Mechanisms for enhancing public engagement with citizen science results

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Abstract

1. Citizen science is frequently cited as a successful approach for increasing public engagement with environmental issues, but this requires a purposeful design that is inclusive of, and responsive to, diverse interests. This paper explores the mechanisms for improving participant and public engagement with citizen science results, using the New Zealand Garden Bird Survey (NZGBS) as a case study. It investigates how citizen science can apply democratic processes to be more responsive, while drawing on insights from behaviour change frameworks to facilitate a purposeful design.

2. By inviting NZGBS participants to select, inform and peer review the design and promotion of new resources, our goal was to embed their values, opinions and perspectives into the developments. This not only empowered 15,844 respondents to contribute directly to the citizen science initiative's governance over 6 years, but also made it more engaging and useful to them and the wider public.

3. New resources were designed to create a sense of collective action, making them attractive, easy to understand and promote on multiple media channels, aiming to reach a wider range of audiences. By diversifying and refining our communication strategy, we successfully enhanced the level and nature of engagement with the resources. The number and diversity of NZGBS participants also increased to involve people from a wider range of backgrounds and roles, ethnicities and ages.

4. By applying a democratic process, we demonstrate how citizen scientist perspectives were elevated, to offset and mitigate the influence of institutional powers, which can dominate and shape engagement processes. We also highlight the value of behaviour change frameworks for understanding how choice architecture, social networks and key influencers, and their complex interactions can create the enabling environment required for engagement.

KEYWORDS
behaviour change, biodiversity, data visualisation, decision making, democratic process, empowerment, participation, social media
1 | INTRODUCTION

Citizen science is the practice of public participation and collaboration in scientific research to increase scientific knowledge (Bonney et al., 2015). It is frequently cited as a successful approach for raising awareness, knowledge, engagement and action on environmental issues (Bonney et al., 2009, 2014; Cooper, 2018; Dickson et al., 2012; Schultz, 2011), with the implementation of purposeful design that is inclusive of, and responsive to, diverse interests proposed as an approach to drive such success (Arnstain, 1969; Conrad & Hilchey, 2011; Shirk et al., 2012).

For purposeful design, behaviour change frameworks and tools have been developed that draw on insights from behavioural economics, social psychology and sociology (Behavioural Insights Team, 2014; Darnton & Horne, 2013; Reddy et al., 2017). These recognise that changing behaviour is a complex process influenced not only by the individual but also by their enabling environment (Park, 2020). Their recommendations include targeting not just the individual (taking into consideration, e.g. their motivations, agency and skills) but also their social realm (being cognisant of the influence of social norms and meanings in relation to their social networks, roles and relationships) and their material context (encompassing their access to, and interactions with infrastructure, technologies, time and schedules).

For responsiveness, using democratic processes to drive ‘participatory governance’ is one approach, enabling citizen scientists to add their values, opinions and perspectives to the decision-making for such endeavours (Reed, 2008). Achieving good outcomes from such processes requires careful consideration of who is participating, how they communicate and make decisions, and the extent of their influence over the resulting decisions and actions (Fung, 2015). Such processes also need to have a clear intent and pathway to satisfying that intent, with its outcomes being meaningful to the participants. If successful, citizen scientists will not only come to support and engage with the institutions and participation practices involved, but also defend any efforts to reduce participation (Irwin, 2006; Rowe & Frewer, 2000).

Recent advances in the development of web-based tools for collecting and visualising citizen science data are widely credited with enabling democratic processes and aiding engagement (e.g. Sullivan et al., 2014). Such tools hold potential to empower people affected by local environmental issues to access local data and make informed decisions (Bonney et al., 2014), and thus may be a powerful approach for applying democratic processes that enhance broader public engagement in citizen science beyond simply increasing participation (Rowe & Frewer, 2000). However, recognising the challenges of implementing good democratic processes, Irwin (2006) recommends approaches are critically reviewed to evaluate the lesson learnt from operationalising them in different contexts. In addition, the impact of ‘democratising’ citizen science is still to be assessed (Conrad & Hilchey, 2011; Dickson et al., 2012) while, similar to conservation

**FIGURE 1** An overview of our democratic process aiming to empower citizen scientists to influence the governance of the NZ Garden Bird Survey. Specifically, citizen scientists were initially invited (in 2014 and 2015) to inform the design of new brand and results resources, as well as a communication strategy for promoting them (via the pathways indicated by the solid black arrows); they were then invited (from 2016 to 2019) to peer review the new results resources and our communication strategies (via the pathways indicated by the grey dashed arrows) to help us to progressively refine them.
management and policy (Baylis et al., 2016), citizen science itself still needs to undergo robust impact evaluation to demonstrate the benefits it delivers.

Here we provide such review and assessment, using the New Zealand Garden Bird Survey (NZGBS; Spurr, 2012) as a case study in which web-based tools were designed and employed with the goal of enabling such democratisation processes to increase engagement with the results of the initiative through four key steps (Figure 1): (a) giving citizen scientists participating in the NZGBS a voice in designing and peer reviewing the new resources; (b) designing brand and results resources that create a sense of collective action, are attractive, easy to understand and promote as well as tailored for audiences with different levels of expertise and online communication channels; (c) promoting the new results resources via multiple online channels to reach and engage as wide and diverse an audiences as possible; and (d) evaluating the level, nature and predictors of engagement, aiming to progressively improve our resources and promotional campaigns. In the discussion we critically review our learning, we highlight the opportunities and challenges for other citizen science initiatives wanting to achieve similar results, while also identifying areas to target for further improvements in NZGBS engagement.

2 | METHODS

Social ethics approval for our research process was secured from the NZGBS’s host organisation, Manaaki Whenua—Landcare Research, which is New Zealand’s national terrestrial environmental research institute (Application numbers: 1314-27-007; 1819/22). Participation in our online surveys was voluntary and through informed consent.

2.1 | Giving citizen scientists a voice

Citizen scientists were invited to contribute to three online surveys: (a) the ‘logo survey’ (run in 2015) to choose a logo for the NZGBS, with the winning concept then used to develop the new NZGBS brand; (b) the ‘design survey’ (run in 2014 and 2015) to indicate what they would like to know about garden birds and how they would like the results reported; this informed the development and promotion of NZGBS results resources and (c) the ‘peer review survey’ (run each year from 2016 to 2019) to signal whether they were aware of the latest NZGBS report resources and, if so, their interest in them; this informed an evaluation of our communication strategies and results resources.

These surveys, administered through the SurveyMonkey platform, took up to 10 min to complete, with responses to all questions being optional. The logo survey was publicised during the 2015 NZGBS campaign on the NZGBS webpage, on Facebook, in an email sent to previous NZGBS participants and a media release. The other surveys were publicised to any citizen scientists who participated in the NZGBS and entered their data online by transferring them directly to the respective survey’s introductory page (except in 2016 when they were directed to a thank you page, which included a survey invitation and link), which stated its intent—to improve their NZGBS experience in the future.

To understand who was taking part, respondents were asked to select which (if any) of a list of five to eight statements about environmental interests and roles applied to them (Question 1, Table 1). For the logo survey, respondents were also asked if they were of Māori (New Zealand’s Indigenous people) descent, their age group (<15, 15–20, 21–35, 31–50, 51–65, >65 years old) and gender (male, female or prefer not to answer). For the peer review survey, respondents were also asked their gender, age (<18, 18–19, 20–29, 30–39, 40–49, 50–59, 60–69, ≥70 years old) and ethnicity (European/Pākehā, Māori, Pacific peoples, Asian, Middle Eastern/Latin American/African, other ethnicity) as well as their NZGBS participation history (with four options: first time, once before, a few times or many times). For the design and peer review surveys, participants were also given the option of providing their email address as a form of identification (on the understanding that this information would not be shared with others).

2.1.1 | Logo survey

Participants were asked to first rank eight candidate logo concepts (MacLeod et al., 2020) in order of preference and then to explain why they selected their most and least preferred options. An open box was provided for any additional comments. A summary of logo competition results was published on the NZGBS webpage.

2.1.2 | Design survey

Participants were asked to indicate their level of interest (not interested, neutral, interested, very interested) for each of the six metrics listed for each of the following questions (Table 1): (a) what they would most like to know about the survey’s findings (i.e. which bird metrics were of interest); (b) what area they would most like to know about (i.e. what spatial scale of results should be presented) and (c) how they would most like the survey results to be presented (i.e. what format should be used to present the results). They were then asked to select which media (from a list of 11 options; Table 1) they would like to use to access information about the survey, with an open box allowing respondents to specify other media options. A preliminary summary of the results from the 2014 design survey was published online, with a link to them from the NZGBS webpage.
In 2016, participants were asked to indicate their level of awareness and/or interest (not aware, neutral, interested, very interested) in the NZGBS data visualisation resources (species factsheets and videos). From 2017 to 2019, participants were asked if they were aware of the latest State of NZ Garden Bird report and, if the response was positive, to indicate their level of interest (aware of it but not looked at it, looked at it but not really interested, looked at it and very interested, looked at it and loved it) for different resources.
(all years: barplots, maps; 2016–2018: interactive maps; 2018–2019: regional summary reports; 2018: regional technical reports), with an open comments box for any additional feedback on the report resources. The survey results for 2014–2018 were summarised in a research report published online in July 2018 but these were not actively promoted (MacLeod & Diprose, 2019).

2.2 | Designing resources

2.2.1 | Brand graphics

A suite of graphics was developed to build the NZGBS brand, make NZGBS resources attractive and readily recognisable, and create a sense of collective action (Behavioural Insights Team, 2014; Darnton & Horne, 2013). These graphics included a new NZGBS logo (developed from the winning concept selected by NZGBS participants; MacLeod et al., 2020), a standardised NZGBS colour palette and a set of digital icons (in colour and grey scales) for 16 common garden bird species. The logo was officially launched in the 2016 NZGBS campaign. The graphics were also loaded to an online datastore to make them readily accessible and secure their legacy (Supporting Information A).

2.2.2 | Results resources

A range of resources were designed and tailored for promoting the NZGBS results to audiences with different levels of expertise and via a range of media channels (Table 2; Supporting Information B). The initial report (‘Story so far: 2007–2015’ published in 2016) focussed on variation in counts for 16 common garden bird species in relation to the garden type (urban vs. rural), feeding activities (fed vs. unfed) and three spatial scales (giving priority to national and regional scales, but also providing some information for suburbs). This report included: the top 10 infographic, species factsheets, species videos and an interactive atlas (Table 2). From 2017 to 2019, the emphasis shifted to reporting trends from national to local scales for at least 14 common garden bird species; these ‘State of NZ Garden Birds’ (SOGB) resources included maps and barplots, which were also collated into national and regional summary reports, all designed for audiences with low to medium expertise (Table 2). In some years, interactive maps and technical reports, designed with audiences with medium to high expertise in mind, were also published to provide more detailed statistics for multiple spatial scales.

Six key tenets for growing engagement guided resource design. First, building the NZGBS profile and creating a sense of collective action (Darnton & Horne, 2013), using the new brand resources (Supporting Information A). Second, prioritising developments to meet participant preferences for metrics, formats and channels for communicating results (based on the findings of the design surveys). Third, delivering standalone graphics resources that are attractive and easily understood by non-specialists (Behavioural Insights Team, 2014; Darnton & Horne, 2013), by using: (a) bird icons to help the user recognise species of interest, while also educating those less familiar with them; and (b) trend classification categories and associated colour coding, to make it easy for the user to identify and interpret key changes in bird counts (MacLeod, Howard, Gormley, & Spurr, 2019; MacLeod, Howard, Green, et al., 2019). Fourth, using motivational messages to enhance awareness of why monitoring garden bird trends is important and convey the benefits to self, friends and family (Schultz, 2011); these concepts included ‘birds as indicators for the health of the environment we live in’ (introduced in the initial SOGB report), birds acting as ‘backyard barometers’ (introduced in the latter two SOGB reports), and as a result ‘we should be listening’. Fifth, starting to embed cultural values into NZGBS resources through the use of te reo Māori (New Zealand’s indigenous language) in consultation with Māori linguistics and Mātauranga Māori (indigenous Māori knowledge) experts (Wehi et al., 2019); this included the application of Māori bird names, a te reo Māori title for the SOGB reports (‘Te āhua o ngā manu o te kāri i Aotearoa’) and te reo Māori translation for some graphics. Finally, seeking to build the NZGBS’s online community’s ownership of the report, by each year including on the national report cover a bird photograph sourced from the NZGBS Facebook group (Libertore et al., 2018).

2.3 | Promoting resources

The annual reports were published on the NZGBS webpage (Supporting Information E). From 2017 onwards, high-quality versions of these ‘pre-canned’ graphics and reports were also available via an online datastore, where third parties could view, download or directly embed them on their own online channels (Supporting Information F); this was not only to secure the resources’ legacy, but also to empower others to actively promote them among their networks and tailor their reporting according to their needs. In parallel with the progressive improvement and diversification of report resources each year (Table 2), the content, presentation and layout of the associated webpages were likewise refined, aiming to make these resources easier to use and more attractive for the user.

The results resources were also promoted each year via three social networks: (a) 54 posts among four social media accounts (on Facebook or Twitter; Supporting Information G), either embedding resources directly in posts or links to the latest online report or associated media articles; eight of these posts were also shared to the NZGBS Facebook group (Libertore et al., 2018); (b) a media release encompassing one or more of the following features (Supporting Information H; Spurr, 2020): links to the NZGBS homepage, latest report on the webpage and/or high-quality graphics on the online datastore, specific examples of the latest resources and the concept of birds acting as ‘backyard barometers’ or its precursor—‘birds as indicators for the environment we live in’; and (c) one or two emails sent to >7,000 previous participants with one or more links (using subtitle, text or image hyperlinks) to the NZGBS homepage and/or latest report on the webpage, with an accompanying image in close proximity to some text links to highlight the resources available (Supporting Information I).
### Evaluating engagement

#### Engagement metrics

Engagement metrics, which were used as the indices of engagement, were downloaded from each of the respective communication channels (Table 3; MacLeod, 2020). For social media, six engagement metrics were downloaded for the lifetime of each post or tweet. Facebook posts were also scored in relation to (a) the probability of reaching and engaging new audiences; and (b) sharing activity by six institute types (formal or informal): community action; nature appreciation; government and science; education and youth; businesses; and Māori. Engagement by media outlets was quantified as the number of articles published in print or online by national and local newspapers, magazines, television and radio channels in the month following each media release (Supporting Information H). Article content (where available) was also evaluated for evidence of reporting of the latest NZGBS results (and whether those were adapted for local contexts or not), referencing of the ‘backyard barometer’ concept (or its precursor) and use of the NZGBS report graphics; note

| Resource                  | Description                                                                 | Story so far | SOGB 2016 | SOGB 2017 | SOGB 2018 |
|---------------------------|-----------------------------------------------------------------------------|--------------|------------|------------|------------|
| Top 10 infographic        | A matrix of bird icons showing changes in the top ten species counted for each year (inspired by a similar one used by the Malaysian Garden Bird Survey); it was annually updated | 1            | (1)        | (1)        | (1)        |
| Species videos            | A light-hearted video to convey (within a minute) an interesting fact about the bird, how many gardens in rural and urban landscapes would need to be visited to find it, whether feeding birds in gardens will influence the chance of seeing the species and the regions in which the bird was most likely found. It finished by encouraging people to visit the NZGBS webpage to learn more. A playlist of the 16 videos was loaded to YouTube and individual videos were also included on the NZGBS webpage | 16           |            |            |            |
| Species factsheets        | Included the species’ icon and video, a fun fact about the bird, its names (Latin, common and Māori), conservation status, feeding habitats and food sources, a simple, colourful bar plot showing how the species counts varied nationally in relation to garden type (urban vs. rural) and feeding activities (fed vs. unfed) and a map illustrating variation in counts across 16 regions | 16           |            |            |            |
| Interactive applications  | Enabled the user to explore how garden bird counts (NZGBS atlas) or trends (NZGBS explorer) vary across suburbs within each region, using three tabs to: (a) introduce the NZGBS and the application; (b) display bird maps, using dropdown menus to select the spatial resolution, species and/or location and spatial scale of interest, with a pop-up window to show the 80% confidence intervals for a given location’s count or trend estimate and (c) survey effort map showing information for each suburb | 1            | 1          | 1          |            |
| Species maps              | Designed as standalone resources, these simple, eye-catching graphics aimed to report a high-level summary of national and regional results. See Supporting Information C for refinements over time | 16           | 16         | 16         | 246        |
| Barplots                  | Generated for individual species at the regional scale, or for all focal species at a given scale (local, regional, national); with a te reo Māori translation available for the national scale. They provided more detail than the maps, while still being simple, eye-catching and standalone; see Supporting Information D for how graphics were refined over time | 16           | 33         | 206        | 425        |
| Summary reports           | Designed for a non-specialist audiences and were available for national and, in later years, regional scales. The report collated relevant subsets of existing bar plots and/or species maps (described above), with additional text, illustrations and graphics to outline the report goals, analytical approach (including the criteria used to draw attention to trends of concern or interest), number of garden surveys per year and volunteer effort. As above, presentation was refined over time | 1            | 17         | 17         |            |
| Technical reports         | Designed for audiences with some basic understanding of statistics, these national and regional reports included an outline of their goal, and the analytical approach and criteria used to draw attention to trends of concern or interest. Graphics displayed: (a) a location map; (b) number of garden surveys per year and (c) median changes in bird counts with the 80% confidence interval for 1,001 bootstrap replicates, and the distribution of the bootstrap replicates in relation to the trend classification categories as well as a quality rating | 17           |            |            |            |
TABLE 3 Channels for publicising results resources, along with the data sources, metrics and model specifications used to evaluate the level, nature and predictors of engagement. (Yearf = campaign year specified as a factor; LMER, linear mixed effects model; GLMER, generalised mixed effects model; GLM, generalised linear model; see Section 2 for more information)

| Channel                          | Data source                        | Metric                      | Replicate unit | n    | Response | Full model formula                                                                 | Function | Error family |
|---------------------------------|------------------------------------|-----------------------------|----------------|------|----------|--------------------------------------------------------------------------------|----------|--------------|
| Social media                    | Facebook Insights; Twitter          | Impressions; number of times posts or tweets appeared on social media newsfeeds | Social media post | 54   | Impressions | ~Resource + Share to group + Year + (1| Channel | + (1| Yearf)      | LMER      | Gaussian     |
|                                 |                                    | Engaged users               | Social media post | 54   | Engaged users | ~Resource + Share to group + Year + (1| Channel | + (1| Yearf)      | GLMER     | Poisson      |
|                                 |                                    | Likes                       | Social media post | 54   | Likes     | ~Resource + Share to group + Year + (1| Channel | + (1| Yearf)      | GLMER     | Poisson      |
|                                 |                                    | Comments                    | Social media post | 54   | Comments  | ~Resource + Share to group + Year + (1| Channel | + (1| Yearf)      | GLMER     | Poisson      |
|                                 |                                    | URL clicks                  | Social media post | 54   | URL clicks | ~Resource + Share to group + Year + (1| Channel | + (1| Yearf)      | GLMER     | Poisson      |
|                                 |                                    | Shares (on Facebook or retweets on Twitter) | Social media post | 54   | Shares     | ~Resource + Share to group + Year + (1| Channel | + (1| Yearf)      | GLMER     | Poisson      |
| Media outlets                   | Media portal; partner organisations| Number of articles          | —              | —    | —        | —                                                                           | —         | —            |
|                                 |                                    | Results included            | —              | —    | —        | —                                                                           | —         | —            |
|                                 |                                    | Barometer included          | —              | —    | —        | —                                                                           | —         | —            |
|                                 |                                    | Graphics included           | —              | —    | —        | —                                                                           | —         | —            |
|                                 |                                    | Local results included      | —              | —    | —        | —                                                                           | —         | —            |
| Webpage                         | Google analytics                   | Page views                  | Individual webpages | 49   | Probability of page view<sup>a</sup> | ~Tier + Resource + Email link<sup>b</sup> + Post link<sup>b</sup> + Year + (1| Yearf) | GLMER     | Binomial     |
|                                 |                                    | Entrances                   | Individual webpages | 49   | Probability of an entrance<sup>c</sup> | ~Tier + Resource + Email link<sup>b</sup> + Post link<sup>b</sup> + Year + (1| Yearf) | GLMER     | Binomial     |
|                                 |                                    | Individual webpages         | Individual webpages promoted via email | 11   | Probability of an email-click entrance | ~Tier + Resource + Number of email links + Post link<sup>b</sup> + Year + (1| Yearf) | GLMER     | Binomial     |
|                                 |                                    | Downloads                   | —              | —    | —        | —                                                                           | —         | —            |
| Datastore                       | Google analytics                   | Page views                  | —              | —    | —        | —                                                                           | —         | —            |
|                                 |                                    | Referrals                   | —              | —    | —        | —                                                                           | —         | —            |

(Continues)
| Channel             | Data source               | Metric                                      | Models specifications                                                                 |
|---------------------|---------------------------|---------------------------------------------|----------------------------------------------------------------------------------------|
| Email               | Vertical response; Mailchimp | Number of clicks                            | **Replicate unit** | **n** | **Response** | **Full model formula** | **Function** | **Error family** |
|                     |                           | Individual emails                          | Individual emails | 7 emails | Total clicks per email | -Year + Number of email links + offset \{log [Opened emails]\} | GLM | Poisson |
|                     |                           | Individual links                           | Individual links | 24 links; 6 emails | Probability of a link click\(^a\) | -Year + Resource + Link type + Accompanying image + (1|Email identity) | GLMER | Binomial |
| Peer review surveys | SurveyMonkey              | Number of people aware of report            | Individual survey responses | 9,261 responses, 7,779 unique respondents | Probability aware of report | -Age*Year + Gender*Year + Ethnicity*Year + Participation*Year + (1|Respondent) | GLMER | Binomial |
|                     |                           | Number of people interested in results resources | Individual responses to multiple questions for respondents aware of report | 16,761 responses; 3,708 unique respondents | Probability interested in resource | -Resource + Age + Gender + Ethnicity + Participation + Year + (1|Respondent) | GLMER | Binomial |
| Design and peer review surveys | SurveyMonkey | Number of people interested in results resources | Individual responses to multiple questions for respondents to design survey (2014–2015) and those aware of report in the peer review survey (2016–2019) | 26,724 responses; 7,479 unique respondents | Probability interested in resource | -Survey*Resource + Survey*Environmental society + Survey*Garden society + Survey*Biological sciences + Survey*Environmental management + Survey*Citizen scientist + Survey*Student + Survey*None of roles or interests + (1|Respondent) | GLMER | Binomial |

\(^a\)As a function of the total page views for the respective set of report resources.

\(^b\)Binary variable for link shared at least once via email (Email link) or social media (Post link): true = 1, false = 0.

\(^c\)As a function of the total number of page views for the respective report resource.

\(^d\)As a function of the total number of opened emails.
that it was not possible to access all the original articles in 2019 so engagement in this year may be underestimated. For each email, engagement was measured as the cumulative number of clicks for each resource link up to the download date (as it was not feasible to specify the observation period of interest). For online resources (NZGBS webpage and datastore), engagement was measured based only on activity associated with the latest report’s webpages within the 4-week period immediately following its respective press release.

### 2.4.2 Predictors of engagement

A series of models were fitted to identify key predictors of engagement with social media and online resources, as well as determinants of resource awareness and interest of different citizen scientist audiences (based on the design and peer review survey results; Table 3; MacLeod, 2020). These analyses focussed on understanding the relative influence of campaign year as well as three factors considered important in influencing behaviour (Behavioural Insights Team, 2014; Darnton & Horne, 2013): materials (the content and presentation of resources), social (whether resources were promoted to online social networks) and individual (age, gender, ethnicity, participation history, interests and roles).

Generalised linear mixed effects models were fitted in most cases, using the glmer function from the lme4 package (Bates et al., 2015) in R (R Core Team, 2020), where the response variable was binary or count data specifying as appropriate binomial or Poisson errors respectively (Table 3). Most models controlled for repeated measures associated with the campaign year (specified as a factor), different channels on social media and email identity for individual link clicks. When modelling awareness and interest of reports, respondent identity was specified as a random effect; this factor accounted for multiple responses from a subset of individuals over time (as identified by those who opted to provide their email addresses) as well as multiple answers to different questions from the same individual within a campaign year (for the interests models only). For the latter models, convergence was added by specifying the ‘bobyqa’ optimiser and in some cases with 100,000 iterations.

The full model was fitted in each case, and a stepwise backwards selection process (using the drop1 function specifying a chi-squared test in R) was then applied to identify the minimum adequate model (MAM). Fitted estimates were then derived for the subset of variables retained in each MAM (using the predictorEffects function from the effects package in R; Fox, 2003; Fox & Weisberg, 2018, 2019).

### 3 RESULTS

#### 3.1 Citizen scientist numbers and composition

The logo survey was completed by 695 people (with most probably being previous NZGBS participants, as there were 659 survey-link clicks directly from an email sent to them). Three-quarters were >30 years old and female; 10% was under 15 years old and 6% was of Māori descent (Supporting Information J). Compared to the design survey, respondents were more likely to be students, and work in environmental management or biological sciences (Supporting Information K).

The design survey received 4,418 responses, equivalent to c. 60% participation rate per year (Supporting Information L). The peer review surveys were undertaken by 10,731 respondents, equivalent to a participation rate of 46% in 2016, increasing to c. 75% for all other years; the number of respondents per year roughly doubled in 2017 and 2018 relative to the preceding year, but then dropped by about 25% in 2019 (cf. 2018). Respondent numbers across all interests and roles dipped in 2016 before increasing and peaking in 2018 (Figure 2); greatest gains were attained for participants who were members of a garden/horticultural society/club, did not relate to any of the environmental interests or roles stated, were students or schoolteachers. Gains were also made across all demographic groups considered between 2016 and 2018, but most then declined in 2019 (Figure 2). Participants within each gender group almost doubled in 2017 and then tripled in 2018 (relative to the baseline). In relation to age, gains were greatest and fastest gains for <20-year-olds but slowest for 40- to 59-year olds, with participation in 2019 only increasing for 20- to 39-year olds. However, the fastest and greatest gains overall and throughout were in relation to ethnicity, with gains in participation by participants of Māori descent (albeit from a very low number at the outset). Participants of unknown ethnicity also increased, with some of this group potentially including people of multiple nationalities (as the early survey design only allowed participants to select a single ethnicity). Taking into account respondents’ NZGBS participation history, gains were achieved across all experience groups from 2016 onwards; notably these gains were greatest for the ‘first timers’, increasing almost sixfold in 2018 (relative to 2016), but this positive trend was not sustained in 2019.

#### 3.2 Citizen scientist design preferences

Interest was high for all six of the listed bird metrics (i.e. >90% of respondents were interested or very interested in each metric), with the highest number of responses and interest levels (98%) being for the bird trend and the most common or rare species options (Supporting Information M). The spatial areas of most interest (≥89%) were national, regional and town/city, with lower levels of interest (68%–82%) for respondents’ own neighbourhoods or gardens.

Infographics (≥76%) were preferred over tables, written summaries or reports as the format for presenting NZGBS results (Supporting Information M). Most respondents preferred to access information about the NZGBS via a webpage or email (≥66%), with newspaper articles (26%), Facebook (≥9%), printed leaflets by post (9%), online blogs (7%) and newsletters (7%) having lower levels of interest. Almost half of the 78 open box comments on media preferences recommended publishing articles in magazines for a local non-government organisation, ornithological society or gardeners.
3.3 Engagement with resources

Total engagement (per campaign year) with social media posts promoting the report resources increased overall, with all metrics (except likes in 2017) more than doubling relative to the baseline year (2016; Figure 3). Total gains for all metrics peaked in 2018, when more people were reached and engaged (eightfold and 25-fold respectively), with a notable 80-fold gain in dialogue. Only the gain in total likes was sustained in 2019. On Facebook, posts published in 2017 and 2018 were most successful at reaching new audiences (Supporting Information N). The number and diversity of institute shares of Facebook posts also increased, with greatest growth for community groups and nature appreciation institutes; at the same time, the proportion of shares by institutes decreased by 50%, signalling a parallel but faster increase in promotional activities by individuals (Supporting Information O).

The number of media articles including NZGBS results roughly doubled in 2017 (compared to the baseline year; Figure 3), and then quadrupled in 2018 (when uptake of the barometer concept and NZGBS graphics also peaked) before dropping again in 2019. Articles reporting local results increased 12-fold from 2016 to 2017, a level that was largely maintained through 2019.

Total webpage views per campaign tripled in the first 3 years (relative to the baseline in 2014) but then increased ≥15-fold in 2018 and 2019 (Figure 3), when user entrances to the webpage via the report resources increased over 230-fold and report downloads increased 10-fold. User access to the online reports via the email links dipped before increasing threefold and then fivefold in 2018 and 2019 respectively (relative to the baseline). Resource views and third-party referrals also increased via the online datastore (up to 40-fold and 93-fold, respectively, in 2019 relative to their 2017 baseline).

The number of NZGBS participants aware of and interested in resources among NZGBS participants tripled and quadrupled from 2016 to 2018, respectively, but then both dipped in 2019 (Figure 3).
3.4 | Predictors of engagement

3.4.1 | Social media

Engagement with individual social media posts was predicted (Supporting Information P) by: resource type (for all engagement metrics except impressions), sharing to the Facebook group (for all except impressions and shares) and campaign year (for likes, comments and URL clicks). Relative to media article links, gains in engaged users were attained for the SOGB report, Story so far resources and, in particular, barplots but not maps; the nature of their engagement activity (measured as likes, comments, URL clicks or shares) was broadly consistent with this pattern (Figure 4). Comments and URL clicks at least doubled when posts were shared to the NZGBS Facebook group. Over 2016–2019, URL clicks increased 10-fold, while likes and comments increased 40-fold.
Individual webpages were more likely to be viewed if they occupied a shallow tier within the nested website and promoted via at least one email link, with a similar pattern detected for webpage entrances but for which the impact of email or social media promotion was more evident (Figure 5: Supporting Information Q). Resource type was the strongest predictor of webpage engagement overall (Supporting Information Q). Compared to technical reports, the ‘Story so far’ resources were much more likely to be viewed, particularly the top 10 infographic, but less likely to be an entry point; for the SOGB resources, the national summary was the most popular (for both views and entrances), closely followed (in descending order) by the report subpages, regional reports, barplots and, to a lesser extent, maps, all of which were also regular entry points.

Email-link entrance probabilities for the webpages were highest for the technical report (c. 70%), closely followed by regional reports, report homepage and species factsheet ones, but only a quarter or less of those for the national summary or report subpages (Figure 5: Supporting Information Q). Email-link entrance probabilities for webpages and total clicks from emails, which both increased over time, were negatively and positively associated with the number of email links provided respectively (Supporting Information Q and R). The probability of an individual link being clicked in an email varied in relation to: resource

**FIGURE 5** Gains in engagement with webpage resources (2016–2019) in relation to the resource type (cf. technical reports baseline, with a resource view probability of 0.02, entrance view probability of 0.03 and email-link entrance of 0.68) and whether the resources were promoted via at least one link on email or in a social media post (cf. none, with entrance view probability baseline of 0.02 and 0.03 respectively). Gains were calculated using the fitted values derived from the MAM (Supporting Information Q)

3.4.2 | Online resources

**FIGURE 6** Gains in email clicks for report links (2016–2019) in relation to the resource type (cf. technical reports baseline, with a click probability of 0.002), link type (cf. subtitle hyperlink, 0.01) and the presence of an accompanying image (cf. no image, 0.03). Gains were calculated using the fitted values derived from the MAM (Supporting Information R)
type, with the most popular (in descending order) being the national summaries, report directories (homepage or subpages) and regional reports (Figure 6); link type, where text and image hyperlinks were at least twice as likely as subtitle ones to be clicked; and an accompanying image, which reduced the likelihood of a link click.

### 3.4.3 Peer review survey

Awareness of results resources was most strongly predicted by participation history, but also varied over time (increasing by c. 25% over 2016–2019) and in relation to the citizen scientists’ age group, roles and interests (Supporting Information S). Awareness was positively associated with previous NZGBS experience (almost quadrupling for those who had participated many times compared to first timers) and, to a lesser extent, age (Figure 7). Participants who identified themselves as environmental society members, working in the biological sciences or environmental management or as citizen scientists were also more likely (in increasing order) to be aware of the resources.

For participants aware of the results resources, interest probabilities were most strongly predicted by resource type and campaign year, with a threefold gain from 2016 to 2019 (Figure 8; Supporting Information S).
Interest levels for all resources (except interactive maps) were at least twice as high as technical reports (in increasing order): videos, summary reports, barplots, maps and factsheets. Interest probabilities also varied in relation to age, ethnicity and participation history. Interest among all age groups was high (>0.7), but was highest for 20- to 39-year olds and lowest for <20- or >59-year-old ones (Figure 8; Supporting Information S). Among the different ethnicities, participants of Asian descent were most interested in the resources. Interest was higher for participants who identified themselves as citizen scientists, teachers or working in environmental management.

Following the release of the new results resources, interest in barplots and maps increased (compared to interest levels stated in the earlier design survey; Figure 9, Supporting Information T) but decreased slightly for the summary reports (cf. the original ‘summaries with text and graphics’ category). Interest also increased for garden society and, to a lesser extent, environmental society members (but dropped slightly for students) as well as those who did not select these three role or interest categories. Interest levels were unchanged for citizen scientists, those working in environmental management or biological sciences or who did not select any of the role or interest categories.

4 | DISCUSSION

Our goal was to embed citizen scientists’ values, opinions and perspectives into a citizen science initiative through a democratic process (Cooper, 2018); this was achieved by inviting NZGBS participants to help select a logo and to inform and peer review the design of new results resources and an associated promotional strategy (Figure 1). This not only empowered participants to contribute directly to the initiative’s governance (Shirk et al., 2012), but also made it more engaging and useful to them and the wider public (Dickson et al., 2012), while creating a sense of collective action (Darnton & Horne, 2013). Over 6 years, NZGBS participants contributed to our process via 15,844 responses to our online surveys (Figure 2). In Table 4, we summarise how our approach for involving NZGBS participants met nine evaluation criteria for a robust participation process (Rowe & Frewer, 2000). Below, we highlight the opportunities and challenges in implementing our democratic process, and the value added from integrating key behaviour change insights into that process, to deliver good outcomes (legitimacy, effective governance and social justice; Fung, 2015).

4.1 | Participation composition

As the composition of participants for the primary NZGBS event is unknown, and participation in our online surveys was determined by self-selection, it is not possible to determine whether respondents to our online surveys were in fact representative. However, the response rate for the design and peer review surveys was high (≥60% in all but one year), with participant numbers increasing and diversifying over time, encompassing a broad range of roles, interests, ages, genders, ethnicities and NZGBS participation histories (Figure 2; Representative criterion, Table 4).

The high response rate to these surveys was likely driven, at least in part, by their presentation, setting and framing. This
TABLE 4  An evaluation of our democratic process in relation to five criteria determining whether it was acceptable to the public and four criteria assessing whether it took place in an effective manner (Rowe & Frewer, 2000)

| Component | Criterion | How our process met the criterion |
|-----------|-----------|----------------------------------|
| Acceptance | Representativeness: Public participants should comprise a broadly representative sample of the population of the affected public | Numbers of people taking part in our online surveys increased and diversified over time, encompassing a broad range of roles, interests, ages, genders, ethnicities and NZGBS participation histories (Figure 2). The response rate for the design and peer review surveys, which were open to anyone submitting their NZGBS data online, was high (≥60% in all but one year). However, despite making an open-call for the logo survey, responses were likely biased towards previous NZGBS participants, as there were a high number of survey-link clicks from the email sent to them. In all cases, however, they were self-selected. |
| Independence: The participation process should be conducted in an independent, unbiased way | The online surveys were designed by the NZGBS’s host organisation, so in that respect were not independent. However, as this paper aims to show these data were reviewed using rigorous methods designed to be objective (including inviting peer review of the surveys designs and seeking social ethics approval for their application). |
| Early involvement: The public should be involved as early as possible in the process as soon as value judgements become salient | Participant input was invited from the outset to inform the development of new brand and results resources for the NZGBS. The form and structure of this scientific citizenship was shaped by our survey design, which enabled dual engagement pathways: structured responses allowed for a fast, standardised evaluation process, which were then cross-checked in relation to the unstructured responses (via open box comments), thus providing a richer understanding of the impact of the engagement process and its value. |
| Influence: The output of the procedure should have genuine impact on policy | The results derived from initial design and logo surveys directed the new resource and media campaign developments, with subsequent ones being used to progressively improve. |
| Transparency: The process should be transparent so that the public can see what is going on and how decisions are being made | A high-level summary of the results from the first design survey and the logo one were reported via the NZGBS website, with subsequent research report summarising the findings of the design and peer review surveys for 2014–2018 published online in 2018, but not actively promoted. Instead, priority was given to delivering to the new brand and results resources and the associated communication strategy and its progressive improvements. Addressing this shortcoming is one motivation for this paper. |

| Component | Criterion | How it was met |
|-----------|-----------|----------------|
| Process | Resource accessibility: Public participants should have access to the appropriate resources to enable them to successfully fulfil their brief | NZGBS participants were invited to take part in the design and peer review surveys immediately after submitting the NZGBS data online, ensuring that they had access to the resources they needed to take part; the anticipated time taken to complete the online survey was stated upfront and all questions were optional, allowing the user to adjust their input in relation to the time they had available. In 2018 and 2019, we added a link to the latest NZGBS report to direct respondents to the resources in case they had missed them. |
| Task definition: The nature and scope of the participation task should be clearly defined | The purpose of the online surveys was stated on the front page, making it clear that its aim was to improve their NZGBS experience in the future. |
| Structured decision-making: The participation exercise should use/provide appropriate mechanisms for structuring and displaying the decision-making process | This paper aims to summarise the process used to develop the report resources and evaluate and improve engagement with them by as wide and diverse an audiences as possible. |
| Cost-effectiveness: The procedure should in some sense be cost-effective | The online surveys were designed to minimise the time investment required by participants but at the same trying to ensure that the process was also as inclusive as possible. |
choice architecture’ design purposefully aimed to minimise the
time and effort required to participate (Behavioural Insights
Team, 2014; Darnton & Horne, 2013; Park, 2020), applying a num-
ber of ‘nudges’ to increase the likelihood of participation (Reddy
et al., 2017): giving participants a timely prompt and making it
easy by seamlessly transferring them to the surveys once they en-
tered their NZGBS data online, while still giving them the choice
of whether to take part or not. The seamless transfer, for example,
removed a small friction cost (or seemingly trivial point of hassle;
Park, 2020) to increase the participation rate by at least 30% (as
evidenced by the drop in participation in 2016 when a separate
survey invitation and link was presented on an interim thank you
page).

Despite making an open-call for the logo survey, responses were
likely biased towards previous NZGBS participants, as there were a
high number of survey-link clicks from the email sent to them, sug-
gestng that link also acted as a nudge.

4.2 Communication and decision-making

Citizen scientist input was invited early in the development process
(thus meeting the Early Involvement Criterion; Table 4). However,
as the form and structure of this scientific citizenship was shaped
by our survey designs, it is important to acknowledge that we held
the professional power to set the structural constraints on the en-
gagement possibilities and consider its implications (Fung, 2015;
Irwin, 2006). To mitigate this influence and give citizen scientists
a strong voice, we used online surveys to: (a) reach and invite a
large diffuse group of participants to take part, while minimising
the disruption and time costs of participation, in a setting where
they had access to the technology and information required to par-
ticipate (thus meeting three evaluation criteria: Representativeness,
Independence and Resource accessibility; Table 4); (b) run user-
friendly surveys via an existing online platform (SurveyMonkey) at
a low cost (Resource accessibility and Cost-effective criteria) and (c)
facilitate participant input via structured responses (ranks or cate-
gory selection), which provided a standardised and rapid mechanism
for evaluating the survey results, as well as unstructured pathways
(open box comments), which provided a more fluid mechanism for
participants to engage and voice their perspectives in a less con-
strained way (Influence, Task definition and Structured decision-
making criteria).

Actively involving the public and NZGBS participants in se-
lecting a logo, for example, gave them ownership from the outset
(Darnton & Horne, 2013). Other benefits of this process were en-
suring that the winning logo would have broad appeal, while also
meeting our design requirements for a simple, clean, memorable,
timeless graphic (Behavioural Insights team, 2014) that leveraged
the links between the public and an iconic, charismatic garden bird
(Smith et al., 2020). This was validated through a review of partic-
ipants’ comments, which expressed a range of values, emotions,
tastes and attitudes (Darnton & Horne, 2013); for example, some
(7%) emphasised their appreciation for the artists and their logo
concepts, while others (2%) contemplated the importance of having
an accurate depiction of bird in the logo (vs. a cartoon) or specifically
signalled (5%) their support, delight, pride, excitement and gratitude
in being part of the selection process and the NZGBS. This feed-
back was valuable not only for cross-checking that the structured
approach met participants needs and interests (e.g. the winning logo
was in fact an accurate depiction of the bird), but also indirectly con-
firming that this survey successfully initiated a sense of collective
action (e.g. participants valued being part of the logo selection pro-
cess, having their voices heard and being part of the wider NZGBS
initiative).

Overall, our research developments (Table 2) focussed on de-
ivering on the resource and communication components that were
most popular (as determined by the design survey; Supporting
Information M). By responding to citizen scientists’ interests in this
way, our project sought to elevate citizen scientists’ perspectives,
which are expected to be more closely aligned to those of the gen-
eral public (Fung, 2015), and thus offset the influence of institutional
powers which historically would have had a more dominant voice
(i.e. institutions directly or indirectly involved in the NZGBS gov-
ernance by way of their NZGBS hosting or partnership roles; Irwin,
2006). In effect, this has enhanced the legitimacy of the
NZGBS’s governance (Fung, 2015), starting to shift it from a con-
tributory model (where a project is designed by scientists, with
the public contributing data) to a more collaborative one (also de-
signed by scientists but with the public contributing data, refin-
ing the project, analysing data and disseminating findings; Shirk
et al., 2012).

Our decision process for prioritising the results’ resource de-
velopments could have been strengthened overall if we had asked
participants to provide more information about themselves in the
initial design survey (e.g. age, gender and previous NZGBS expe-
rience). However, at the outset, we deliberately minimised the
length of the design survey to avoid overburdening participants,
being cognisant of the fact that they had already contributed their
bird count data, while also being uncertain about their appetite
for engaging with our democratic process. However, having access
to that more detailed information would have enabled us to un-
derstand participant subgroups’ interests and needs from the start
(Smith et al., 2020) and thus weight priorities and tailor more effec-
tive engagement strategies to reach, communicate and motivate
key groups (Donovan & Henley, 2010; Scheufele, 2018). In effect,
this would have allowed for a more robust evaluation of whether
our project also delivered social justice—that is ensuring that our
governance mechanism did not advantage some groups over oth-
ers (Fung, 2015).

4.3 Influence and empowerment

The NZGBS development met its intent—to deliver resources and
promotional campaigns that incorporated and reflected citizen
scientist values, interests and needs to successfully build public and participant engagement with results resources (Figure 3)—and in doing so empowered participants to contribute to the governance of a citizen science initiative. Engagement levels increased for social media posts, media outlets and online resources (webpage, data-store and email). The depth of that engagement was also enhanced, with more people actively investigating, discussing and promoting the results resources. Overall, this signals a willing, mutual and beneficial exchange with NZGBS participants and the public, thus meeting the requirements of effective social marketing campaigns (Smith et al., 2020). In effect, our project therefore delivered effective governance (Fung, 2015).

Overall, the key elements shown by analysis to improve engagement were those hypothesised by the behaviour change framework, a combination of individual, social and material factors (Figures 4–9). By making our materials attractive, easy to understand and readily accessible (Behavioural Insights Team, 2014), we motivated and empowered others to promote them. For example, we successfully nudged media outlets to tailor their reporting for local scales and promote our key motivational message (e.g. ‘birds as backyard barometers’) and high-quality ‘pre-canned’ graphics (by including these or links to them in a media release). This is significant because media outlets can act as key influencers, helping build engagement with citizen science results as a social norm, thereby encouraging others to adhere to it (Darnton & Horne, 2013; Park, 2020). Similarly, social media posts were shared by more numerous and diverse institutes, who can also act as key influencers, helping to increase resource visibility and salience, thus shaping engagement as a social norm (Smith et al., 2020). However, as individuals are most likely to influence other people within their own social networks or peer groups, their increased sharing of social media posts was a key achievement (Clayton et al., 2013; Park, 2020).

Valuable insights were gained from the peer review surveys; these signalled that, despite our progress in building public engagement with the results resources (Figure 2), there is still plenty of scope for improving the NZGBS campaign strategies to reach and engage wider and more diverse audiences. Roughly only half of NZGBS participants were aware of the results resources and 80% of them were interested (Supporting Information S), with different suits of factors (relating to audiences composition) predicting resource awareness and interest (Figures 7–8). This highlights the complexities associated with implementing successful behavioural interventions (Reddy et al., 2017), with further refinements required to better tailor and target campaigns to understand, reach and engage key groups (Smith et al., 2020) and ensure that some are not advantaged at the expense of others (to facilitate the good governance goal of social justice; Fung, 2015). Encouragingly, however, as we adapted our campaigns in response to our engagement evaluations and the peer review surveys, awareness of and interest in results resources also improved between 2016 and 2019. Furthermore, compared to the original design surveys, interest levels were overall either unchanged or improved in the peer review ones (Figure 9).

5 | CONCLUSIONS

Citizen science is considered a mechanism for democratising science—facilitating the public and science to work more closely together, thereby empowering the public to engage actively in dialogue and decision-making around environmental issues (Bonney et al., 2015; Irwin, 1995). Citizen scientists are thus ‘people exercising their rights and responsibilities to participate in collective scientific endeavours’ (Cooper, 2018); as citizen science stakeholders, they can be affected by or can directly affect decisions about the governance of a citizen science initiative (Reed, 2008). However, the degree to which citizen scientists participate in the governance of such endeavours will influence the extent to which they can add their values, opinions and perspectives to decision-making (Reed, 2008).

Substantial gains in logic, innovation and invention can be achieved from collective intelligence, where people with diverse backgrounds and skills work together towards shared goals (Woolley et al., 2010). In our case, applying a democratic process to drive participatory governance demonstrated how citizen scientist perspectives can be elevated, to offset the influence of institutional powers which would otherwise have a dominant voice, while also confronting the challenges of mitigating its influence in shaping the engagement process (Fung, 2015; Irwin, 2006). Working together to better meet the needs and interests of citizen scientists and the public successfully built and diversified the audiences engaging with citizen science results.

Integrating behaviour change insights in our purposeful design was a critical factor contributing the success of our initiative, helping us to understand and address the influence of individual, social and material contextual factors on engagement behaviour (Behavioural Insights Team, 2014; Darnton & Horne, 2013; Park, 2020; Reddy et al., 2017). While the democratic process was vital for identifying the diverse needs and interest of individuals, the behaviour change frameworks were valuable in understanding the role of choice architecture, social networks and key influencers, and their complex interactions, in creating the enabling environment required to influence engagement. Adding to this complexity is the different timescales that these factors operate.

Overall, this highlights four key challenges for other citizen science initiatives wanting to make similar gains. The first challenge is the magnitude of effort and resource required to make a real-world difference in terms of engagement, not just with previous participants but also the wider public. Second is the strategic budgeting of the available effort and resourcing that is needed to have biggest impact, a complexity that is generally under-appreciation. Third is recognising that the data visualisation and communication processes needed to make real difference requires progressively building a broad range of skills and capability for learning how to build engagement. Fourth is acknowledging that climbing the social engagement ladder takes time, initially aiming to build awareness of the citizen science results and their importance, then using those resources to build user confidence and capability to engage and eventually actively participate in the citizen science initiative itself.
(Schultz, 2011), and going beyond that to inform, grow awareness and engage the wider public.

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**CONFLICT OF INTEREST**

The authors have no conflict of interest to declare.

**AUTHORS’ CONTRIBUTIONS**

C.J.M. and K.S. conceived the ideas, designed the methodology and collected the data; C.J.M. analysed the data and led the writing of the manuscript. All the authors contributed critically to the drafts and gave final approval for publication.

**DATA AVAILABILITY STATEMENT**

The data presented or analysed in this paper are available via the Manaaki Whenua—Landcare Research online datastore: NZGBS logo development (https://doi.org/10.7931/h9jn-d531; MacLeod et al., 2020); NZGS press releases (https://doi.org/10.7931/s5sx-a784; Spurr, 2020); and NZGBS results engagement (https://doi.org/10.7931/h5b4-8646; MacLeod, 2020).

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