imbalance, their potential to have positive influence on levels of public awareness, and concern of marine and coastal ecosystems is increasingly acknowledged (Agnew et al., 2022; Branchini et al., 2015; Dean et al., 2018).

While some benefits of participating in citizen science programmes are considered to be well evidenced (e.g. an increase in knowledge and opportunity to develop new skills) (Bela et al., 2016; Braun & Dierkes, 2019; Santori et al., 2021), others are less well understood. This is in part due to the range of citizen science formats and structures that are available (i.e. passive citizen science through digital platforms, immersive nature-based expeditions to co-development driven citizen science) (Edwards et al., 2021)—and the challenges of developing an effective citizen science programme and series of activities cannot be underestimated (Marshall et al., 2012). In all instances, these include the need to ensure the production of high-quality data (precise and accurate) and the use of simple data collection protocols that can be replicated by participants with a range of backgrounds, level of education and interests. Complexity arises with the voluntary nature of citizen science as people's motivation and dedication to collecting high quality data and engaging in science fluctuates (McAteer et al., 2021). Moreover, it is important to recognise that people are inherently selective and will only volunteer their time for something they have an interest in; as such, levels of participation in citizen science programmes relating to charismatic or endangered species tend to be considerably higher than those less popular (such as wetlands; McKinley et al., 2017). Time or perceived time a participant has, is also a factor which influences participation (West & Pateman, 2016). With a willingness to devote extended periods of time to a volunteer programme potentially waning, new ways to effectively engage communities has led to the development of new forms of citizen science programmes, including short duration programmes.

Further, as efforts to address global ocean issues continue, it is increasingly necessary to consider how citizen science programmes can contribute to environmental behaviour change, and the parallel concepts of literacy and citizenship, and whether brief encounters of science and nature really can evoke change. While these concepts are known to be driven, at least in part, by an individual's knowledge, recent numerous studies have recognised the limitations of this knowledge-deficit model for behaviour change, highlighting the importance of other factors, including acknowledging diverse types of knowledge and better understanding of awareness, perceptions, emotional connection to an environment and the capacity to enact behavioural changes (Kaiser & Fuhrer, 2003; Kollmuss & Agyeman, 2002; McKinley & Burdon, 2020; Siegel et al., 2018; Stoll-Kleemann, 2019). The successful translation of the skills, knowledge and experiences garnered through citizen science into enhanced levels of environmental literacy, pro-environmental behaviours, and indeed, environmental citizenship, are beginning to be identified (Bela et al., 2016; Day et al., 2022; Santori et al., 2021). Nevertheless, studies accurately assessing the impact of citizen science on direct behaviour change and conservation action remain limited (Haywood et al., 2016), with most evaluations unable to capture longitudinal data or lacking clear ways of assessing behaviour change and impact (Somerwill & Wehn, 2022). Additionally, there is little data on which characteristics of a citizen science programme are responsible for creating this change, for example, whether it be immersion in nature, learning, social inclusion or a combination (Day et al., 2022). The facets of behaviour change are explored through this study, with explicit consideration of the themes of Knowledge, Perception and Behavioural Intentions. Moreover, there is limited knowledge to date on how perception is influenced by socio-demographic characteristics (Jefferson et al., 2015); a factor which may be crucial to effective design of citizen science programmes that elicit action and enhance stewardship. Recognising the heterogeneity of community groups, this study explores the influence of a range of socio-demographic characteristics on participants' overall experience of the programme ad their intended behaviour change.

As calls for enhanced societal engagement, stewardship and literacy towards the global ocean and coasts continue, citizen science offers a gateway to immersive experiences and delivery of behaviour change with these aspects garnering increased attention (Dean et al., 2018; Groulx et al., 2017). Furthermore, as the potential value of effective and well-designed citizen science programmes in achieving international environmental goals, such as the UN Sustainable Development Goals (Fraisl et al., 2020), there is an opportunity to engage more and indeed different audiences in these programmes, to reflect on what citizen science looks like, and to explore the effectiveness and impact of these programmes. Using a 2-year HSBC Blue Carbon Citizen Science Programme, a collaborative initiative between HSBC, Earthwatch Institute Australia (hereafter Earthwatch), Deakin University (hereafter Deakin) and Cardiff University, as a case study, this paper contributes to this gap. Although the paper draws on a relatively small participant group ($n = 89$), it nevertheless provides valuable insights into the impact of a short duration, immersive citizen science experience on knowledge and understanding, and perceptions of climate change, ecosystem services and of the challenges facing wetlands. In addition, the study explores the effect of an immersive citizen science experience on desire to act and long-term behaviour change, and compares this with a classroom-based learning experience.

2 | METHODS

2.1 | HSBC Blue Carbon Citizen Science Programme

This research was undertaken as part of a 2-year HSBC Blue Carbon Citizen Science Programme aimed to empower Australian industries to build a sustainable future, by transforming corporate employees into citizen scientists who advocate the value of natural ecosystems, while contributing to coastal wetland research. Specifically, this programme was designed to: (i) collect data for blue carbon research, (ii) increase participants' knowledge and awareness of coastal wetlands and related environmental issues and (iii) foster environmental citizenship and encourage behaviour change.

The programme ran in Australia (Sydney and Melbourne) and New Zealand (Auckland) between June 2018 and March 2020. Each 'Citizen Science Day' included a new group of 8–30 staff members from HSBC or partner organisations representing sectors including (but not limited to) aviation, finance, travel, oil and gas, ports and professional services. Participant recruitment was based on a self-selection process, with invitations to participate disseminated through the internal communication outlets of each company (e.g. internal newsletter and website). To allow for comparisons between immersive citizen science experiences and classroom-based learning, the programme was available in two different formats; a full-day citizen science format, including an introductory workshop session and a fieldwork experience (hereafter referred to as Citizen Science), and a half-day workshop (hereafter referred to as Workshop-Only) with participants self-selecting engagement with the programme.

2.1.1 | Citizen science experience

This experience began at the HSBC offices where participants received three educational talks from HSBC, Earthwatch and Deakin University (described in detail below). The talks were followed by a 30- to 60-min journey to a local wetland (see SM1 for details on the field sites), where citizen scientists had lunch and participated in citizen science activities. Here, Deakin University scientists explained the research project and demonstrated the field protocols which varied between sites depending on the research project and the characteristics of the wetland. Participants worked in teams to undertake citizen science activities such as surveying and measuring coastal vegetation (i.e. mangroves, saltmarsh and swamp oaks), collecting soil cores and microbe samples, and deploying tea bags (see SM1 Table 1 in Data S1 for details on data collection). At the end of the day, participants took part in a final de-brief which included a discussion about the information learnt during the day and a conversation of sustainable behaviours that can be adopted to reduce adverse effects to local ecosystems and nature (e.g. reduce meat consumption, buy local produce). A total of 296 participants were engaged in the full-day format of the programme.

2.1.2 | Workshop-only experience

The workshop-only experience delivered only the educational talks and ran for half a day. The first talk, from Earthwatch, defined natural capital, ecosystem services and climate change and provided case studies outlining the risks of climate change on natural capital and the benefits of considering natural capital into business practices. The second talk, delivered by HSBC, highlighted the ability of Australia's financial sector to steer towards a sustainable economy and explained HSBC's green finance commitments. The last talk, delivered by Deakin University, introduced coastal ecosystems and the concept of blue carbon, and provided an overview of typical fieldwork in coastal wetlands. Participants were encouraged to calculate their own carbon footprint (using WWF's Carbon Footprint Calculator) and discussed a range of sustainable behaviours they could adopt. The discussion was led by Earthwatch, who provided information on sustainable choices and actions to reduce individual impact on natural ecosystems. A total of 37 participants were engaged in the workshop-only experience.

2.2 | Questionnaire design and development

The impact of the citizen science experience on participants' knowledge, perception and understanding of coastal wetlands and the intention to change behaviours and adopt sustainable practices was examined using three sequential online questionnaires. The first questionnaire was distributed to participants before they participated in each experience, developing a baseline understanding of participant knowledge, perception and understanding of wetlands, their ecosystem services and other related topics. It also collected information on participants´ demographics including gender, age group, education level and cultural background. Participants completed a second questionnaire immediately following their participation in each experience, which sought to determine any immediate changes in knowledge, perception and understanding towards wetlands and any intended behaviour changes. Finally, to evaluate retention of changes in knowledge, perception and understanding, and to identify whether behaviour change had taken place, a third questionnaire was distributed to participants between 6 and 8 weeks after participation. The knowledge and perception statements did not change across the questionnaires. However, the behavioural intention statements were only present in the second and third questionnaires and varied slightly between the questionnaires. The structure of each questionnaire is summarised in Table 1, and the list of statements is outlined in Table 2. The research was carried out according to Deakin University's Human Ethics permit: STEC-16-2018—informed consent was obtained from participants prior to each questionnaire with information about the research process, and ethical considerations relating to participants' involvement in the study outlined (e.g. data storage, anonymity, voluntary participation). Only questionnaires where participants had completed this section and confirmed their consent to participate were included in the final sample.

2.3 | Quantitative data analysis

To allow comparison between the experiences, participant responses were grouped according to whether they participated in the workshop-only or in the citizen science day. To aid with analysis, the 65 questions/statements included in each questionnaire were grouped into categories linked to knowledge and understanding, perception and behavioural intentions (Table 2). Each category of statements was designed to investigate if the programme: (1) increased participants' knowledge and understanding of wetlands, natural capital and blue carbon ecosystems, (2) changed participants' perception of the benefits of wetlands in supporting livelihoods and well-being, and the importance of addressing environmental issues such as climate change and pollution and (3) influenced participants' intention to make behavioural changes to contribute to combating some of the environmental issues society is currently facing. Only responses from participants who had completed all three questionnaires were included in the analyses, representing 28% of the total participants ($n=89$, Table 3). Considering the large number of statements used in the questionnaires, the numerous demographic factors that could influence participant's responses (e.g. age and education level), the variation in sample size across formats and demographic

TABLE 1 Summary of the main sections and themes included in each questionnaire.

	Questionnaire 1 'Before'	Questionnaire 2 'After'	Questionnaire 3 'Retention'
Section 1	*Your Experience of Wetlands*: Mix of open and closed questions covering participants' experience of wetlands. These included whether participants had knowingly visited a wetland; if yes, where these sites were located and also an open question asking the first three words that come to mind when respondents think of wetlands	*Visit to Wetlands and Citizen Science*: Series of both open and closed questions exploring participants' experience, the activities they had undertaken, what they had enjoyed and what they learned from taking part. This section also asked questions about the impact participating in the session had on respondents' intention to adopt behaviour changes	*Visit to Wetlands and Citizen Science*: The majority of questions in this section were a repeat from Questionnaire 2, with some additional questions regarding whether respondents had changed behaviour as a result of participating in the Citizen Science Day. Through repetition of the section, retained behaviour change and changes in understanding could be examined
Section 2	*Your knowledge of Wetlands*: Series of closed, tick box style questions covering topics relating to participant's knowledge of wetlands and their ecosystem services	*Your knowledge of Wetlands*: As in Questionnaire 2, this section included a series of closed, tick box style questions covering topics relating to knowledge of wetlands and their ecosystem services	*Your knowledge of Wetlands*: This section repeated the questions from Questionnaires 1 and 2. As above, repetition of this section sought to examine retention of any change following participation in the programme
Section 3	*The Wider Environment*: This section sought to understand respondents' views on other environmental issues, in particular, climate change. It included a mix of questions, including a series of closed, tick box style questions, as well as an open question asking for views on climate change	*The Wider Environment*: As in Questionnaire 1, this questionnaire sought to understand respondents' views on wider environmental issues, and in particular, whether involvement in the programme had impacted their views	*The Wider Environment*: Again, the questions in this section were a repeat from Questionnaire 1 and 2 to assess retention of behaviour change and/or awareness raising
Section 4	*About you*: Socio-demographic questions including information on respondent age, gender, employment, education and cultural background	Not included in Questionnaires 2 and 3 as data could be linked through respondents unique ID code	

groups and the range of statements used across questionnaires, several analytical approaches have been utilised to understand the data (summarised in Figure 1 below). The methods include ordination and ANOVA-like statistics testing multiple scales of potential change (i.e. differences) across time, activity and demographic groups. These scales include general broad patterns of the averaged responses, group-based (i.e. combined) responses using matrices and question-based tests that enable tracking individual's response change with time, here after referred to as *Response Average Analyses*, *Response matrix analyses* and *Single Response Analyses*. Each of these is outlined in detail in Supplementary Material 1.

2.4 | Qualitative data analysis

Data collected through the open questions were analysed using standard qualitative data analysis techniques (Braun & Clarke, 2006). Responses were collated and reviewed following an emergent coding protocol to highlight dominant thematic codes (e.g. 'Important to conserve and protect'). To allow for comparisons between the questionnaires, Questionnaire 1 was reviewed and coded first, the only member of the authorship team with social science research training, with the emergent codes then used as a framework for coding Questionnaires 2 and 3. Where new thematic codes emerged from the data during the review of Questionnaires 2 and 3, these were added to the coding framework. A content analysis approach was then applied to better understand the frequency of key themes within the data. These questions provided additional insight into how participants' views and attitudes towards coastal wetland environments, as well as the issue of climate change, evolved during their involvement with the programme. Where appropriate, quotes collected through these questionnaires are presented in italics to support the discussion. Due to the disciplinary expertise of the authors, the analysis was carried out solely by the lead author through multiple iterations of thematic coding—this also meant that no inter-reliability could be assessed. While we recognise this as a limitation of the analytical approach, this was a direct function of the composition of the research team.

3 | RESULTS

Our results are grouped into three sections aligning with the three aims of the paper. The first section outlines the analysis highlighting the impact on participant knowledge and understanding of coastal wetlands and natural capital concepts. The second section focuses on the results explaining the impact on participant perceptions. Both these sections include results from the *Response Average*, *Response matrix* and *Single Response Analyses*. The last section outlines the potential impact of the HSBC Blue Carbon Citizen Science Programme

TABLE 2 Question list used to determine changes in knowledge, perception and understanding towards wetlands, and any intended behaviour changes.

Category	Question/potential response	Statement/term/benefit
Knowledge and Understanding	How much you agree (Strongly agree, Agree, Neither agree nor disagree, Disagree, Strongly disagree and Unsure) with the following statement	Wetlands are important for food production Land reclamation can have a positive impact on coastal marshes Wetland environments will experience no negative impacts as a result of sea level rise Wetlands are important for carbon storage Wetland environments are important habitats for birds and other wildlife Climate change means there is a need to ensure wetlands are well managed Changing climates can be positive for coastal areas Wetlands are sufficiently protected and well managed Urban development is a positive process for coastal areas and has no impact on wetland environments Mangrove trees are a valuable resource Wetlands, such as mangroves and saltmarshes, can offset coastal erosion Wetlands are an undervalued environmental resource Wetland environments can improve water quality Wetlands are not valuable for recreation and tourism Saltmarshes are important for spiritual, sacred and religious values Wetland environments are not effective nurseries for fish species
	Please indicate your knowledge (Expert knowledge, Knowledgeable, Have some knowledge, Have heard of the term and Never heard of the term) of the following terms	Blue Carbon Ecosystem services Sustainable Development Natural capital Natural accounting Green bonds
Perceptions	Please indicate the importance of the following benefits that you think society might get from wetland environments (Very beneficial, Moderately beneficial, Somewhat beneficial, Slightly beneficial and No benefit)	Recreation (e.g. birdwatching) Tourism Coastal protection from flooding Habitats for biodiversity Reducing impacts of waste and pollution Health and Well-being Agricultural land Natural landscape Nursery habitats for fisheries Pollination Environmental Education Carbon Storage Prevention of coastal erosion Reducing climate change impacts Wild food and foraging
	Please indicate to what extent you feel (Essential, Important, Somewhat Important, Neutral, Not important, and Never heard of term) the following are important environmental issues that should be addressed	Recycling Renewable energy Coastal squeeze Carbon Footprint Land reclamation Coastal erosion Coastal water quality Habitat creation Sea Level Rise Climate change
	How concerned are you, if at all, (Very concerned, Fairly concerned, not very concerned, Not at all concerned, Do not know and Do not believe in climate change)?	About climate change (sometimes referred to as global warming)

TABLE 2 (Continued)

Category	Question/potential response	Statement/term/benefit
Behavioural Intentions	Following today's visit, how likely is it that you will undertake the following activities	Talk about wetlands to fellow colleagues, family and friends Reduce my dependence on fossil fuels and favour green energy (e.g. Solar panels and electric car) Reduce use of single use plastics (e.g. plastic bottles) Increase recycling at home Favour sustainable practices (e.g. Reduce meat consumption) Take part in local beach/coastal clean-up events Use more eco-friendly products (e.g. washing detergents) Use sustainable travel options (i.e. cycling/ public transport/car-pooling to work) Consider buying local produce to reduce carbon footprint of groceries Look for practices/procedures in my business unit that have a positive impact on natural ecosystems

TABLE 3 Summary of responses relating to enjoyment (Questionnaire 2 for both experiences).

Citizen science $N = 77$		
Theme	**% of mentions**	**Examples of themes**
Collaboration and taking part in the research	58%	'Actual participation on the site to get soil cores and other statistics of the mangrove trees'
Being in wetlands	21%	'Getting out in the wetlands to take samples and measurements'
Learning/Developing new knowledge	14%	'Learning through doing, understanding the why of the research, meeting researchers'
The whole day	9%	'Everything part of it, as I saw and learnt new things in each of them' 'Fun day overall, actual research work was quite challenging yet enjoyable'
Presentations	6%	'Learning about Blue Carbon in the briefing, and feeling that the measurements I was taking was useful to the research' 'The presentations were great because they made a lot of information easily digestible. Let's make mangroves sexy!'
Working with the scientists	5%	'Team work with the scientists and knowing I am doing something which is meaningful'
Being outdoors	5%	'Stomping through the dry grass that was as tall as me'
Meeting new people	3%	'Meeting people'

on behavioural change and only results from the *Response Average Analyses*.

In total, the programme had 333 participants across Sydney, Melbourne and Auckland. Out of these, 89 participants completed all three questionnaires with 11 of them attending the workshop-only and the remaining 78 attending the citizen science day. These 89 participants were used as the comparative groups, with their profiles summarised in Figure 2. Of this group, 3% had never visited a wetland, while 21% had visited once, 48% 2–3 times and 28% had visited a wetland more than three times. Unfortunately, from the 78 participants of the citizen science day, only 45 specified their location (including 32 from Sydney, 4 from Melbourne and 9 from Auckland). These sample sizes challenge our ability to explore response variability relating to the three cities, thus location is not used as a factor in any of the analyses. However, we hope that some of this variance is captured by the differences due to the participant's cultural background, which is explored within the demographic factors (Figure 2).

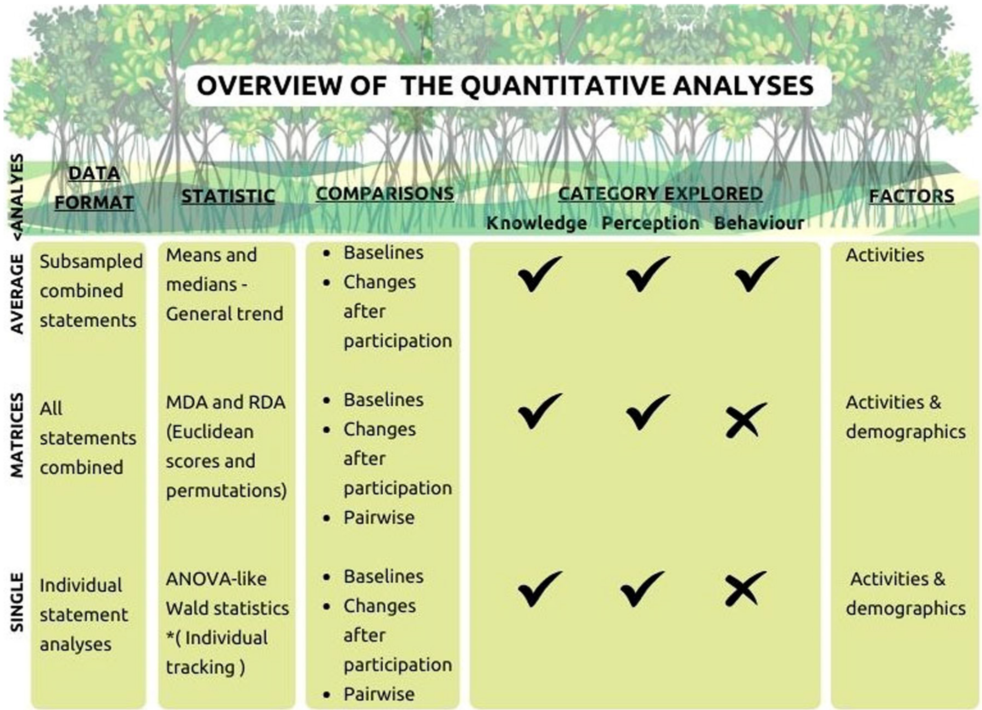

FIGURE 1 Analytical approaches used and their respective statistics, how the data were treated (whether it was combined, or each participant response was tracked individually), what statement category was explored, what comparisons were made and what factors were assessed in such comparisons.

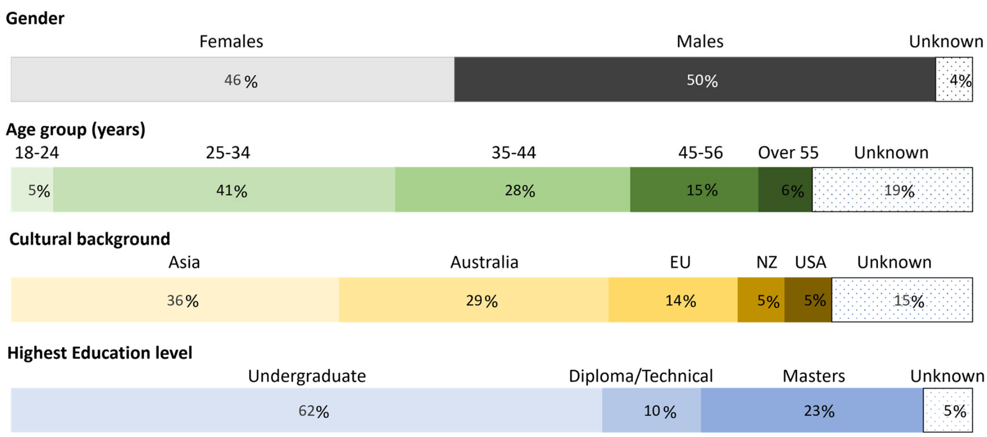

FIGURE 2 Profile of the 78 participants who attended the full day citizen science day. Responses from these participants were used in the statistical analyses.

3.1 | Impact on participant knowledge of coastal wetlands and natural capital concepts

There was variability in the baseline knowledge and understanding of the importance of wetlands and natural capital concepts between participants who attended the workshops-only and citizen science experience. MDA analyses showed greater dispersion of the knowledge matrix for workshop participants than for citizen science participants before attending the programme (Figure 3). Additionally, the centroids for the two baselines matrices were further apart than the centroids of the knowledge matrices after participation in the programme (Figure 3), but the variation in the baseline knowledge between Workshops-only or citizen science activities were not significant (pairwise comparison $p = 0.0655$, SM2 Table 3 in Data S1). No demographic characteristic influenced the dispersion of the baseline knowledge across participants (pairwise comparison $p > 0.05$, SM2 Table 3 in Data S1).

Despite the dispersion observed in the participant's baseline knowledge and understanding of the importance of wetlands, a general increase in knowledge after participating in the programme was detected by all analytical approaches. MDA showed a significant shift, more specifically a decrease, in the dispersion of knowledge matrices across time (Figure 3, ANOVA $p < 0.0001$—SM2 Table 2 in Data S1). The percentage of participants that recognised the importance of wetlands increased from an average of 70%–82% after participating in the citizen science activities, and from 65% to 83% after the workshops-only (Figure 4). Furthermore, the percentage of participants with a higher understanding of natural capital concepts increased from an average of 11%–39% after participating in the citizen science activities, and from 8% to 31% after the workshops-only. Thus, the knowledge gain of natural capital concepts was slightly higher than the knowledge gain of the importance of wetlands.

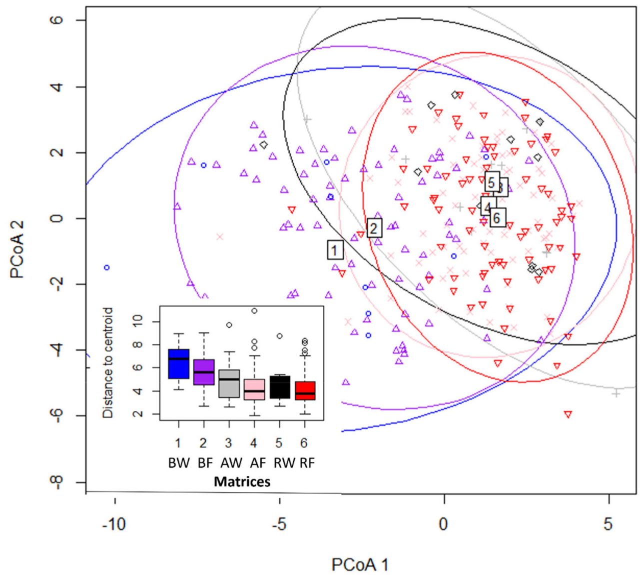

FIGURE 3 MDA results showing the first two principle correspondence axes explaining 41.5% of the response variance in knowledge before the Workshop-Only (matrix 1—blue circles), before the citizen science activity (matrix 2—purple triangles) (i.e. baselines), after the Workshop-Only (matrix 3—grey crosses), after the citizen science activity (matrix 4—pink exes), 2 months after the Workshop-Only (matrix 5—black diamonds) and 2 months after the citizen science activity (matrix 6—red inverse triangles).

RDA captured a significant knowledge increase in participant responses in relation to the value of wetlands for food production, carbon storage, coastal erosion, water quality, spiritual value, as well as the lack of sufficient protection, appropriate management of these ecosystems, as well as sustainable development, green bonds and natural capital and accounting (where RDA scores where >0.5 for each statement, Figure 5 and SM2 Table 6 in Data S1). Single response analyses also detected significant increases in knowledge and understanding of the value of wetlands for food production, coastal erosion, water quality, spiritual value, sustainable development, green bonds and natural capital and accounting as RDA. Furthermore, analysis highlighted an increase in knowledge and understanding of ecosystem services and natural capital concepts, the value and importance of wetlands as habitat for wildlife and the need to ensure they are well managed ($p < 0.0024$, SM3 Table 1 in Data S1).

However, there were no significant differences detected in participants' knowledge across the activities (i.e. citizen science vs. workshop-only) based on the response matrix approach. The RDA best model ($p = 0.001$) included the time since the intervention as a sole factor explaining 10% of the dispersion of knowledge across questionnaires (SM2 Table 4 in Data S1). The lack of centroid separation in addition to the overlap of the ellipses in the MDA analyses after participating in either of the activities (Figure 3) support the RDA results. Single response analysis did not find either any effect of activity in the change of knowledge observed (i.e. Activity*Time, SM3 Table 1 in Data S1).

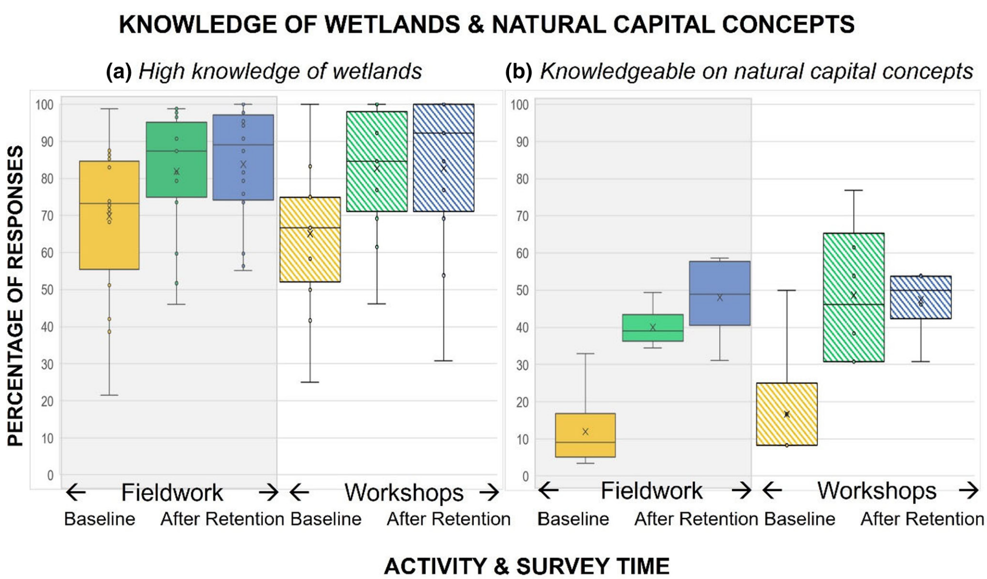

FIGURE 4 Changes in the responses of participants that (a) recognise the importance and role of wetlands and (b) consider themselves knowledgeable on natural capital topics, before and after participating in the citizen science (grey-shaded background) or Workshop-Only experiences. Percentages were calculated as the combination of the 21 statements relating to knowledge. Error bars are indicative of standard deviations across statements.

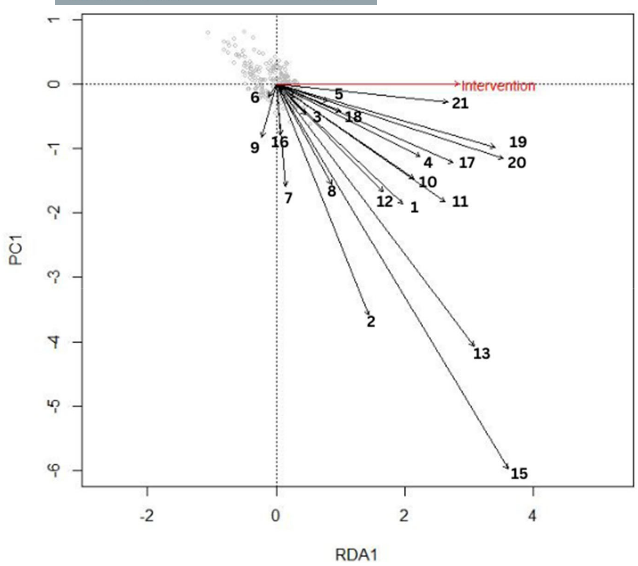

FIGURE 5 RDA analysis showing the knowledge scores (grey circles) across the sole RDA axes and the first principal component axes. Where the degree of change with time of intervention (Questionnaire distribution in relation to the programme) is shown by the red arrow, and the black arrows highlight the knowledge statements that influenced the most the change in participant response across time. Longer arrows are indicative of statements with greater importance thus greater change in time. The numbers for each arrow relate to the knowledge statements as follows: (1) Wetlands are important for food production, (2) Land reclamation can have a positive impact on coastal marshes, (3) Wetland environments will experience no negative impacts as a result of sea level rise, (4) Wetlands are important for carbon storage, (5) Wetland environments are important habitats for birds and other wildlife, (6) Climate change means there is a need to ensure wetlands are well managed, (7) Changing climates can be positive for coastal areas, (8) Wetlands are sufficiently protected and well managed, (9) Urban development is a positive process for coastal areas and has no impact on wetland environments, (10) Mangrove trees are a valuable resource, (11) Wetlands, such as mangroves and saltmarshes, can offset coastal erosion, (12) Wetlands are an undervalued environmental resource, (13) Wetland environments can improve water quality, (14) Wetlands are not valuable for recreation and tourism, (15) Saltmarshes are important for spiritual, sacred and religious values, (16) Wetland environments are not effective nurseries for fish species, (17) Level of knowledge on ecosystem services, (18) Level of knowledge on sustainable development, (19) Level of knowledge on natural capital, (20) Level of knowledge on natural accounting and (21) Level of knowledge on green bonds. The RDA axis explains 10% of the change in participant knowledge before, after and 3 months after participating in the programme.

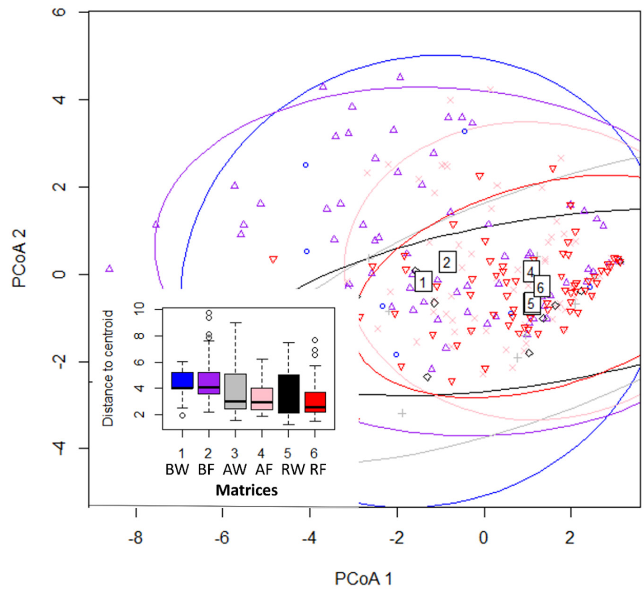

FIGURE 6 MDA results showing the first two principle correspondence axes explaining 57.5% of the response variance in perception before the Workshop-Only (matrix 1—blue circles), before the citizen science activity (matrix 2—purple triangles) (i.e. baselines), after the Workshop-Only (matrix 3—grey crosses), after the citizen science activity (matrix 4—pink exes), 3 months after the Workshop-Only (matrix 5—black diamonds) and 3 months after the citizen science activity (matrix 6—red inverse triangles).

Interestingly, according to matrices analyses, the only demographic characteristic with some influence in driving differences in responses after attending the citizen science activities was cultural background, with knowledge dispersion (i.e. centroid placement and distance to the other matrices SM4 Figure 1b in Data S1) being significant between participants with European background and all other cultural backgrounds expect Asia (pairwise comparison $p < 0.04$, SM2 Table 3 in Data S1). While single response analyses tracking individuals, detected an effect of cultural background with differences between the knowledge of the impact of wetlands on coastal areas between participants from New Zealand versus North America, the current level of protection and management of these environments between participants over 55 years and younger participants, and sustainable development between participants in age groups 35– 44 and 45–54 years (i.e. pair*time interaction $p < 0.0024$, SM3 Table 3 in Data S1).

3.2 | Impact on participant perceptions of the benefits of wetlands and the importance of addressing environmental issues

There was variability in the baseline perception of the benefits wetlands provide and the importance of addressing environmental issues among participants who attended the activities, with those partaking in citizen science activities showing a greater variation in perceptions than those attending only the workshops (i.e. MDA dispersion, Figure 6). Yet these differences were not significant (pairwise comparison p 0.6171, SM3 Table 3 in Data S1), and demographics did not influence the dispersion of the baseline knowledge across participants (pairwise comparison $p > 0.05$, SM2 Table 3 in Data S1).

Positive changes in people's overall perception towards wetlands and their ecosystem services were detected after participation in the programme. Overall, the increase in perception of the benefits of wetlands was greater than the increase in perceiving a higher importance for addressing environmental issues. Citizen science participants recorded a mean 23% increase from 46% to 69% identifying wetlands high benefits after participating in the activities, while workshop-only participants recorded a mean 28% increase from 38% to 64%, as well as a mean 15% increase from 55% to 70% identifying a greater degree in the importance of addressing environmental issues after part-taking in the citizen science activities, and from 61% to 76% for workshop-only participants (Figure 7). Furthermore, MDA showed a significant shift, more specifically a decrease, in the dispersion of knowledge matrices across time (Figure 7). Dispersion in the perception of participants that attended the citizen science activities narrowed significantly, while such trend was not significant for those that attended the workshops-only (Figure 7, $p = 0.0001$ between the baseline and after participation in citizen science activities, as well as baseline and retention, SM2 Table 3 in Data S1). RDA captured a significant general change in perception for participants attending the programme (Figure 8), particularly with regard to the benefits wetlands provide for reducing pollution, supporting pollination, carbon storage, reducing the impacts of climate change and addressing coastal squeeze (i.e. RDA scores where >0.5 for these statements, SM2 Table 6 in Data S1). Single response analyses also detected significant increases in the perception of the importance of wetlands and need to address environmental issues, with significant differences tracked with time at the individual level the following benefits: reducing impact of waste and pollution, nursing habitats for fisheries, pollination, environmental education, carbon storage, prevention of coastal erosion and reducing climate change impacts, as well as the following environmental issues: coastal squeeze, carbon footprint and land reclamation ($p < 0.0019$, SM3 Table 1 in Data S1).

However, there were no significant differences detected in participants' perception across the activities (i.e. citizen science vs. workshop-only). The general trends with time were similar for those who participated in the workshops only or joined the citizen science activities, where in both cases, high dispersion was consolidated and streamlined after participation in the programme (Average Response and MDA concurred in such pattern, Figures 6–9). The RDA best model ($p = 0.001$) included the time since the intervention, gender and activity and explained 8.7% of the change of perception across questionnaires (SM2 Table 4 in Data S1). Single response analyses detected the influence of activity only concerning individual's change in their concern about climate change after participating in the programme (Activity*Time, $p = 0.0004$, SM3 Table 1 in Data S1). While individuals attending the citizen science activities disclosed an increase in their concern level about climate change, the Workshop-only appear to have the opposite effect with participants disclosing a decreasing concern (Figure 9, SM3 Table 4 in Data S1).

Further analysis indicated that some differences in the retention of perception change after participating in citizen science activities could be related to gender as suggested by the RDA best model, and also detected some variation in relation to cultural background more specifically between the retention of the perceptions acquire after participating in the programme between Australians and Asians, and the change in perception of people over 55 years and younger participants (MDA pairwise $p < 0.05$, SM2 Table 3 in Data S1). Single response analyses tracking individuals, some differences in perception change according to: (1) gender in relation to the perception of benefits wetlands provide through biodiversity, natural landscape, environmental education and addressing poor water quality; (2) age in relation to addressing carbon footprint and coastal water quality, as well as on

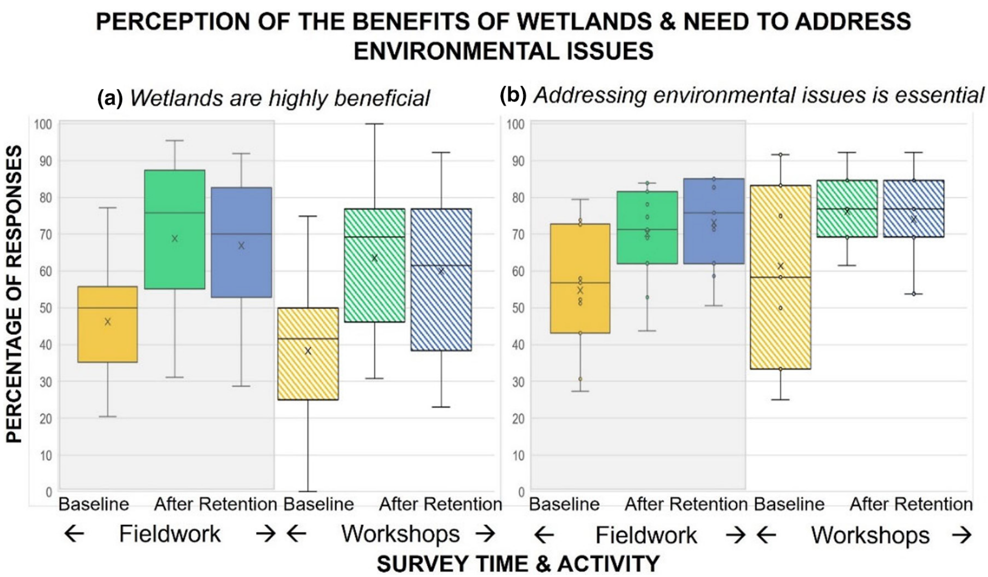

FIGURE 7 Changes in responses of participants that (a) acknowledge that wetlands are highly beneficial and (b) believe that addressing environmental issues is essential, before and after participating in the citizen science (grey-shaded background) and Workshop-Only experiences. Percentages were calculated as the combination of the 26 statements relating to perceptions. Error bars are indicative of standard deviations across statements.

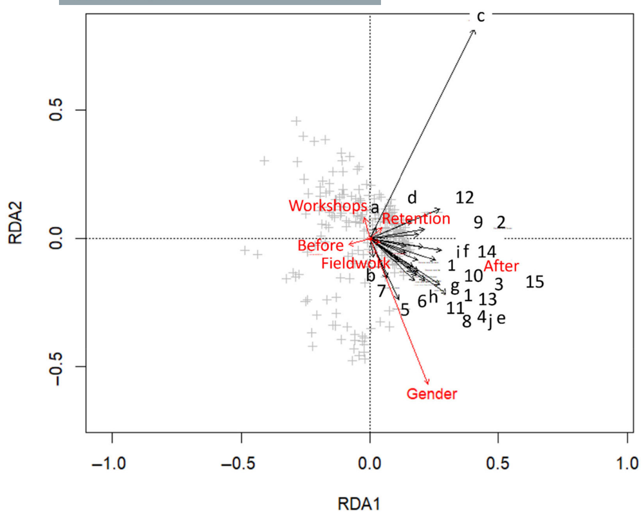

FIGURE 8 RDA analysis showing the perception scores (grey crosses) across the first two RDA. Where the degree of change with time of intervention (Questionnaire distribution in relation to the programme), the activity attended, gender are shown by the red arrows and the black arrows highlight the perception statements that influenced the change in participant response across time. Longer arrows are indicative of statements with greater importance thus greater change in time. The numbers for each arrow relate to the importance of the following benefits wetlands provide: (1) Recreation (e.g. birdwatching), (2)Tourism, (3) Coastal protection from flooding, (4) Habitats for biodiversity, (5) Reducing impacts of waste and pollution, (6) Health and Well-being, (7) Agricultural land, (8) Natural landscape, (9) Nursery habitats for fisheries, (10) Pollination, (11) Environmental Education, (12) Carbon Storage, (13) Prevention of coastal erosion, (14) Reducing climate change impacts and (15) Wild food and foraging. And the letters refer to the importance of addressing the following environmental issues: (a) Recycling (b) Renewable energy, (c) Coastal squeeze, (d) Carbon Footprint, (e) Land reclamation, (f) Coastal erosion, (g) Coastal water quality, (h) Habitat creation, (i) Sea Level Rise and (j) Climate change.

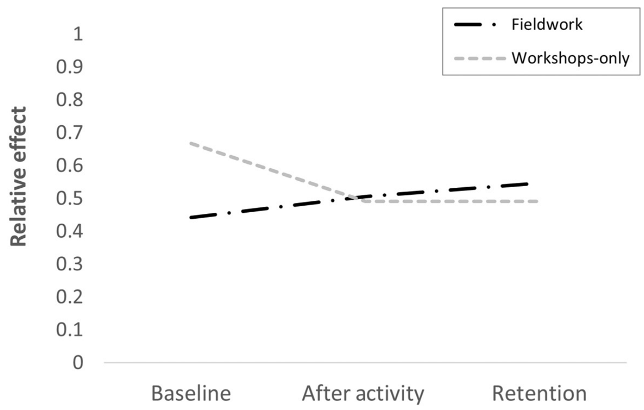

FIGURE 9 Relative effects for the participants' level of concern about climate change showed significant differences in the trend across activities, citizen science activities versus workshop-only.

participants view on the importance of climate change; and (3) cultural background in relation to the benefits wetlands provide on agriculture and natural landscape, as well as on participants view on the importance of climate change and their level of concern relating to climate change (i.e. pair*time interaction $p = < 0.0019$). More specifically, the male baseline appeared to be lower than that of females, there was considerable variability in the baseline perception according to cultural background and younger adults seem believe that addressing environmental issues is of high priority even prior to attending the programme (Figure 10). Citizen science activities were found to have a higher relative effect in females than that seen in males, variable effect based on cultural background with theme specific patterns and greater impact on people over 25 years old (i.e. higher increase in relative effect of the programme in their perception; Figure 10).

Further insight into perceptions (and to some degree, knowledge) was gathered through a series of open questions asking respondents to list the top three words that come to mind when they first thought of wetlands. Analysis of open questions from all programme participants across all three questionnaires revealed a clear change in tone of responses before and after participants had joined the citizen science activities, with an increase of responses reflecting the key role wetlands play in nature and to support human livelihoods (including their value to provide natural solutions to mitigate climate change) and the benefits these environments provide. For those who participated in the workshop-only, responses were diverse with between 10 and 18 categories identified across both sets of questionnaires (note that there were fewer categories identified in the data from workshop-only groups). While there were common themes across the questionnaires, the dominance of themes changed between the first and third questionnaire, indicating a change in perceptions and knowledge among participants (SM 4 Table 1 in Data S1). It is of note that, while most responses could be perceived as being positive, or neutral (e.g. saltmarsh or mangrove), there were some terms and phrases that indicated some participants began with, and indeed a small proportion retained, negative views of the coastal wetlands. For example, descriptions of coastal wetlands as 'muddy' or 'swampy' were more common in Questionnaire 1 for participants of both workshop-only and citizen science experiences (16% and 19%, respectively), as well as references to wetlands being 'smelly' or 'unpleasant'. However, in Questionnaires 2 and 3, there was a change in tone with many more responses reflecting the diverse benefits of coastal wetlands (e.g. biodiversity enhancement), awareness of their coastal/ocean location and being vegetated environments. Increased recognition of the role of coastal wetlands in carbon storage was found between Questionnaire 1 and 2 in both groups, with one respondent indicating that coastal wetlands are the 'Most efficient carbon converter', further evidencing the change in knowledge and perception.

Participants were also asked to free list the first three words that came to mind when thinking about climate change. Responses collected through each questionnaire were quite

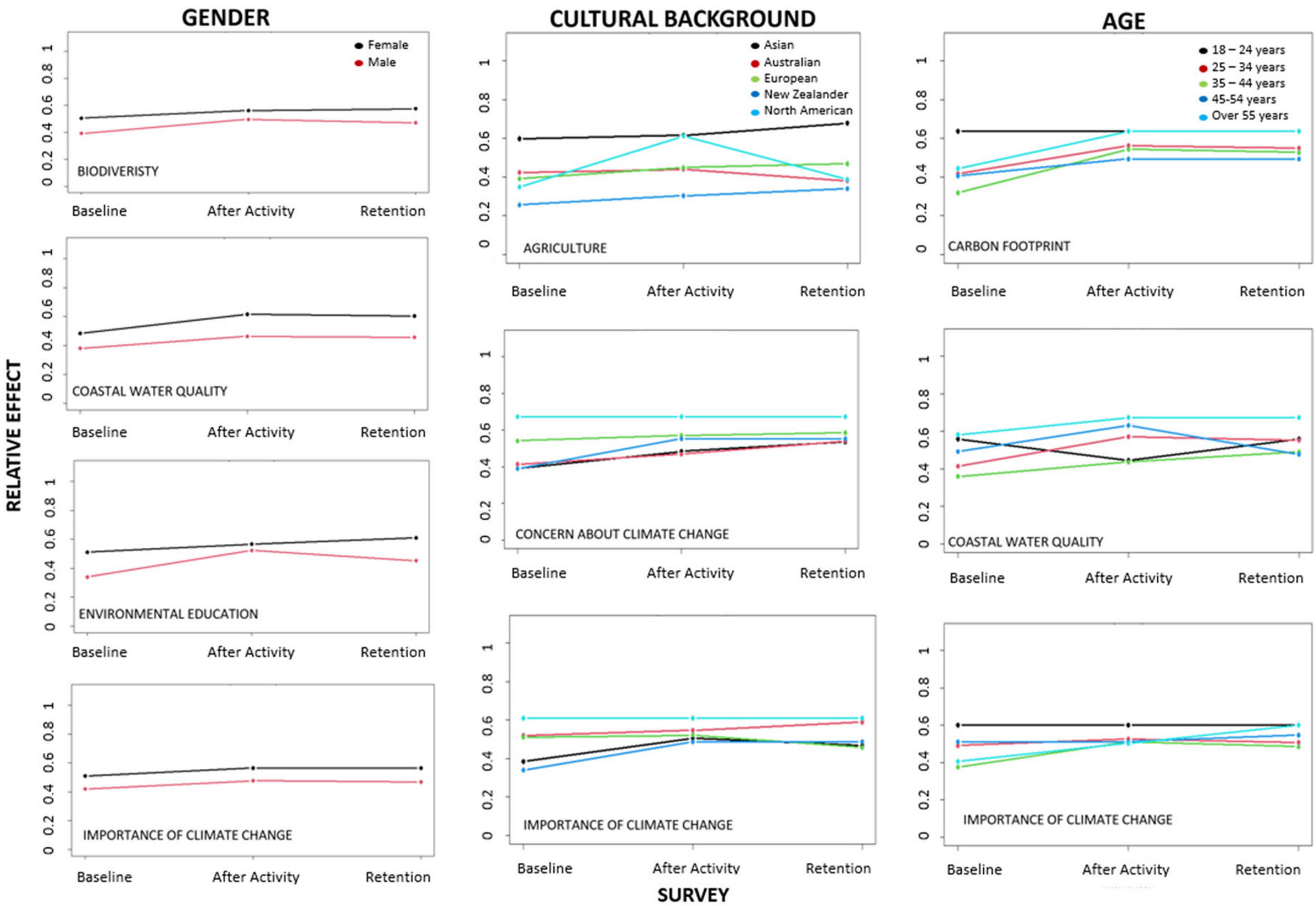

FIGURE 10 Relative effects for some of the perception statements, where significant differences were observed across time for specific demographic groups, for citizen science participants.

varied, with between 10 and 21 categories identified across the two experiences and their corresponding questionnaires (See SM4 Tables 3 and 4 in Data S1). It should be noted that there was some commonality across the questionnaires, with 'extreme weather and changing climate' and 'environmental degradation' found to be the top five categories identified in the citizen science group, while the theme of 'carbon emissions', including blue carbon, carbon storage/sequestration and more, was in the top five categories across all questionnaires for the workshop only group. However, the frequency of mentions was found to increase between Questionnaires 1 and 2 for both groups but decreased between Questionnaires 2 and 3. This trend mirrored the same pattern in responses relating to 'wetlands', where mentions relating to the theme of 'blue carbon/ carbon storage/ carbon sequestration' was also seen to increase between Questionnaires 1 and 2 for both sets of participants. It is also of note that responses relating to bushfires or forest fires were found to increase in the later questionnaires. Finally, it is worth highlighting that there was some evidence of scepticism regarding the severity and urgency of climate change in some of the responses, with some participants questioning whether information surrounding it is 'unnecessarily emotional' and whether climate change is 'that significant'.

3.3 | Potential impact of Blue Carbon Citizen Science participation on sustainable behaviour

Results from Questionnaire 3 revealed that most participants used the knowledge gained during the programme to make changes in their behaviour at home or work. Forty-five per cent of the workshop-only and 64% of the citizen science participants stated that information and skills had already been used, with a further 45% and 34%, respectively, stating an intention to do so in the future. Examples of how new knowledge had been used included: participants' communicating their learning with others (e.g. 'I have explained the effectiveness and importance of blue carbon to family and friends'), adopting new behaviours (e.g. increased recycling, reduced use of single use plastics) and becoming 'more thoughtful about carbon footprint and climate change'. When comparing across the two experiences, we found that both treatments were effective at empowering participants and promoting behavioural change, with most participants (>70%) indicating they were somewhat or extremely likely to adopt some sustainable practices after participating in either the citizen science or workshop-only experiences (see Figure 11). However, citizen science activities encouraged a greater percentage of participants to adopt a larger number of sustainable practices. Over 80% of the respondents from the

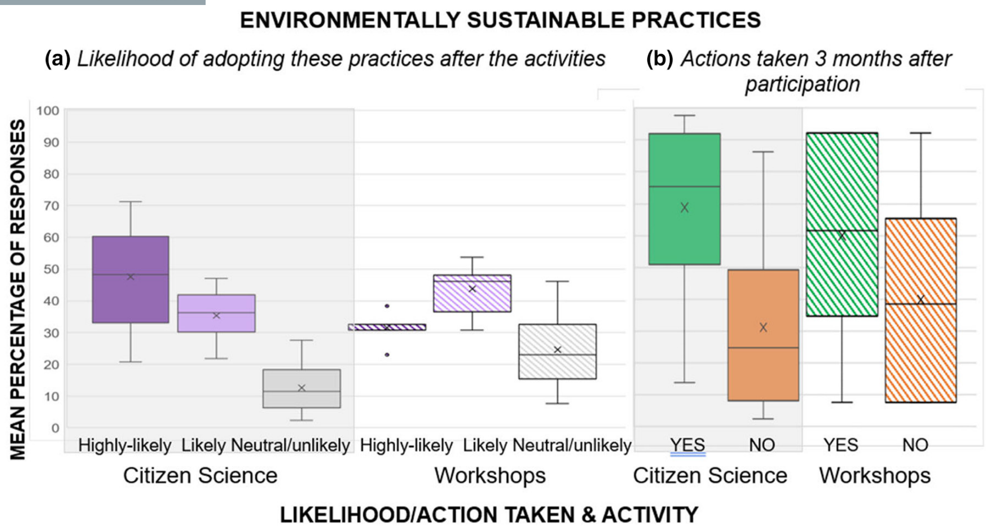

FIGURE 11 Mean percentage response (a) per likelihood of participant adopting sustainable practices (purple boxes) after participating in the citizen science (grey-shaded background-solid boxes) and Workshop-Only experience (hatched boxes), and (b) whether they had effectively taken those actions by 6–8 weeks. Actions taken are indicated by green boxes and actions that were not adopted are shown by orange boxes. Mean percentages were calculated as the average of the 10 sustainable actions included in the category of behavioural intentions. Error bars are indicative of standard deviations.

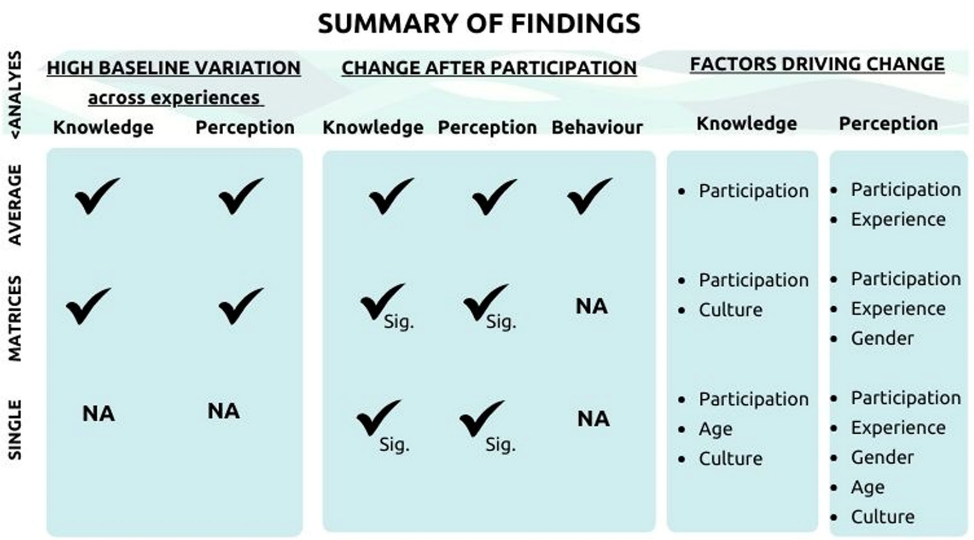

FIGURE 12 Summary of findings highlighting which analytical approaches detected variation in participants' baseline, the change after participation in the programme while specifying when those findings were statistically significant (i.e. sig.), and what factors were driving the change. NA, Not applicable to the particular area or dataset.

citizen science day expressed their intention (i.e. somewhat or extremely likely) to adopt at least seven out of the 10 sustainable practices, whereas only three of these 10 sustainable practices were likely to be adopted by over 80% of the workshops-only participants. Six to eight weeks after the programme, almost all participants (98% of those participating in the citizen science and 95% of those attending the workshops-only) had taken at least one sustainable action discussed during the programme and an average 68% and 60% of those participating in citizen science and the workshops-only respectively, had taken numerous sustainable actions (Figure 11). Over 80% of citizen scientist participating in the citizen science acted on at least five out of the 10 sustainable practices, while 80% of workshop-only participants only acted on three of these 10 sustainable practices listed.

In summary, knowledge was equally gained through either experience possibly because both activities shared the same educational component. Perceptions were positively influenced by both activities, but to a higher degree by the immersive citizen science activities, while behavioural intentions and adopting sustainable practices were also promoted at a higher degree by the immersive citizen science activities (Figure 12). Given the wide range of additional factors outside the scope of our study that may have influenced the participants' ability to learn, challenge their perception and promote the adoption of sustainable practices, including financial circumstances, peer pressure, ongoing motivation and support. We believe that the small portion of the response trends explained (10%) by participating in the programme, is substantial and a source of the measured change in participants' knowledge, perception and behaviour.

3.4 | Benefits of engaging in the programme and participant learning

While the immediate benefits of citizen science programmes are widely lauded, this project sought to understand the impacts of participating in the programme and how this might spill over into everyday life and behaviours. To this end, within the second and third questionnaires, respondents were asked to provide information about their enjoyment of the programme, the usefulness of the activities and the material covered and how or if they shared their experience with others.

In Questionnaire 2, respondents were asked to indicate what they enjoyed most about their participation in the programme, with responses from the citizen science group summarised in Table 3. As shown, the most frequent theme mentioned by respondents was ‘collaboration and taking part in activities’ which ranged from finding and collecting tea bags, taking measurements of the mangroves and being involved in research activities. When compared with the results of those individuals who took part in the workshop-based programme, 40% indicated that they had enjoyed the whole experience, while the themes of expanding understanding and knowledge of blue carbon and understanding HSBC's sustainability agenda was highlighted by 30% of participants, with learning about wetlands more broadly mentioned by 20%.

In addition, across the second and third questionnaires, respondents were asked to indicate whether they had learned anything from their participation in the programme, to rate the perceived level of usefulness of the day and provide examples of the usefulness of the citizen science programme. From the respondents who completed the final questionnaire, an overwhelming majority (94%) of respondents rated the day as either an ‘effective’ or ‘highly effective’ learning opportunity. This mirrors the 100% of respondents from both the Citizen Science and Workshop groups indicating through the second questionnaire that they had learned something from the experience. In terms of usefulness, both groups identified building knowledge and learning about the wetland environments, their wider role in everyday life and actions that can be taken to be the most useful aspect of their experience (Tables 4 and 5). For the fieldwork group, this was followed by the practical experience of being involved in research (25%) and being encouraged to change behaviour and share information (18%), with the latter mentioned by the workshop group second most frequently (40%).

4 | DISCUSSION

The potential role of citizen science in contributing to environmental solutions has garnered significant attention in recent years, and yet, while initiatives are not new, there remain gaps in our understanding of the best approaches and designs of citizen science activities to influence lasting participant learning and behaviour change. Through

TABLE 4 Usefulness of the Citizen Science Days and the wider programme from the citizen science group.

Theme	% of mentions	Example of theme
Building knowledge and raising awareness about actions	79%	‘Gained knowledge about the importance of blue carbon – didn't appreciate how important they are’ ‘It showed me how to appreciate wetlands and why they need to be protected’
Practical experience/contributing to research	25%	‘It was useful to be directly in the environment that the study relates to. Often we read about theoretical studies or scenarios and testing methodologies used by experts in their relevant areas of expertise. It was fantastic to be on the ground employing specific techniques in the environment to which the study relates to give context to the whole exercise’
Encouraged to share information and change behaviour	18%	‘I now understand how mangroves are really important. I also got practical tips like using keepcups when buying coffee or eating less meat’
Influenced my work life	7%	‘Using my knowledge about climate change and how I can make a difference in business (client interactions)’
Reconnected with nature	6%	‘Not only did it refresh my enthusiasm on natural ecosystems but broadened my knowledge across Natural capital, climate change, ecosystems and wetlands’
Meeting new people	1%	‘Gave me a new understanding on blue carbon and it was a great chance to interact with my team outside of work’

TABLE 5 Usefulness of the workshops and the wider programme from the Workshop group.

Themes	% of mentions	Example of theme
Building knowledge and raising awareness about actions	70%	'For someone with no prior knowledge, this is a good introduction to key topics; also sparks interest in future learning'
Encouraged to share information and change behaviour	40%	'I had very little knowledge of blue carbon and in particular wetlands and ecosystem services so this program has helped me understand the role of wetlands in reversing climate change. I have made others aware of the importance of blue carbon and how I could personally contribute to their conservation'
Reconnected with nature	10%	'Appreciating our land'
Business explanation	10%	'I liked the business explanation from HSBC'

the HSBC Blue Carbon Citizen Science Programme, we explored the impact of an immersive citizen science experience on participant perceptions, knowledge and behaviour, monitoring retention of those aspects over time, and comparing this with the impact of a classroom-based learning experience. Drawing insight from the results of this study, key observations regarding the potential for citizen science, even short-term experiences, such as this one-off initiative, as a mechanism for learning and behaviour change relating to coastal systems and climate change are presented below, with themes including: (i) citizen science as a mechanism for learning and behaviour change, and (ii) the challenges and opportunities for citizen science of the future.

4.1 | Citizen science—A mechanism for learning and behaviour change?

Despite their longevity as a conservation and public engagement tool, historically these initiatives have not always been designed to understand learning gained as a result of participation in citizen science activities (Bruckermann et al., 2019), although this is changing (Bonney et al., 2014; Dean et al., 2018). Furthermore, learning and knowledge exchange opportunities are being increasingly delivered across multiple platforms—this is the case for formal learning, as well as within citizen science programmes (see Bruckermann et al., 2019). This form of multi-modal delivery was a component of the Blue Carbon Citizen Science Programme, with all participants involved completing the same feedback questionnaires, allowing comparisons between the different experiences to be made.

Although both experiences encompassed an educational component of classroom-based teaching delivered by wetland scientists, we found evidence of variation in the impact of the different experiences. Baseline knowledge of wetlands and natural capital concepts prior to engaging in this programme was generally scarce, thus the programme was able to significantly increase participant knowledge of these ecosystems. We found that, overall, engaging in the HSBC Blue Carbon Programme influenced learning to some degree—regardless of the type of experience or participant's demographics. We found that those who indicated they had some baseline knowledge of the topics being explored through the programme gained additional insight, while those with little prior knowledge indicated that they experienced significant improvements in their levels of knowledge and understanding as a result of their participation in the programme, regardless of the experience type—this is in line with research findings from earlier studies (Bonney et al., 2014; Dickinson et al., 2012).

Perceptions of wetland ecosystems were positively influenced by both the citizen science and workshop activities with demographics sometimes influencing the degree of perception change. This is likely due to differences in the baseline, as well as potentially how demographics relate to the degree and ability of participants to challenge their previous knowledge and beliefs, their capacity to adopt new ideas and adjust their perceptions. Despite this, the citizen science activities played a greater role in influencing participants perceptions and highlighting the importance of the benefits wetlands provide. This indicates that a key factor of improving perception of less attractive topics is in fact knowledge enhancement and is line with studies such as Toomey and Domroese (2013), who found attitudes towards coyotes positively changed after their involvement in the New York City Coyote Project and the literature review by Peter et al. (2019), which showcased multiple citizen science projects improving negative attitudes towards species or nature in general. Whether the positive shift in attitudes is influenced also by the exposure to scientists, and how this impacts perception compared to a programme with no scientist interaction would be interesting to explore. Studies have demonstrated that collaborative learning between science and non-scientists can facilitate transformation (Groulx et al., 2017; Ruiz-Mallén et al., 2016), and participating in the research and working with scientists was commonly identified by participants as an enjoyable element of this programme. Yet, a recent paper by Santori et al., 2021 illustrated that an independent App-based turtle citizen science programme with no scientist interaction also positively influenced attitudes. Further investigation on whether this characteristic is critical to the design of future citizen science programmes and to what extent it contributes to eliciting behaviour change needs to be undertaken.

While the results suggest that impact can be recognised through both experiences, the perceptions of wetland ecosystems and issues relating to them were found to be more influenced by participation in the citizen science activities rather than the workshop-only experience. These findings suggest that participation in experiences which provide real-world immersion in an environment have more impact—even if that experience and exposure is only over a short period of time, as is the case in this study. Acknowledging the importance of experiencing an environment as part of the mix of factors which influence behaviour change corresponds with the growing recognition that taking a knowledge only approach is not sufficient to drive and retain meaningful changes in behaviour (Kollmuss & Agyeman, 2002; Nilsson et al., 2020). The larger number of sustainable actions, and the higher degree of conversion from intent to action by those attending citizen science activities, reflects the greater power of immersive experiences have, to promote behavioural change (i.e. Figure 12). As outlined by others, various characteristics of field-based experiences made available through citizen science programmes are likely to contribute to changes in perception, including for example the immersive nature and procedural learning gained through participation in the citizen science activities (Dean et al., 2018; Ruiz-Mallén et al., 2016), the real-life experience and hands-on exposure to a relatively unexperienced ecosystem (McKinley, Jefferson, & Hart, 2020) and fostering of feelings of capacity to contribute (Day et al., 2022) and engage in environmental issues which may have previously felt outside of an individual's locus of influence.

The questionnaires also revealed that the citizen science activities were more successful in influencing participants' likelihood of behaviour change when compared to the workshop-only experience. Over 80% of citizen science participants expressed their intention to adopt at least seven out of the 10 sustainable practices, compared with 80% of the workshop-only participants indicating they were likely to adopt only three of these practices. This echoes similar trends on the impact of citizen science experiences found by other authors, including Turrini et al. (2018) and Cinches and Lubos (2020) who found that participants' knowledge, attitudes and behaviour change in relation to climate change increased following engagement in hands on citizen science activities. However, while the results indicate at least some translation into real action because of both types of experience, there are differences between the two groups seen in Questionnaire 3. Over 95% of all participants undertook at least one form of action towards sustainability (e.g. participating in local litter collections or reducing consumption of single use plastics) following their participation in the programme. Once again, however, analysis found that a greater number of sustainability practices (five out of 10) were enacted by the citizen science participants compared to the workshop only participants (who carried out an average of three out of the 10 activities listed). While there may have been other external drivers influencing this, this suggests that the experience of physically engaging in the citizen science activity and fieldwork results in a greater likelihood that an individual will carry out a change in behaviour. Understanding which specific characteristics lead to this is important of future development of effective citizen science projects. A recent study by Day et al. (2022)) found intentions to engage in conservation action was only influenced by experiencing a sense of contribution. In this study, contribution to research scored as the second most useful aspect of the programme for the citizen science participants, suggesting this aspect may be the most likely reason for the greater commitment to carry out sustainable actions. Furthermore, collaborating and taking part in the research was the most enjoyable component of the day for citizen science participants. Given that enjoyability is an intrinsic motivator and correlated to motivation and long-term behaviour outcomes (Phillips & Chapman, 2012), this may also be a key aspect to empowering action.

While we found differences between the two experiences examined in this study, a key finding is the recognition that individuals respond in different ways to learning and engagement experiences. Both experiences resulted in changes in self-reported knowledge, perceptions and intention to undertake behavioural changes, suggesting that while it is evident that for some, the immersive element of citizen science is a fundamental part of their experience and appears to be a driver in change in perceptions and commitment to act, for others, the workshops can be enough to influence their learning, perception and behaviour change. Additionally, results suggest that participants may retain information about different topics at varying rates. As we increasingly look to citizen science programmes as a method for not only collecting data, but also as activities which connect communities while increasing science, or indeed ocean literacy, there is a need to embrace multiple platforms of delivery to cater for a wide spectrum of participants (Eleta et al., 2019).

Future citizen science initiatives should be cognisant of these interactions from the outset and should integrate these into design and implementation if they aim to have greater influence on long-term conservation, particularly for less charismatic ecosystems. In addition, this research found that although participants acquired knowledge similarly regardless of personal characteristics, results found that changes in *perceptions* was found to vary depending on individual characteristics and socio-demographic parameters. Given increasing calls for improved investigations as to how perceptions vary with individual characteristics (Jefferson et al., 2021), such as education, gender or age, future citizen science initiatives should ensure that these relationships are assessed as part of programme evaluation.

4.2 | Citizen science: Opportunities for the future

In the first instance, efforts should be made to improve the reputation of citizen science initiatives and, in particular, the transdisciplinary programmes which bring together actors from across multiple sectors. The cross-sector partnership and funding of the Blue Carbon Citizen Science Programme between corporate, academia and for purpose sectors highlights the potential opportunity of corporate sponsorship and engagement with citizen science initiatives. In response to growing pressure for industry to address the current global ecological and climate crises, there is an opportunity for businesses to integrate citizen science initiatives into their Corporate Social Responsibility (CSR) and sustainable development objectives through their existing schemes (Plewa et al., 2015).

Further, there is a need to build on the historically ecological remit of many citizen science programmes through improved integration of social sciences and arts and humanities methodologies and research questions, explored in detail by Heiss and Matthes (2017). Framing citizen science initiatives in such a way that promotes citizen science as a clear mechanism for meaningful action and a way in which communities can get involved in complex and sometimes difficult to understand environmental issues (Eleta et al., 2019) is needed. As evidenced in this study, citizen science initiatives provide participants with an opportunity to get involved in environmental issues in their local area, and to become advocates of change. Crucially, for those ecosystems which have received less attention than other easier to reach or charismatic species, there is an opportunity for initiatives such as the HSBC Blue Carbon Citizen Science Programme to enhance engagement with wetland environments, generating a community of 'Blue Carbon Custodians' (UNESCO, 2020). Related to this, there is a need for further exploration into the relationship between citizen science initiatives and its potential role in changing public perceptions towards coastal spaces (Dean et al., 2018; Groulx et al., 2017; Jefferson et al., 2015, 2021), fostering ocean and climate literacy, delivering behaviour change (McKinley & Burdon, 2020) and initiating social learning and interactions (Day et al., 2022). While this study does not specifically examine demonstration of behaviour change, it provides valuable insight into self-reported changes in attitudes, as well as information on self-reported intended and actual changes in pro-environmental behaviour. Consequently, there is an opportunity to frame citizen science programmes as a pathway for 'gateway behaviour' (Stafford & Jones, 2019; Toomey & Domroese, 2013).

While this study did not focus heavily on the cultural services that might be derived from coastal wetlands, there were some reflections on this through the free-listing questions, with words including 'fishing', 'fun', scenic' and 'tranquil' identified through the analysis. Although these were not dominant topics within the study, it is nonetheless important to recognise these values attributed to wetlands from participants and worth considering how citizen science programmes could be designed to better capture non-ecological information. Numerous scholars have recognised a significant gap in the ways in which social sciences or arts and humanities approaches are included within citizen science initiatives (Chaubey & Singh, 2021; Heiss & Matthew, 2017; Kullenberg & Kasperowski, 2016). While there are challenges to the use of citizen science in this context (Heiss & Matthew, 2017), as the marine social science research and practitioner community continues to grow in response to calls for transformed relationships between specificity and the ocean (as set out by the UN Ocean Decade) and an increasing recognition of the role of transdisciplinary research, citizen science initiatives clearly have a role to play in expanding the understanding the human dimensions, and how these may change in response to future change.

As the number of citizen science initiatives continues to increase, there is a need to better understand participant motivations, perceptions and their experiences of citizen science programmes (Davis et al., 2019; Day et al., 2022; Larson et al., 2020; McAteer et al., 2021). While the majority of participants in the Programme were offered the opportunity to participate through their employment and to indicate what they had/had not enjoyed or found useful, their individual *motivations* for taking part were not explored. For example, this study did not explore the emotional connection individuals might experience towards an environment and how this might influence motivations to participate, or influence intended behaviour change and wider environmental literacy (McKinley, Pages, et al., 2020; McKinley et al., 2023). Although it could be said that attempts to capture this were inherent within the question responses related to cultural ecosystems services, specific analysis on these topics was not collected and represents a recognised gap in wider understanding of citizen science. Neither did this study capture data on group dynamics, exiting relationships or any informal discussions taking place during participation in the programme—all of which may have an fluence on participants' experiences and overall retention. A recent study by McAteer et al. (2021) highlights the importance of understanding these intrinsic and extrinsic motivational drivers and participant expectations of their experience (i.e. what do people expect from their investment of time) to ensure citizen science initiatives can be better designed to deliver high-quality research, actively foster environmental stewardship and literacy and ensure participant retention. These findings echo those from other scholars including Wright et al. (2015), who found variations in volunteer motivations to influence participant satisfaction. As efforts to better understand nature, and indeed ocean connectedness, and its role in engendering behaviour change continue, understanding motivations and emotional connections associated with citizen science initiatives could provide valuable insights.

Finally, for these efforts to realise their true potential, it is crucial that existing and future citizen science initiatives consider what is being 'offered' to citizen science participants (Strasser et al., 2018). Increasingly, there are calls for citizen science to extend beyond the traditional view of them being a mechanism for data collection (Phillips et al., 2019) and there are opportunities for citizen science initiatives to be tailored so that they are grounded in co-design and co-development, enhancing participant engagement, and supporting participant engagement with science (Strasser et al., 2018). Ensuring citizen science initiatives include regular monitoring and evaluation processes so that initiatives can be adapted to changing needs of both the science and the participants would help to facilitate this (Bruckermann et al., 2019).

4.3 | Concluding comments

While citizen science has been a long-recognised tool for marine conservation and education, data collected by citizen scientists are not always perceived to be of high quality, valid and reliable (Aceves-Bueno et al., 2017). However, the Blue Carbon Citizen Science programme has already fuelled two peer-reviewed publications advancing Australian coastal research (Palacios et al., 2021; Waryszak et al., 2021) and proving that volunteering programmes can be effective mechanisms to collect large environmental datasets. Despite participant training requiring a large amount of time and resources, the effort is highly rewarded for large-scale, repetitive, long-term monitoring projects that require a lot of resource. This paper explores how short-term immersive citizen science experiences may impact participant perceptions, knowledge and understanding of the environment in which they are working and compares these with a workshop experience. While the study shows both experiences to have an impact on learning, perceptions and intention to adopt behaviour changes, the immersive experience afforded through the citizen science programme enabled a greater understanding of the multiple benefits of wetlands, a broader perception of values and a greater fulfilment of pro environmental actions 3 months post the experience. It highlights that even a short duration citizen science experience is able to positively influence lasting pro environmental action and appears to realise changes in knowledge and perceptions which are retained. As efforts to better understand how different communities and audiences interact with and perceive coastal environments develop alongside growing calls for more and improved citizen science initiatives, there are also opportunities for citizen science initiatives to contribute not just to the collection of ecological data but also to contribute more meaningfully towards a transformed relationship between society and nature, enhancing environmental literacy and stewardship, and fostering behaviour change.

Following this in-depth evaluation process of the HSBC Blue Carbon Citizen Science Programme, it is clear that there is need to recognise the importance of different learning experiences in transforming societal relationships with previous undervalued or misunderstood ecosystems, such as coastal wetlands. The role of the structured knowledge-based presentations in both experiences tested in this study highlight the need for future citizen science initiatives to include a structured knowledge component, as this was shown to lead to changes in perceptions and intention to change behaviours in both experiences. This can be further developed through the hands-on fieldwork component of citizen science, which may enhance intrinsic and extrinsic motivators, such as feelings of enjoyment and environmental awareness, leading to greater levels of retained behaviour change.

Ensuring future citizen science programmes do not only focus on the attractive or topical species or ecosystems and also take in unpopular aspects of coastal environments is one key opportunity to maximise the potential role of citizen science activities in achieving the goals of international environmental declarations (e.g. the UN Decade of Ocean Science for Sustainable Development, or the UN Decade for Ecosystem Restoration). Public perceptions, behaviours and connections to environments can be changed through participation in citizen science initiatives regardless of appeal. There is a need, therefore, to build on current momentum associated with evaluation of perceptions and motivations of citizen science participants, ensuring that this is built into citizen science programme design from the outset. Understanding participants, their backgrounds and their experience of the citizen science initiative are all aspects of truly enhancing the potential of future citizen science. Coupled with this is a need for future citizen science initiatives to include funding for longitudinal evaluation—monitoring of this type is frequently a one-off. To truly understand the impact of citizen science programmes, even short-term experiences such as those offered through the Blue Carbon Lab Citizen Science Days, on societal environmental and scientific literacy and stewardship, there must be better understanding of how long the experience stays with participants and how the impact is retained and translated into their everyday lives. In order for this type of assessment to be done well, there is a need to explore opportunities for innovative funding, design and development of interdisciplinary citizen programmes supporting the inclusion of social science and arts-based methodologies within citizen science activities, drawing on concepts like transformational learning or behaviour change theory, to contribute to more in-depth evaluation of the impact of citizen science programmes on learning, knowledge development and behaviour change, and crucially, how these are retained over time.

AUTHOR CONTRIBUTIONS

Emma McKinley, Peter I. Macreadie and Maria M. Palacios conceived the ideas and designed methodology; Emma McKinley, Maria I. Garcia and Maria M. Palacios collected the data; Emma McKinley and Maria I. Garcia analysed the data; Emma McKinley, Maria I. Garcia and Maria M. Palacios led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

Due to permissions linked to the ethics approval, data have not been archived publicly.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Data S1. Supplementary Materials.

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