REVIEW ARTICLE

The current state of community-based environmental monitoring in New Zealand

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Abstract: Volunteers engaged in community-based environmental monitoring (CBEM; a form of citizen science) can track changes in species abundance and distribution, measure ecosystem health, and provide data for local, regional and national environmental decision-making. A total of 296 environmental restoration-focused community groups throughout New Zealand responded to an online questionnaire, the objective of which was to investigate the current state of CBEM and contextual factors shaping groups' monitoring activities. Over one-half of groups reported using photo points and 5-Minute Bird Counts (5MBC), with just over one-third (35%; *n*=218) able to quantify their restoration project objectives through management outcome monitoring (e.g. 5MBC + predator control). Ecosystem monitoring toolkits specifically designed for community users were not widely used (19%; *n*=157). Groups managing larger areas (e.g. >8 ha), with medium to high partner support and working on Department of Conservation (DOC) or private land were more likely to be conducting their own monitoring. The number of active members in the group and average age of active members did not significantly influence monitoring activity. 'Random Forest' modelling showed that total project area had the strongest independent influence on whether and how groups undertook environmental monitoring. Major challenges for establishing new monitoring programmes were reported as a lack of funding, people (both 45%; *n*=98), and technical skills (31%). Overall, our results show that significant gains in CBEM could be made by targeting support towards groups managing small areas. The significant positive effect of partner support and constraints imposed by resourcing and technical skills on monitoring activity show that government agencies and science professionals could play a critical role in growing CBEM. Prioritising these collaborative partnerships to design and implement monitoring programmes will maximise the value of monitoring, by meeting groups' and potentially partners' information needs.

Keywords: biodiversity conservation; citizen science; community environmental groups; community-based monitoring; environmental restoration; partnerships; volunteer monitoring

Introduction

In New Zealand, community volunteers are increasingly expected to contribute more effort toward achieving conservation outcomes throughout the country (Department of Conservation 2013). Although research indicates that community environmental groups make a major contribution through weed and pest control and revegetation (Hardie-Boys 2010; Phipps 2011; Peters et al. 2015b), these efforts and their outcomes cannot be quantified due to a lack of fundamental data on groups' monitoring activities.

More than 600 community environmental groups carry out restoration projects across forest, wetland, freshwater and saline ecosystems (Ross 2009; Peters et al. 2015b). A greater public awareness of environmental declines in New Zealand (Hughey et al. 2013) and more people with discretionary time and wealth (Haklay 2015) may be contributing to increasing group and project numbers. The majority of groups are small, self-organising initiatives primarily made up of volunteers although some may employ one or more staff and/or contractors e.g. to assist with weed and predator control (Hardie-Boys 2010; Peters et al. 2015b). Groups' project partners typically comprise resource management agencies (e.g. regional councils and DOC) and non-government organisations (NGOs), with some support also received from science organisations, iwi [tribal groups] and businesses (Peters et al. 2015b). Support is mostly provided in the form of funding, assistance with on-ground works such as pest animal control, and technical advice (Cursey 2010; Hardie-Boys 2010).

A sizeable proportion of community environmental groups carry out some form of environmental monitoring to measure environmental change within their restoration projects (Peters et al. 2015b). Monitoring activities carried out by volunteers (generally with no formal science education) may be termed 'participatory resource monitoring' (Van Rijsoort & Zhang 2005), 'volunteer biological monitoring' (Engel & Voshell 2002), or 'community-based environmental monitoring' (CBEM as used in this study; Conrad & Hilchey 2011). As such, CBEM can be an effective means for tracking changes in species abundance and distribution (Singh et al. 2014) and changes in ecosystem integrity (Hoyer et al. 2014). Monitoring carried out by volunteers forms a key component of citizen science, which has become a popular method of conducting large-scale, long-term ecological studies (Silvertown et al. 2013).

In New Zealand, diverse monitoring toolkits for forests, wetlands, streams, rivers and estuaries have been designed to assist community environmental groups to plan and implement monitoring programmes for their restoration project sites (Biggs et al. 2002; Tipa & Teirney 2003; Handford 2004; Denyer & Peters 2012). Toolkits that bring together recognised protocols can form a bridge between volunteers, the science community and environmental managers by lending credibility and a recognisable structure to volunteers' data (Ottinger 2010).

There is potential for data generated through CBEM to contribute to regional and national-level monitoring programmes as well as international biodiversity-related agreements (Levrel et al. 2010; Danielsen et al. 2014). Substantial savings are possible when the investment in volunteer time to collect data is calculated against savings made in agency administration costs (Levrel et al. 2010). The social outcomes of volunteer participation in monitoring include improved scientific and environmental literacy and greater community involvement in decision-making (Trumbull et al. 2000; Brossard et al. 2005; Crall et al. 2012; Singh et al. 2014). In addition, volunteers' field-based activities can function as a catalyst for enhancing stewardship, while interactions between participants can engender a stronger sense of community and shared purpose (Lawrence 2006). Encouraging volunteers to participate in environmental monitoring requires significant effort (Dickinson et al. 2012). Therefore, gaining a clearer understanding of the challenges faced by volunteers can help to inform programme design and implementation, as well as facilitate recruitment, upskilling and retention of volunteers for projects generally.

Recent studies of community environmental groups in New Zealand provide insights into CBEM by project type (Byrd 2008; Dune Restoration Trust of New Zealand 2012; Bellingham & McGlone 2013) or location (Harrison 2012). However, the study designs differ markedly, precluding the ability to achieve a countrywide overview of CBEM let alone develop measures of restoration outcomes that, in the future, could contribute to biodiversity conservation across groups regionally or nationally. Furthermore, little is known about how widely community environmental monitoring toolkits are used, and how effectively they facilitate the collection of data that support groups' restoration objectives.

To enhance our understanding of community groups' monitoring activities and the wider potential for their monitoring programmes, this study sought to address five questions. The first three relate to defining the current state of CBEM in NZ. A further two questions investigate the contextual factors shaping current CBEM activities.

(1) Which methods are used by groups to measure environmental change within their restoration projects?
(2) How useful are monitoring toolkits?
(3) Which component(s) of their restoration projects do groups wish to monitor in the future?
(4) Are there distinct characteristics that define groups carrying out their own monitoring compared with those not carrying out monitoring?
(5) What are the major challenges for developing community based environmental monitoring programmes?

Methods

Online questionnaire

An invitation to complete an online questionnaire comprising both closed (fixed answer) and open-ended (free text) questions was emailed to 540 community environmental groups throughout New Zealand (Chatham Islands excluded). The questionnaire was accessible to community groups during August and September 2013 (see Appendix S1 in Supplementary Material).

To develop a list of questionnaire recipients, community environmental group email addresses were selected from the following online databases: DOC (Department of Conservation undated-b), Sanctuaries of New Zealand (undated), Royal Forest and Bird Protection Society of NZ (Forest & Bird 2011), Nature Space (undated), and the Waikato River Clean-up Trust (Waikato Regional Council undated). Non-public databases administered by the NZ Landcare Trust, WWF-NZ (Habitat Protection Fund recipients) and Waikato Biodiversity Forum were accessed with permission by the respective database managers. Groups not present on databases were: likely to operate mostly independently of resource management agencies, NGOs and others; small, informal entities; non-computer users; and/or predominantly without restoration-related objectives.

Prior to emailing the questionnaire, the study was widely publicised through various channels (e.g. NZ Landcare Trust newsletters and e-bulletins, the Nature Space website and Waikato Biodiversity Forum e-newsletter). One personalised email containing a link to the questionnaire was sent to each lead group coordinator. Where this address was not known, emails were sent via a third party (e.g. to funding recipients held in internal databases) or to the 'info@' address supplied by the group.

A research blog (www.monicalogues.com) was developed to share findings with study participants and interested parties as well as to provide transparency to the research process. In line with human research ethical approval criteria, names identifying groups and locations were deleted from quotes included in the following pages to maintain research participant confidentiality.

Analyses

The questionnaire comprised mostly closed questions with a set of fixed answers provided. Open-ended questions such as 'Other monitoring methods used (please describe)' were added to selected closed questions to enable elaboration on fixed answers. Data from closed questions were summarised by frequency and are presented below as percentages of total responses received. Responses to open-ended questions were analysed thematically with the emerging themes grouped to enable frequency calculations.

Project partners of community groups comprised DOC, local government, iwi, science providers, business and private contractor(s). These partners provided diverse forms of support, namely project site visits, technical support, data management, on-ground works, cultural advice, funding/sponsorship, administration, and equipment/venue loans (Peters et al. 2015b). To develop an index of low, medium or high partner support per group, the number of project partners reported by each group was combined with the reported number of incidences of support provided to each group. A single partner with a broad mandate for working with community groups may therefore provide a range of support e.g. site visits, assistance with on ground works, equipment loans and so forth. In contrast, partners such as businesses are more likely to provide a narrower range of support and may be unlikely to provide cultural advice. 'Low' partner support was defined as zero to two partners or incidences of support; 'medium' partner support as three to eight partners and/or incidences of support; and 'high' partner support as nine and above partners and/or incidences of support.

A Pearson's chi-square test was carried out on seven individual group and project variables to examine effects on groups' monitoring activities. These activities comprised groups currently carrying out their own monitoring, having monitoring carried out by others (e.g. resource management agencies) or not currently monitoring. Predictor variables comprised groups' reported interest in future monitoring, the number of years the group was established, group size and individual participants' age, size of the project area, perceived level of support from project partners, and project land tenure (see Peters et al. 2015b). The Pearson's chi-square test was carried out using SPSS (Version 21.0; IBM Corp 2012).

It is possible that the predictor variables were not independent and could interact with one another to influence the response (i.e. groups' monitoring activities). To account for this, we sought to model the response using multiple predictor variables. The regression tree approach 'Random Forest' was chosen because it accounts for categorical predictors (since it comprises 'trees' built by making bifurcating splits in the dataset), is commonly used for multinomial classification modelling, and efficiently models interactions between predictors (Breiman 2001).

The Random Forest model was constructed using all seven variables, with the relative influence of each variable recorded within this model as the mean Gini decrease (a measure of how often a variable is used to divide the dataset in building regression trees). The independent effect of each variable was then assessed by calculating the change in classification error rates when each variable was removed from the full model (i.e. the model containing all variables). Finally, models were built using all possible combinations of predictor variables (with a minimum of two predictors). The model with the lowest classification error rate was recorded. For all models, 500 individual trees were fitted. Classification error rate was assessed using cross-validation where the data were divided into subsets of training data (used to build the model) and evaluation data (used to assess classification error rate). For each cross-validation, one-fifth of the data was removed at random as evaluation data and the rest of the data was used as the training set. Random Forest modelling was carried out using the 'randomForest' package in R (Version 3.1.3; R Core Team 2015).

Terminology

'Science-based monitoring' was broadly defined in the questionnaire as the systematic measurement of change over time using science-based methods. While this definition left room for interpretation, it provided sufficient limits for questionnaire participants to distinguish formal methods (such as standardised bird counts) from informal methods (such as general impressions of birds seen or heard) used to gauge environmental change within community groups' projects. 'Monitoring methods' is used as an umbrella term to describe protocols such as 5MBC and methods such as regularly photographing from photo points and surveying vegetation plots.

Results

Of the 540 community groups we contacted, 296 (55%) responded. However, sample sizes we report here vary from question to question as not all questions applied to all groups and some groups chose not to answer some questions. Responses to the question of what best describes the group's science-based environmental monitoring activities, from a set of answers provided, showed that nearly one-half (49%; *n*=282) of the questionnaire participants reported carrying out their own science-based environmental monitoring. A small percentage of respondents (4%) reported employing a contractor to carry out either all, or part of, the group's monitoring activities e.g. 'Bat specific data is done by contractor. Pests and trapping (sic) tunnels done by us'. Over one-quarter of groups (27%) reported that they were either currently not monitoring but that they had done so in the past. The remaining groups (21%) reported monitoring being carried out by others such as DOC and local government.

Monitoring methods used

When asked which monitoring methods were being used by their group or contractor, photo points and 5MBC (Dawson & Bull 1975) were reported as being used by one-half of the respondents (54% and 53% respectively; *n*=143) (Table 1). Vegetation plots and Residual Trap Catch index (Warburton 1996) were reported as used by just under one-half of the groups (45% and 43% respectively). In open-ended responses asking for descriptions of other monitoring methods used (*n*=72), groups reported using both tracking tunnels (36%) and chew cards/wax tags (14%) for indicating the abundance and diversity of pest animals. General flora and fauna surveys (methods used were unspecified) were reported by 29% of these groups. The same number of groups (29%) reported using methods other than 5MBC, such as counting birds using a 'visual census', while others reported using variations e.g. 'One Minute Bird Count', '20-minute bird counts every 6 months', and, 'One-hour bird count'. One group reported combining methods that drew from differing cultural viewpoints e.g. 'We have a mixture of Mātauranga māori [indigenous knowledge] and western science to help us understand our environment so that we can make better informed decisions on the future management of our resources'.

Just over one-quarter of groups (26%; *n*=282) undertook tallies of litres of herbicide used, number of trees planted or predator traps laid out, or by hours of volunteer labour carried

Table 1. Monitoring methods used by community environmental groups or their contractors. Groups could select more than one method (*n*=143).

Monitoring methods used by groups	% of groups
Photo points	54
5-Minute Bird Counts	53
Vegetation plots	45
Residual Trap Catch Index	44
Stream invertebrate counts	23
Lizard counts	18
Foliar Browse Index	12
Don't know	6

out in order to track the effectiveness of their management actions. Monitoring to quantify the outcomes of management action was indicated by groups carrying out predator control (*n*=218) in conjunction with 5MBC (35%). For groups that carried out weed control (*n*=249), management outcome monitoring was indicated by the use of photo points (31%) or by setting up vegetation plots (26%). Nearly two-thirds (62%; *n*=157) reported carrying out monitoring for ≥6 years, either by themselves or using a contractor. Nearly one-fifth of groups (19%) had carried out monitoring over 3–5 years, with 10% of groups in the 1–2 year category.

Monitoring toolkit use

When asked which monitoring toolkit was most used by the group or group's contractor, just under one-fifth of respondents (19%; *n*=157) reported using toolkits specifically designed for community group use. Of the available toolkits, 11 groups used the Forest Health Monitoring and Assessment Kit (Handford 2004), seven groups were using the Stream Health Monitoring and Assessment Kit (Biggs et al. 2002), five groups the Wetland Monitoring and Assessment Kit (Denyer & Peters 2012) and three groups the Cultural Health Index (Tipa & Teirney 2006). Open-ended questions highlighted a range of methods used by community groups prepared by different organisations, for example 'NZ Dune Restoration Trust folder & WWF handbook' and 'DOC resources, field sheets, best practise method'. Other respondents developed their own methods based on existing material e.g. 'Influenced by FORMAK [Forest Health Monitoring and Assessment Kit] methodology, but don't use them formally or frequently' or 'Cultural Health specific to [name of group] developed by our enviro-team'.

When asked to rate responses on a 5-point Likert scale (Likert 1932), over three-quarters of groups (18, *n*=24) using toolkits reported either agreeing or strongly agreeing that overall monitoring priorities were able to be met by using their toolkit(s). Overall, 13 groups (total *n*=21) reported agreeing or strongly agreeing that toolkit design and layout was effective, though seven groups reported a neutral response. The same number of groups (13 out of 21) reported that technical terms and concepts were adequately explained, with five groups reporting a neutral response. Twelve groups (total *n*=21) reported that data entry was straightforward using the templates provided and six groups reported a neutral response. Most groups (19 out of 24) reported either agreeing or strongly agreeing that onsite training in toolkit methods was necessary for collecting quality data. However, group responses for the ability of toolkits to enable scientifically robust data to be produced were varied. Seven groups (total *n*=23) reported a neutral response, while 15 groups reported either agreeing or strongly agreeing. Nearly three-quarters of groups (17 out of 23) reported either agreeing or strongly agreeing to the need for ongoing technical support and training to maintain data quality.

Table 2. Project components that community groups indicated they would like to monitor in the future. Groups could select as many components as were relevant to them (*n*=239).

Components of projects for future monitoring	% of groups
Type and number of birds	62
Establishment of native plants	54
Water quality	41
Spread of weeds	39
Type and number of lizards	39
Type and number of fish	37
Nothing else	14
Change in water level	9

Future monitoring

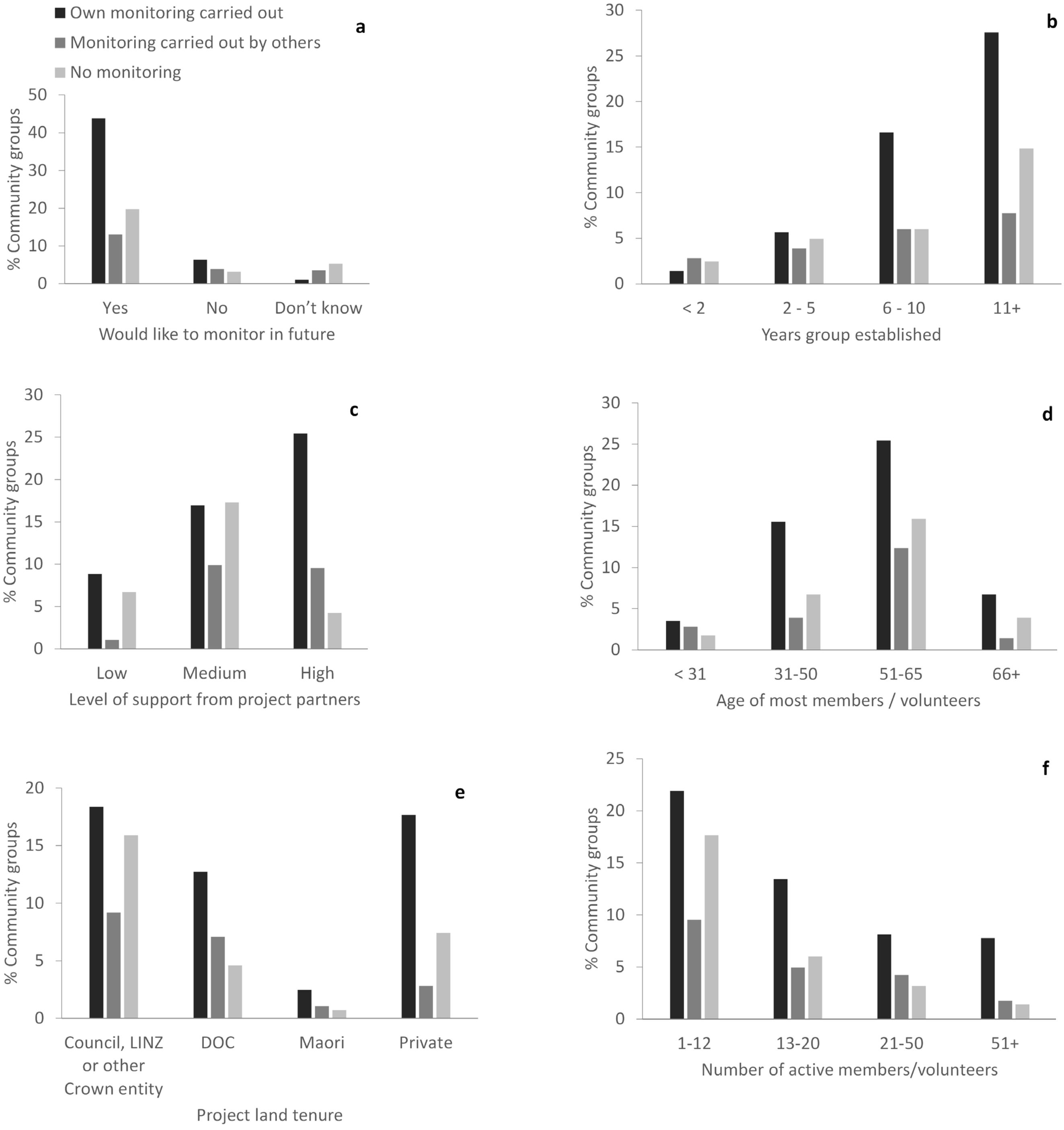
More than two thirds (70%) of all groups (*n*=296) wanted to continue or expand their monitoring programmes in the future. Of the total number of groups that detailed the project components they wished to monitor in the future (*n*=239; Table 2), nearly two-thirds (62%) reported an interest in monitoring birds, followed by native plant establishment (54%). The desire to monitor water quality in the future was reported by 41% of groups.

When asked which other project components groups wished to monitor in the future, open-ended responses (*n*=40) were diverse. An interest in invertebrate monitoring was reported by 23% of groups and bats by 10% of groups. Proposed qualitative studies included surveying walkway users and investigating group effectiveness in changing community attitudes. Basic management-related components included visitor numbers, volunteer hours and the type of work undertaken.

Group characteristics

The views or attributes (seven selected variables from Peters et al. 2015b) of community groups that carry out their own monitoring, engage others (e.g. resource management agencies) to monitor for them or do not currently carry out any monitoring are shown in Figure 1. Future monitoring intentions, the total project area and the level of support received by project partners each had a strongly significant effect on monitoring activity (Table 3). In general, groups planning to monitor in the future, managing project areas >8 ha or with high levels of partner support were much more likely to conduct their own monitoring or engage others to do so. The total length of time the group had been established, along with project land tenure were also significant, though to a lesser degree. Here, groups established for more than five years or working on DOC, private or Māori land were more likely to conduct their own monitoring.

Total project area had the strongest influence in the model containing all variables, followed by number of members and the length of time the group had been established (Table 4). The full model had a classification error rate of 45%, meaning that it misclassified the monitoring response of groups 45% of the time. Total area also had the greatest independent influence while the desire to monitor in the future had the second greatest independent influence. No variable had an independent effect greater than 4.2% (i.e. 4.2% increase in classification error when removed from the full model). This suggests that some of the variables are strongly related and may capture similar information. Only four variables (total project area, future monitoring, years group was established for and number of members) had a positive independent influence on classification accuracy (i.e. classification error increased when they were removed from the full model). This suggests that the remaining variables (age of members, level of partner support, project site land tenure) do not add any useful independent information for explaining groups' monitoring activities. The model giving the lowest classification error rate (39%) included the two



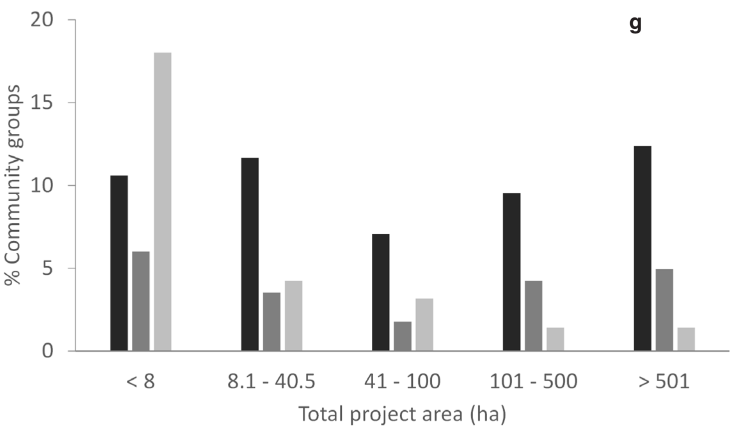


Figure 1. Characteristics of groups carrying out their own science-based environmental monitoring, groups that have monitoring carried out by others and groups that do not carry out any monitoring measured against key group and project variables: (a) whether the group would like to monitor in the future, (b) number of years the group has been established for, (c) level of support provided to the groups from project partners, (d) age group of most members/volunteers, (e) project land tenure, (f) number of active members/volunteers in group participating in at least 30% of all activities such as predator trapping, committee meetings and planting, and (g) total project area in hectares. DOC administered land and other Crown land (i.e. land administered or owned by Crown agencies other than DOC) are distinguished, since groups regard DOC and territorial authorities as separate project partners.

Table 3. Community groups' (*n*=283) environmental monitoring programmes compared with group and project variables. P-values are for Pearson Chi-square tests. Symbols are as follows: p<0.05*, p<0.01**, p<0.001***

Group and project variables	χ 2	Df	p-value
Would like to monitor in the future	23.397	4	<0.001***
Length of time group established	15.154	6	0.019*
Number of active members/volunteers	11.889	6	0.065
Age of members/volunteers	7.829	6	0.251
Total project area	52.322	10	<0.001***
Level of support from project partners	33.370	4	<0.001***
Project land tenure	16.056	6	0.013*

Table 4. Influence of individual variables within the Random Forest model containing all predictor variables (mean decrease Gini) and change in classification error rate (i.e. % groups misclassified) when each variable was removed from the full model (mean % decrease in error). Variables included in the model with the lowest classification error are highlighted in bold. The classification error rate of the full model was 45% while the error rate of the best model was 39%.

Predictor variables	Percentage decrease change in error	Mean decrease Gini
Total project area	4.2	20.6
Future monitoring	2.1	8.7
Length of time group established	1.4	11.6
Number of active members/volunteers	0.7	14.6
Age of members	-0.7	10.8
Level of partner support	-0.7	9.2
Project site land tenure	-2.1	10.4

variables with the greatest independent influence (total area and future monitoring).

Chi-square tests between all seven group and project predictor variables (see Appendix S2 in Supplemental Material) revealed that several predictor variables were strongly correlated, as expected from the Random Forest results. Partner support and total area were significantly correlated (p<0.01), as were partner support with both the number of active members/volunteers and length of time group established (both p<0.05). It is therefore possible that the small independent influence of partner support in the Random Forest model is due to its influence on the response being captured by other variables, notably total area and future monitoring.

Monitoring challenges

When groups were asked to identify the range of challenges they faced for developing a monitoring programme, a lack of human resources (45%; *n*=98) and funds (45%) were most frequently reported. For one group, a lack of people resulted in, '…a toss-up between spending the effort on monitoring and spending it on actually dealing with a problem you are monitoring.' Given these resourcing challenges, the relative value of monitoring was questioned by one group '…you need to be quite clear that data you are spending effort in accumulating is going to tell you what you need to know'. Nearly one-third (31%) of groups reported a lack of technical skills necessary for setting up a monitoring programme. Just under one fifth (19%) reported monitoring as not being the role of the group or monitoring not being necessary for their project as, for example, monitoring was already being carried out in their project area. Not knowing what to monitor was reported as a challenge by 17% of groups and a further 10% of groups reported not knowing who to approach for assistance in setting up a monitoring programme.

Open-ended responses (*n*=28) to the same question provided additional insights into the challenges of setting up a monitoring programme such as a lack of leadership, and the need for partnerships, 'All that we need is someone motivated to drive the set-up of a monitoring programme and get the relevant agencies on board'. The lack of community-oriented tools and methods, e.g. for measuring invertebrates, along with the lack of ability to rescale methods to suit smaller project areas were reported as further challenges. The overall value of monitoring was called into question by one group member, who argued that '…too much time can be spent on monitoring and not enough on killing invasive introduced species'.

Discussion

Monitoring methods used

The first question addressed in this study was how and why groups measure environmental change in their restoration projects. The choice of monitoring methods is likely to be influenced by factors such as groups' scientific literacy (i.e. understanding of science), access to technical support, and number of volunteers able and willing to carry out monitoring. Groups' lack of technical expertise and human resourcing were regarded as creating barriers for setting up new monitoring programmes and are discussed later. The two most commonly used monitoring methods were photo points and 5MBC. With nearly two-thirds of community environmental groups carrying out monitoring for six or more years, data sets are potentially available to supplement local, regional and national studies.

The results show that a minority of groups are monitoring the outcomes of their management actions e.g. by combining pest animal control and 5MBC. This suggests some alignment between the restoration activities carried out – e.g. controlling predators such as ship rats (*Rattus rattus*), brush-tailed possums (*Trichosurus vulpecula*), and stoats (*Mustela erminea*) – the monitoring methods they used and their overall restoration objectives i.e. protecting, restoring or enhancing native flora or fauna (Peters et al. 2015b). However, as outcome monitoring is resource intensive (Clayton & Cowan 2010), it is not surprising that major funders such as DOC primarily require management outputs (e.g. volunteer hours, area treated with possum control) to be reported (see Department of Conservation undated-a). Byrd's study (2008) also highlights the lack of quantitative measures used in publicly funded projects to enhance biodiversity on private land. Although output monitoring reduces groups' analysis and reporting requirements, there is a risk that funders' requirements may determine the design of groups' monitoring programmes *in lieu* of measuring restoration management outcomes.

Monitoring toolkit use

The second question considered the use of monitoring toolkits, designed to make science more accessible to community groups with little or no formal science education. Despite the limited number of toolkit users in this study, most users reported being able to meet their monitoring priorities and produce robust data by using toolkits; providing evidence of the toolkits' utility. On the other hand, low use may result from a perception that current toolkits will not meet groups' monitoring needs, a lack of knowledge of available toolkits, or ongoing support requirements (e.g. toolkit methods training and field support). Handford (2006) suggests that resource management agencies adopt toolkits and become points of contact for community users of them. With toolkits embedded in an institutional structure, more coordinated support in the form of technical advice and training could be provided. Additionally, adapting toolkit content to suit current technology may also improve uptake by enhancing efficiency (e.g. entering data online), improving toolkit accessibility (e.g. making content more widely available), providing real-time data, and facilitating data analysis both within and between projects (e.g. by being able to visualise results immediately) (Newman et al. 2012).

Future monitoring

The third question asked which project components groups wanted to monitor in the future. More than two-thirds of all community environmental groups reported wanting to continue or expand their monitoring programmes. Bird monitoring is a priority, with the importance of birds overall demonstrated by the increased number of avian translocation proposals by community groups independently or as community-DOC partnerships (Cromarty & Alderson 2012). Species translocations to habitats where they are locally extinct or in low numbers is a recognised approach to ecological restoration and groups' desire to increase their bird monitoring activities may contribute to filling knowledge gaps concerning the post-release survival of translocated birds (Parker et al. 2013).

There was a sharp increase in groups reporting a desire to monitor water quality in the future (41%; n=296) reflecting the national focus on widespread declines in freshwater quality in New Zealand (Parliamentary Commissioner for the Environment 2013) and heightened public awareness of these issues (Hughey et al. 2013). The government has signalled efforts to improve freshwater management through legislation that includes processes for the community to participate in setting goals for freshwater quality outcomes (Ministry for the Environment 2013). Community environmental groups with a science-based understanding of water quality trends in their local area may play a strong role in defining community values for freshwater (Ministry for the Environment 2013). Although a third version of the Stream Health Monitoring and Assessment Kit was in development at the time of writing (A. Wright-Stowe, NIWA, pers. comm.), toolkits supported by agencies and science providers for measuring the water quality of lakes and rivers (with the exception of the Cultural Health Index) are still required to facilitate wider community group involvement in freshwater data collection.

Group characteristics

The fourth question asked if specific characteristics defined groups carrying out their own monitoring compared with those not monitoring (i.e. where monitoring is carried out by others such as resource management agencies or not at all). Determining key differences has implications for the type and level of support provided by project partners.

Few groups established for ≤5 years carried out monitoring, suggesting that the immediate demands, e.g. of weed and predator control and revegetation (Peters et al. 2015b), were prioritised over baseline data collection. Developing monitoring programmes that begin with baseline monitoring are likely to require stronger support from project partners. A partnership approach from the outset may also create opportunities for designing monitoring programmes that meet both groups' and partners' information needs. In the USA, community-generated water quality data are used by resource managers to determine recreational use standards, thus creating a direct link back to community members, while science professionals use community data in meta-studies for investigating broader trends (Hoyer et al. 2014). Although regional councils and DOC already support groups for advisory and operational activities (Peters et al. 2015b), science professionals may play a stronger role in facilitating community monitoring programmes given the direction from government to strengthen engagement between scientists and the wider public (Ministry of Business Innovation and Employment et al. 2014).

The statistical analysis of relationships between predictor variables drawn from group and project characteristics showed that groups carrying out monitoring were most likely to receive a medium to high level of support from project partners, underscoring the necessity for this input to sustain groups' monitoring programmes. There were strong correlations between total area and partner support demonstrating that groups operating large-scale projects are likely to work with diverse partners and, equally, that partners are likely to prioritise large-scale projects. This highlights the scope for greater input into medium to smaller scale projects that collectively could yield useful data on species distribution and population numbers (Topia & Gardiner 2014).

Monitoring challenges

Finally, groups were asked to identify challenges for establishing monitoring programmes. In order for project partners to better utilize groups' monitoring data, e.g. to support conservation management decision-making, the lack of funds, volunteers and technical expertise must be addressed. The interdependent nature of these challenges highlight the difficulty groups have of understanding complex and diverse ecosystems and of managing the factors that influence monitoring programme design and implementation.

Nearly two-thirds of groups had been monitoring for ≥6 years, clearly demonstrating that groups view their projects as long-term undertakings and that achieving their project objectives requires ongoing commitment. Although groups' data are primarily used *in situ*, e.g. for managing their own projects (Peters et al. 2015a), providing more cohesive evidence that outcomes from CBEM activities across community groups demonstrate improvements in biodiversity may strengthen the case for more secure, longer-term funding.

Groups typically have a small core of active participants, which requires monitoring to be prioritised. Ageing participants may struggle with the physical demands of monitoring e.g. operating long predator monitoring lines in rugged terrain (Peters et al. 2015b). Although new technology such as self-setting traps may save labour, groups may also benefit from strategic collaboration with other local groups to pool limited resources and share expertise (see Whangarei Heads Landcare Forum 2010). An alternative model is where the coordination of monitoring efforts is provided by project partners, enabling data to be used by all parties (New Zealand Landcare Trust 2013; Topia & Gardiner 2014). Groups' lack of technical skills may signal the need for improved access to training programmes, that training programme content requires modification to better suit groups' information needs, or that the frequency of training opportunities needs to be increased. While context-specific training for community members has been shown to improve participants' scientific literacy (Crall et al. 2012), increasing opportunities for informal knowledge exchange (e.g. where groups can share practical knowledge and experience gained through their own monitoring programmes) may also benefit groups (Fernandez-Gimenez & Ballard 2011).

Future research

As groups' restoration project objectives have been previously studied (Peters et al. 2015b), a more detailed investigation of the alignment between groups' monitoring methods and their project objectives is warranted. Monitoring needs to be carefully targeted, with adequate power (precision) for its purpose, while still being cost-effective. Given the complexity of science-based monitoring for community volunteers with little or no formal science training, opportunities for strengthening groups' technical skills and overall scientific literacy may need to be explored. Further research could also explore drivers influencing community groups' selection of monitoring methods e.g. illuminating how and why methods such as bird counts are modified by groups. This would enhance our understanding of groups' monitoring priorities as well as assist with designing appropriate forms of support that ensure that data are robust and meet data users' needs.

Conclusion

This study provides a national overview of CBEM and demonstrates that a large number of community groups have well-established and highly varied monitoring programmes in place to measure change within their environmental restoration projects. The characteristics that distinguish groups undertaking monitoring from those not monitoring have implications for the type and level of partner support provided. Although ongoing support for groups is vital particularly for large scale projects, encouraging groups currently not monitoring to do so should be considered. In this respect, toolkits form a useful means of promoting the importance of monitoring and guiding programme development by providing standardised methods suitable for community use. Investing in content design and delivery upgrades as well as training and support for users would ensure that methods are understood and applied with rigour. Prioritising long-term funding to enhance collaboration between groups, scientists and environmental managers would also ensure that study design is robust, the monitoring meets group and project partners' needs, and that data use may be maximised through better integration with agency data sets.

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Supplementary Material

Additional supporting information may be found in the online version of this article:

Appendix S1. Online questionnaire emailed to 540 community environmental groups.

Appendix S2. Chi-square tests between group and project predictor variables.

The New Zealand Journal of Ecology provides online supporting information supplied by the authors where this may assist readers. Such materials are peer-reviewed and copy-edited but any issues relating to this information (other than missing files) should be addressed to the authors.

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