On the merits and pitfalls of introducing a digital platform to aid conservation management: volunteer data submission and the mediating role of volunteer coordinators

Abstract

Against a backdrop of accelerating digital innovation in nature conservation and environmental management, a real-world experiment was conducted with the research aims of assessing: 1) the effects of introducing a digital data-entry platform on volunteer data submission; and 2) the extent to which coordinators influence digital platform use by their volunteers. We focussed on a large-scale volunteer-based initiative aimed at eradicating the non-native American mink (*Neovison vison*) from northern Scotland. This geographically dispersed conservation initiative adopted a digital platform that allowed volunteers to submit records to a central database. We found that the platform had a direct and positive effect on volunteer data submission behaviour, increasing both the number and frequency of submissions. However, our analysis revealed striking differences in coordinator engagement with the platform, which in turn influenced the engagement of volunteers with this centrally introduced digital innovation. As a consequence, the intended organisation-wide rolling out of a digital platform translated into a diversely-implemented innovation, limiting the efficacy of the tool and revealing key challenges for digital innovation in geographically-dispersed conservation initiatives.

Highlights:

- Digital innovation is often enthusiastically employed but effects poorly studied
- We build a data-entry platform to assist a geographically-dispersed organisation
- The centralised platform increased data submission by volunteers
- The digital orientation of project coordinators influenced volunteer platform use
- Digital tools need be introduced with caution and attention for mediating effects

Key words: Volunteer-based management; Technological innovation; Environmental citizen science; Human-computer interaction; Invasive species control; Volunteer coordination.

1. Introduction

Environmental management increasingly makes use of digital technologies (Arts et al., 2015; Bakker and Ritts, 2018; Sullivan et al., 2014). The prominent use of the internet in environmental citizen science is a clear example (Dickinson et al., 2010; Kelling et al., 2015; Kobori et al., 2016). Digital technologies provide new and often user-friendly ways of generating, handling, organising, analysing, and communicating data and information (Chapron, 2015; Stein, 2008). The promise of more data and opportunity to scale up operations has led many conservation organisations to adopt advanced digital hardware and software such as drones and apps (Galán-Díaz et al., 2015; Miller-Rushing et al., 2012). While the practical benefits may be taken for granted, they are not guaranteed (Druschke and Seltzer, 2012; Gallo and Waitt, 2011; Jordan et al., 2012). For example, the interpretation of citizen science data is often clouded by concerns regarding their accuracy, quality and reliability (Kremen et al., 2011; Wiersma, 2010). Also, without online tools that engage and are well aligned with project goals, projects may fail to acquire sufficiently large datasets over prolonged periods of time (Van der Wal et al., 2016; Wald et al., 2016). New tools may change the nature of a volunteers' engagement with conservation, and this may in turn be influenced by how coordinators of conservation volunteers (hereafter conservation coordinators) decide to introduce such tools to their volunteers. This paper engages that topic. Social processes are known to strongly influence volunteering (Asah and Blahna, 2012; Bruyere and Rappe, 2007; Pagès et al., 2018). Yet, in spite of the 'mission-driven' character of nature conservation (Mace, 2014), many digital innovations in this realm are introduced without their social impacts being studied (Arts et al., 2015). Here, we focus on a common innovation in nature conservation, namely the introduction of a new

55 data reporting platform, and set out to address two research aims: 1) to assess whether
56 volunteer data submission (i.e. number and frequency of submission, and number of
57 records in a single submission, a.k.a. batch size) changes with the use of a digital platform;
58 and 2) to determine to what extent coordinators influence the usage of a digital platform by
59 their volunteers. The first aim was addressed by means of a randomised experimental set-
60 up linked to a real-world nature conservation case (Section 3.1). The second aim was
61 investigated through mixed qualitative methods (Section 3.2).
62

63 **2. Materials and methods**

64 ***2.1 Context of study***

65 This study revolved around the Scottish Mink Initiative (SMI), one of the world's largest
66 volunteer-based invasive species management programmes in terms of area covered
67 (approximately 29,500 km^2). The objective of the initiative was the detection and
68 subsequent removal of the invasive American mink (*Neovison vison*, mink hereafter) across
69 northern Scotland (Bryce et al., 2011; Melero et al., 2015). Volunteers were recruited by SMI
70 to adopt and operate one or more rafts used for monitoring. The rafts were required to be
71 checked every 10-14 days, when practical. If mink were detected, then volunteers could
72 request and operate a trap. At the time of study, volunteers were directed by four full-time
73 employed coordinators, each operating in regions of different size and geography (Figure 1).

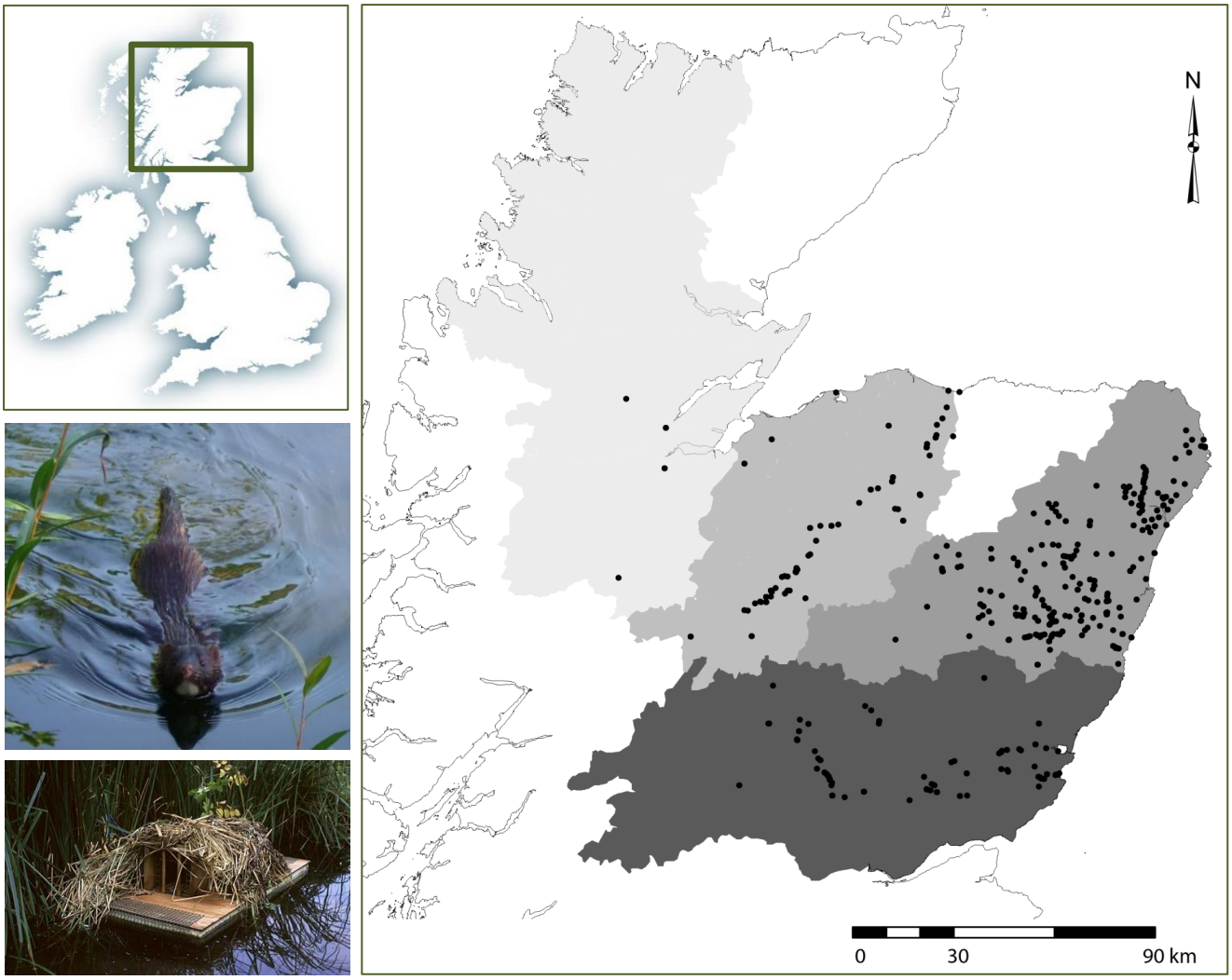

Figure 1. Images of an American mink and raft, and maps of northern Scotland with mink captures (black dots) from April 2011 to January 2013 in the four experimental focal regions of the volunteer coordinators (C), from lightest grey to darkest grey respectively: C-Highlands, C-Cairngorms, C-Aberdeenshire, and C-Tayside. Mink control also took place in the area in white surrounded by grey but was part of a separate funding scheme.

Volunteers were assigned to the coordinator operating in their area; there was no option for volunteers to choose their coordinator. Volunteers were asked to report all mink signs recorded on their raft to their regional coordinator. Typical means for doing so included phoning, texting, emailing, and face-to-face interaction. Raft check records were either 'absence records' (no signs of mink) or 'positive records' (footprints or scats). To assess

whether volunteer data submission changes with the use of a digital platform, a digital data-entry submission platform was developed with SMI that allowed volunteers to report to a central database through a web browser (on e.g. a desktop, laptop, mobile phone or tablet) (Figure 2).

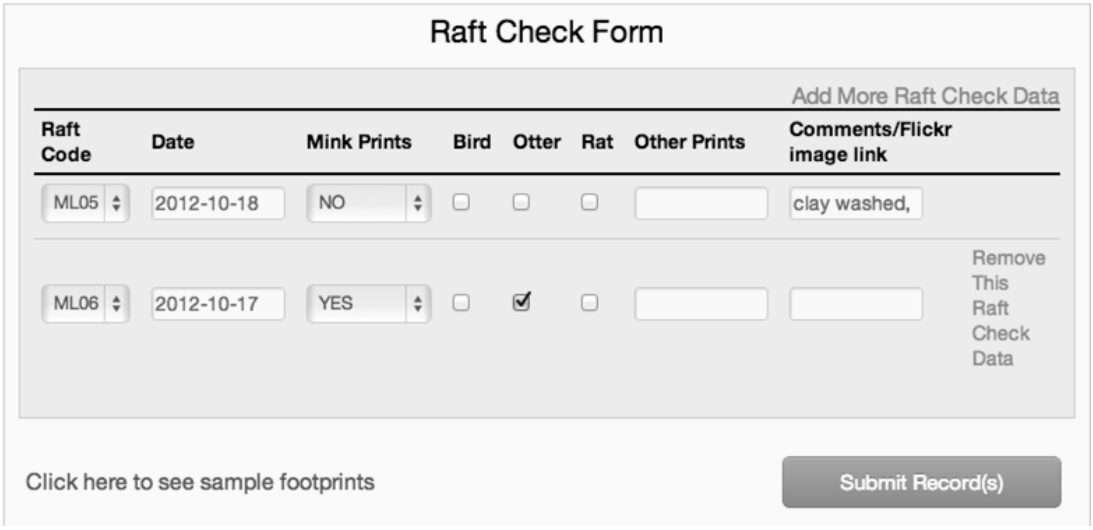

Figure 2. Screenshot of the 'raft check form' as part of the newly introduced digital submission platform.

The primary goal for SMI with respect to new submission platform, was to improve efficiency of data collection and data submission in this geographically dispersed initiative. Of particular importance, was the need for volunteers to report that mink were not present upon a raft being checked, a metric of success of the project. The platform was tested and improved upon for over a year, and then launched as an experiment. Thereafter, SMI continued on a smaller funding base with a changed organisational structure, providing a natural end to us studying the digital innovation.

2.2 Experimental approach

At the start of the experiment, all volunteers conducting raft checks were randomly divided into a control group (one-third) and treatment group (two-thirds), using the Excel randomization function. Control volunteers were not informed about the online platform. Treatment volunteers were invited (up to 3×) to use the platform (i.e. submit raft checks online), receiving full instruction via email or hard copy letters depending on their preferred mode of communication. Coordinators were asked to take into account treatment allocation when dealing with their volunteers. Three control group volunteers became aware of the platform through interactions with treatment group social acquaintances and requested permission to use it. Some shifting was expected and permission was granted. During the 9.5 months long experimental period, 60 different volunteers (15 control, 45 treatment) contributed 776 raft check submissions. The experimental approach led to four distinct groups (Table 1).

Table 1. Groups and volunteer platform usage for each coordinator (cells with a darker background indicate treatment group). Sum of submissions by all volunteers indicated in subscript.

	Coordinator Tayside	Coordinator Highlands	Coordinator Cairngorms	Coordinator Aberdeenshire	*Total*
A. Control group but using platform	**2** 42	**0** 0	**1** 20	**0** 0	**3** 62
B. Treatment group and using platform	**8** 97	**4** 81	**9** 271	**4** 91	**25** 540
C. Control group and not using platform	**6** 17	**6** 50	**0** 0	**0** 0	**12** 67
D. Treatment group but not using platform	**14** 41	**5** 53	**1** 13	**0** 0	**20** 107
Total	**30** 197	**15** 184	**11** 304	**4** 91	**60** 776

123 Differences in submission were tested for by contrasting control (A+C) and treatment (B+D)
124 groups, and two specific further comparisons (B vs. C and B vs. D groups, respectively).
125 These specific comparisons promised to be the most meaningful ones as a consequence of
126 our experimental set-up – paying heed to a real world situation with autonomous, in-situ
127 participants – because they denoted more directly the actual effects of the platform.
128 Submission behaviour was appraised on the basis of three indicators: 1) number of raft
129 checks submitted per volunteer; 2) frequency of submission, i.e. the number of times each
130 volunteer logged in to submit their data, with a higher frequency pointing at a more
131 convenient and direct way for volunteers to submit data; and 3) mean batch size, i.e. the
132 number of raft checks submitted per volunteer divided by their frequency of submission,
133 with low mean batch size indicating less delay between raft checks and submission of
134 records. This led to a total of nine statistical models (three indicators x three pre-defined
135 contrast). Differences in the number and frequency of submissions were tested for using
136 GLMs with negative binomial error distribution and log-link function to model the over-
137 dispersed count data appropriately. Differences in mean batch size were also tested for with
138 GLMs but using a gamma distribution with log-link as the coefficients of variation were
139 positive, continuous, skewed to the left and increasing with the mean (Bates et al. 2015). All
140 GLMs were run using the lme4 package of R 3.2.2. For each volunteer submission behaviour
141 indicator three global models were built, one per pre-defined treatment group comparison
142 (control vs. treatment, B vs. C or B vs. D). All models included coordinator as categorical
143 factor, to account for their effect on volunteer behaviour. Initial fixed effects in the models
144 were therefore group, coordinator and their two-way interaction. Subsequent model
145 simplification was based on minimum AIC selecting models with $\Delta AIC < 2$ (Table S1).

2.3 Qualitative social analysis

To investigate how coordinators engaged with the new digital platform, we determined how they approached their role in relation to SMI and the platform, using the concepts of respectively 'organisational orientation' and 'innovation orientation' (cf. Pruden, 1973; Tibbles et al., 2008). Three sources of data were used:

- Semi-structured, face-to-face interviews (n=9, mean duration: 39 minutes) conducted during the platform's development phase with the coordinators participating in the experiment (n=4), people who had previously acted as coordinator (n=2), a coordinator operating in a different Scottish region (n=1), a scientific advisor to SMI (n=1) and SMI's director (n=1). These interviews were aimed at understanding the methods and social structures of the organisation, SMI's relationship with its volunteers, and the perceived potential role of digital technology. For reflections on the impact of the platform and volunteer-related matters, follow-up interviews were conducted with SMI's director and coordinators at the end of the experiment period (n=5, mean duration: 37 minutes). All 14 interviews were recorded and transcribed verbatim.
- *Email communications with coordinators* concerning questions posed after the end of the experiment relating to: best volunteers, impacts of platform on e.g. volunteer retention and volunteer performance.
- *Coordinators' diaries* to capture all daily interaction with their volunteers for two months. Diary entries comprised duration, medium and initiator of contact, as well as the reason for contact. This resulted in 13 handwritten A5 pages by coordinator C-Aberdeenshire, 45 by C-Cairngorms, 4 by C-Highlands and 31 by C-Tayside.

Analysis of these sources of data consisted of qualitative classifications of the text; common themes in the data were abstracted by means of deductive coding using NVivo software (cf. discourse analysis – Hajer et al., 2006; Jørgensen and Phillips, 2002; Thomas, 2006). Subsequently, as an inductive part of the analysis (Fereday and Muir-Cochrane, 2006), these themes were used to assess the coordinators' organisational and innovation orientation using the following two typologies:

- Organisational orientation (typologies of employees – McCroskey et al., 2005; Pruden, 1973): *upward mobiles* (react positively to key managerial decisions [such as the introduction of a digital platform] and can thrive in the new situation); *indifferents* (by and large uncommitted to a key managerial decision); *ambivalents* (show signs of both positivity and lack of commitment).
- Innovation orientation (perspectives on Information and Communications Technology (ICT) – Arts et al., 2016; Bekkers et al., 2006; Siguaw et al., 2006): *technological perspective* (ICT approached as a set of tools to achieve specific goals); *organisational perspective* (emphasising capacities of ICT to process information, organise work and improve communication); *conceptual perspective* (ICT used as a lens to understand practices).

3. Results

3.1 Experimental approach

Best models for all three indicators tested for (number of submissions, frequency of submission and mean batch size) included (volunteer) 'group' and 'coordinator' but not

their interaction (all ΔAIC > 4; Table S1). Treatment volunteers (group B+D) provided 1.6× more submissions, and did so 1.8× more frequently than control volunteers (group A+C), though neither odds-ratio was significant (Figure 3; Table S2). Most prolific were control group volunteers who nevertheless used the platform (group A, n=3), but their low number precluded statistical testing. Treatment volunteers using the platform (group B) generated 3.9× more submissions than control volunteers not using the platform (group C) and 4.0× more than treatment volunteers not using the platform (group D) (Figure 3; Table S2). With regard to frequency of submission, treatment volunteers using the platform (group B) scored again higher, with 4.4× (vs. group C) and 4.5× higher values (vs. group D). As a result, the mean batch size was 1.7× lower in the treatment group compared to the control group. A similar (1.6×) yet non-significant difference was found when comparing batch sizes of treatment volunteers using the online system (group B) with control volunteers not using the system (group C) (Figure 3; Table S2).

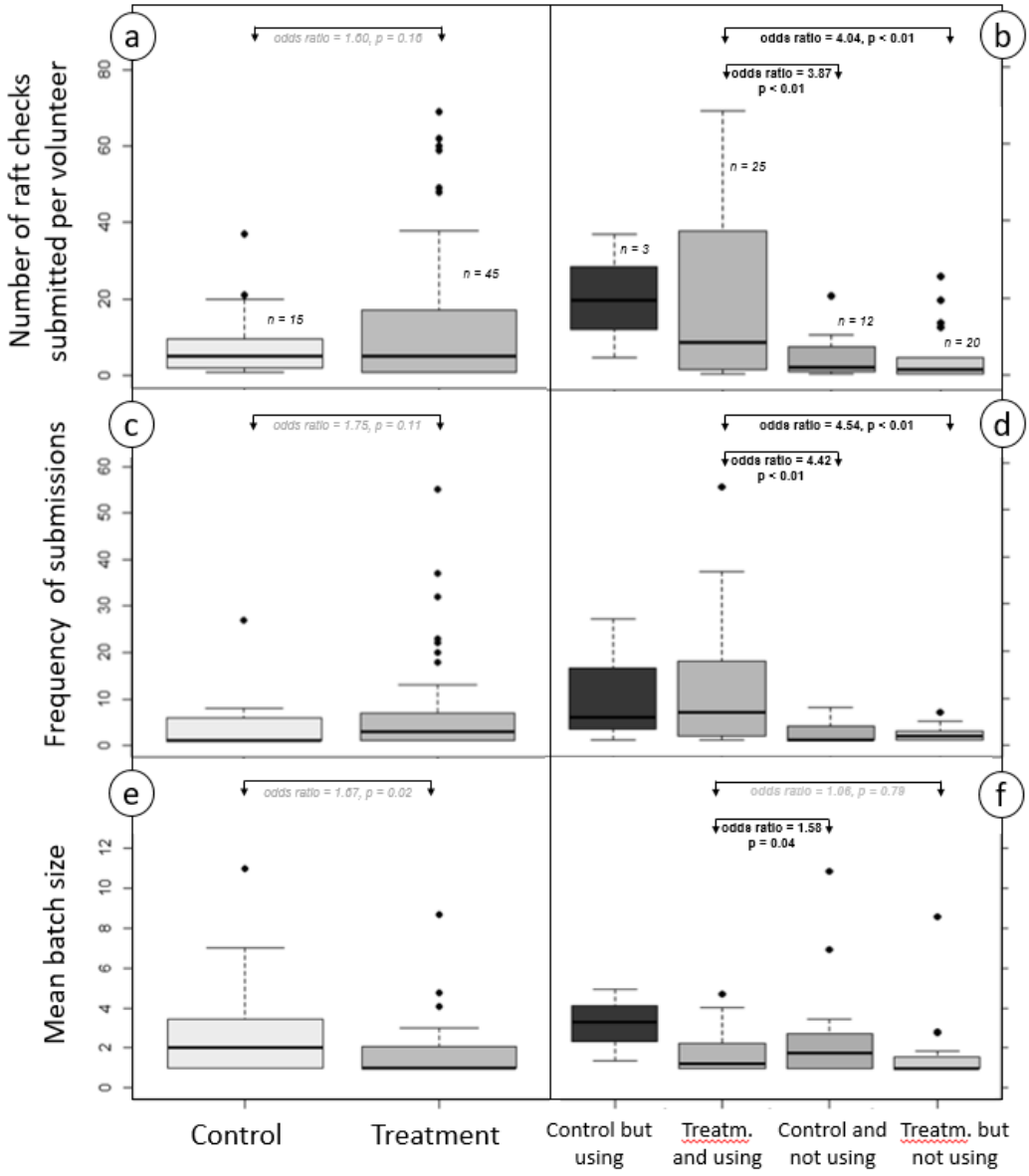

Figure 3. Boxplots of number of raft checks submitted per volunteer (a, b), frequency of submissions (c, d) and mean batch size (e, f). Panels a, c and d provide summary statistics for the two intended treatment groups (control vs. treatment) and panels b, d and f for the four realised treatment groups. Depicted are the median, 1st and 3rd quantiles, 95% confidence intervals (whiskers) and outlying points. Summary test results are given for the respective contrasts; those in black indicate statistically significant differences between groups.

Striking differences emerged when inspecting volunteer submissions across the four coordinators (Figure 4; Table S2). C-Aberdeenshire had very few associated volunteers

(n=4), all of which were of the treatment group (100%) and indeed using the web portal as such (group B). C-Cairngorms had considerably more associated volunteers (n=11), and those were primarily also from the treatment group B (90%) and none from group C, the 'offline' control group. The other two coordinators (C-Highlands and C-Tayside) had both more volunteers (n=15 and n=30) and fewer of them were from the treatment group (44% and 36%). This included several volunteers who submitted a low number of records once or twice, which significantly reduced the average number of submissions per volunteer and frequency of submission compared to the other two coordinators (Fig. 4, Table S2). In fact, the coordinator with the largest number of volunteers (C-Tayside, n=30) had also the greatest number of volunteers from the control group, submitting occasionally and via the coordinator.

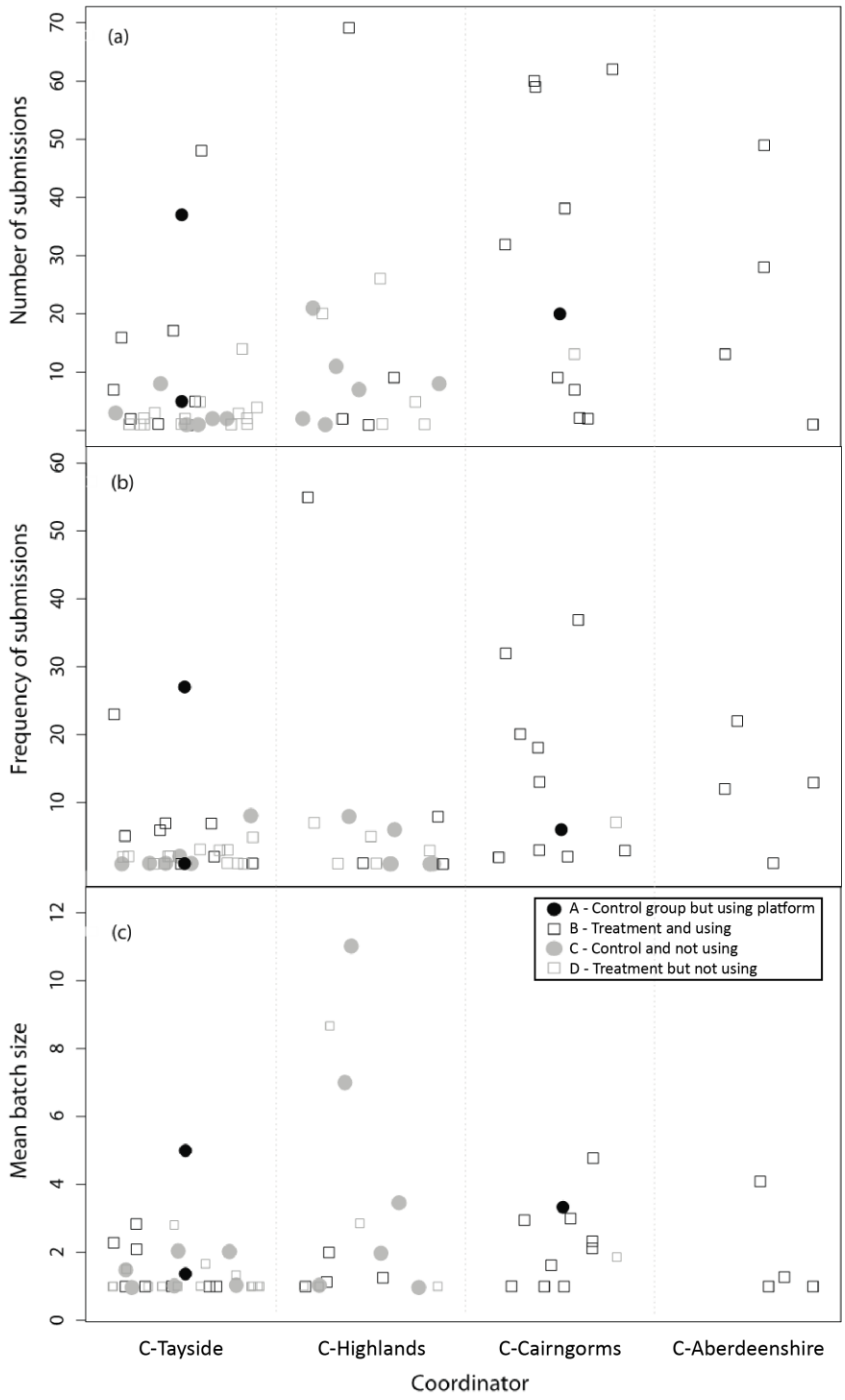
(a)
Number of submissions
(b)
Frequency of submissions
(c)
Mean batch size
A - Control group but using platform
B - Treatment and using
C - Control and not using
D - Treatment but not using
C-Tayside
C-Highlands
C-Cairngorms
C-Aberdeenshire
Coordinator

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Figure 4. (a) Number of volunteer submissions, (b) frequency of submissions and (c) mean batch size, by coordinator (C-Tayside, n=30; C-Highlands, n=15; C-Cairngorms n=11; and C-Aberdeenshire, n =4), and in relation to the experimental treatment categories (A=Control group but using platform, n=3; B=Treatment group and using platform, n=25; C=Control group and not using platform, n=12; and D=Treatment group but not using platform, n=20). Values on the x-axis are slightly offset to aid visualisation. Points represent individual volunteers.

3.2 Qualitative social analysis

The intention of SMI's director was to roll out the digital platform uniformly across northern Scotland. The director observed that "it is extremely difficult for us to be able to get data and be able to manage such large areas, especially in a strategic way". Moreover, he believed that the platform would be key to the continuity and stability of the organisation: "All the future work that we are doing (...) is going to be through the [platform]." Our qualitative analysis showed, however, that there were strong differences among coordinators in their engagement with the platform. This was underpinned by the different coordinators' organisational and innovation orientations. Five dimensions of 'organisational orientation' emerged from the qualitative data, and for each dimension, coordinators demonstrated diverging views (Table 2).

Table 2. Classification of coordinators in relation to organisational and innovation orientations.

	Coordinator			
	C-Tayside	C-Highlands	C-Cairngorms	C-Aberdeenshire
Organisational orientation	*Upward mobile:*	*Ambivalent:*	*Upward mobile:*	*Ambivalent:*

- Own role within organisation	Compliance with organisational agreements and rules	Catching mink	Establishing volunteer networks	Catching mink and using volunteers where to do this
- Importance of data	Promoting collection of records	Little emphasis on data collection	Promoting collection of records	Little emphasis on data collection
- Ideal volunteer	Complies with organisation	Catches lots of mink	Keeps in touch	Catches lots of mink
- Interaction with volunteer	Making it easy for them	No news is no mink	Putting communication onus with volunteers	No news is no mink
- Volunteer feedback about the platform	Both positive and negative responses	Possibly little used	Both positive and negative responses	Not keen on new technology
Innovation orientation	*Technological perspective:*	*Organisational perspective:*	*Organisational perspective:*	*Technological perspective:*
- Own interaction with platform	Proficient	Proficient	Proficient	Struggled to operate
- Expectations and opinion of platform	Still double-checking data but better than before	Reduced workload, stressed platform importance	Reduced workload, improvements needed but helped structuring SMI	Reduced workload, important for uniform approach to data collection

First, regarding their *own role within organisation*, C-Tayside put emphasis on compliance with the organisational agreements and rules conveyed by the director. C-Highlands was primarily focussed on catching mink himself. The same applied to C-Aberdeenshire who approached volunteers largely to help decide where to concentrate his efforts. C-Cairngorms stressed the importance of establishing self-operating volunteer networks to minimise future coordinator input.

Second, on the *importance of data*, C-Highlands and C-Aberdeenshire put relatively little emphasis on data collection by volunteers; for them data was foremost a means to catching mink. C-Tayside and C-Cairngorms, on the other hand, kept promoting the submission of 'absence records' – deemed important to demonstrate mink absence and 'active volunteer' presence.

Third, on what comprises an *ideal volunteer,* C-Tayside described this as an eager volunteer who checks rafts frequently and communicates findings timely and accurately. Moreover, to her, ideal volunteers understand the "bigger picture" and "do things the way they are supposed to". C-Highlands said: "as far as I am concerned the best one is always the one that catches a lot of mink". For C-Cairngorms, the ideal volunteer was one that is keen and keeps in touch, while C-Aberdeenshire described the ideal volunteer as someone with a vested interest in the environment, who is "always vigilant".

Fourth, regarding *interaction with volunteer*, C-Tayside mentioned: "If you want people to do something you have got to (...) give it to them on a plate". This contrasted starkly with C-Aberdeenshire and C-Highlands who assumed that "if you do not hear anything there is nothing out there" (C-Highlands). C-Cairngorms explained that she generally speaks to "every single person in the same way", and that she tried to encourage volunteers "to contact me when they need to, rather than me having to contact [them]".

Fifth, *volunteer feedback about the platform* was the final dimension. C-Tayside and C-Cairngorms received mixed messages, with some volunteers submitting more records now than they did before, but with other volunteers who "do not want to have to sit in front of the computer" (C-Tayside). C-Highlands said he only received feedback from two volunteers about the platform, and concluded "I am not sure if [volunteers] actually use [it]". Likewise,

C-Aberdeenshire noted: “The problems I have found (…) is that they are not overly keen in adopting new technology”.

Two key dimensions of ‘innovation orientation’ were identified, and for each diverging views were demonstrated among the coordinators (Table 2). The first dimension was that of *own interaction with platform*. The data revealed that all coordinators showed proficiency from the onset except for C-Aberdeenshire, who struggled to operate the platform on his own during the experiment and needed help from another coordinator. C-Highlands and C-Cairngorms seemed to have used the data collected by the platform at face value. Yet, C-Tayside used the platform to provide feedback to volunteers and to control the quality of incoming data: “when I get a message from the [platform] saying that somebody has entered data, I double-check it”. Regarding the second dimension, e*xpectations and opinion of platform*, three coordinators believed the platform led to reduced administration workload, or that it would do so in the near future. C-Tayside, however, stressed that she still had to double-check all data that came in. But she also compared it to the situation before: “we needed to do something because it was no good the way it was”; “we had excel spreadsheets and they were just on our computers (…) that is never a good plan”. She also expected the platform to become central to SMI’s work in the future. C-Highlands said he had little dealings with it, but also stressed the importance of the platform for the future: “[no more] Excel sheets (...) a brilliant way to go”. C-Cairngorms felt that improvements around the interface were still needed, but that it had helped in structuring SMI’s operations. C-Aberdeenshire stressed the value of the “uniform approach” to data collection across SMI as a result of the platform.

4. Discussion

By experimentally launching a new data submission system we were able to demonstrate the gains this digital innovation pursued: more submissions, offered in smaller batch sizes at greater frequency. Yet, our approach was bound by some limitations related to this type of participatory research, such as an experimental runtime of 9.5 months and whether this was long enough to capture 'wear-off' from curiosity about a new digital platform. In addition, the generation of four experimental groups reveals that the implementation of a digital platform acts as a selector, attracting some and repelling others, and therefore likely changing volunteer demographics (Pagès et al., 2018). This raises the question whether volunteers who use such an innovation as intended are also those who serve the organisation best otherwise (e.g. the most active and persistent). Indeed, platform development revolving around data collection, as arguably is common amongst volunteer-based conservation organisations (Arts et al., 2015; Will et al., 2015), can sit at odds with drivers of volunteer motivation and retention. Our qualitative findings provide evidence for previous suggestions in this direction (Andow et al., 2016; Asah and Blahna, 2013; Bell et al., 2008; Bruyere and Rappe, 2007).

While the innovation was introduced organisation-wide, and highly valued by the director, each coordinator moderated the platform use by volunteers. Spanning much of Scotland, the coordinators operated in starkly differing physical environments, with different mink densities and 'types' of volunteers. Hence, it is possible that the nature of the regions

328 indirectly demanded different engagement of coordinators towards the platform. But
329 viewing the coordinators' operations in the context of their organisational and innovation
330 orientations made understandable the differential use of the platform regardless of
331 differences in environmental context. While we did not have enough quantitative data to
332 statistically detect 'volunteer group' x coordinator interaction terms in our statistical models
333 (Table S1), our qualitative data points at the engagement of employees with new
334 technology what is at stake here, whilst finding no evidence for region specificity as
335 additional key factor. With regard to the struggles of one coordinator with the technology,
336 there is firstly the reality of a top down innovation decision by an organisation for its staff:
337 not all employees might be able or willing to promote or use the innovation. This seems a
338 regularly overlooked element of innovation introduction in natural resource management
339 (Arts et al., 2015; Jordan et al., 2012). Secondly, conservation organisations likely look for
340 more computer-savvy staff if digital technology is to play a larger role in their futures (Arts
341 et al., 2013). While both aspects are important, we have also found that – in light of the
342 financial challenges that many conservation organisations or projects face (Sauermann and
343 Franzoni, 2015; Will et al., 2015) – a digital platform may provide a backbone for continuity
344 and stability; a central system to underpin effective data governance.
345
346 Whilst our studied initiative has characteristics that may differ from other organisations
347 operating in natural resource management, such as being geographically highly dispersed
348 and possibly demanding region-specific engagement of coordinators with their volunteers,
349 we observe that the introduction of digital data submission platforms is a common
350 innovation. Many conservation organisations face similar challenges in terms of lack of

technical expertise, varying degrees of volunteer motivation, inefficient path-dependencies, and funding limitations (Bell et al., 2008; Newman et al., 2012, Pagès et al., 2019). These aspects are likely to drive leadership of conservation organisation (Dietz et al., 2004; Bruyere, 2015), with managers pushing more and more for digital innovation in order "to be more effective in achieving positive results" (Black et al., 2011: 329).

Such top-down technological innovation is usually meant to be rolled out uniformly by conservation organisations. The role of the 'human layer' in between volunteers on the ground and conservation organisation policies is often taken for granted; yet, it is central to effective implementation of innovation (Newman et al., 2012). Our analysis has brought to light striking differences in how volunteers and coordinators engage with a newly introduced digital platform, collectively turning centralised innovation into new local realities. Our findings show that uniform implementation of digital innovation may not be achieved because of different organisational and innovation orientations of coordinators, and that differential appreciation among volunteers can directly affect data submission behaviour, and thus impact on a conservation organisation's goals and interests.

5. Conclusion

Following the co-development and introduction of a digital data-entry platform to aid conservation management, we set out to address two research aims: 1) to assess whether volunteer data submission changes with the use of a digital platform; and 2) to determine to what extent coordinators influence the usage of a digital platform by their volunteers. The merits of introducing a digital platform to aid conservation management resided primarily in changes in volunteer data submission: the number and frequency of submissions increased

and batch sizes reduced. Moreover, the platform functioned as a backbone for continuity and stability, an aspect of digital innovation that may be particularly valuable for geographically dispersed initiatives.

Still, several pitfalls were identified too. Likely as a result of different organisational and innovation orientations, coordinators seemed to have influenced the adoption of a technology by volunteers, which was planned to be rolled out evenly across the initiative. This uniform implementation affected the organisation's goals and interests. In addition, the introduction of the technology acted as a selector, attracting some volunteers but deterring others. This could change the 'type' of volunteers in the longer term, which may or may not suit the organisation's direction of travel. In particular, it remains to be seen whether digitalisation serves both the volunteer and the conservation initiative alike. Volunteer-based conservation initiatives are often grounded in physical work, which requires and attracts 'hands-on' volunteers (Pages et al 2019). Computer tasks may sit at odds with this, and thus with a key motivation of volunteers to become involved.

Our conclusions lead to a message of caution in relation to the introduction of digital technologies: increased efficiency and efficacy of data collection and information handling are not without pitfalls. These pitfalls notably relate to human factors: volunteer attraction, retention and coordination. Conservation organisations should therefore not just blindly develop or implement digital tools, but also reflect on mediating factors and mechanisms that ensure uptake and continued use of those tools.

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403

404 **References**

405 Andow, D.A., Borgida, E., Hurley, T.M., Williams, A.L., 2016. Recruitment and retention of
406 volunteers in a citizen science network to detect invasive species on private lands.
407 Environ. Manage. 58, 606–618.
408 Arts, K., Ioris, A.A.R., Macleod, C.J.A., Han, X., Sripada, S.G., Braga, J.R.Z., Van der Wal, R.,
409 2016. Environmental communication in the Information Age: Institutional barriers and
410 opportunities in the provision of river data to the general public. Environ. Sci. Policy 55,
411 47–53.
412 Arts, K., Van der Wal, R., Adams, W.M., 2015. Digital technology and the conservation of
413 nature. Ambio 44, 661–673.
414 Arts, K., Webster, G., Sharma, N., Melero, Y., Mellish, C., Lambin, X., Van der Wal, R., 2013.
415 Capturing mink and data: Interacting with a small and dispersed environmental, in:
416 Framework for Responsible Research and Innovation in ICT FRRIICT - Case Study. pp. 1–
417 5.
418 Asah, S.T., Blahna, D.J., 2013. Practical implications of understanding the influence of
419 motivations on commitment to voluntary urban conservation stewardship. Conserv.
420 Biol. 27, 866–875.
421 Asah, S.T., Blahna, D.J., 2012. Motivational functionalism and urban conservation
422 stewardship: implications for volunteer involvement. Conserv. Lett. 5, 470–477.
423 Bakker, K., Ritts, M. 2018. Smart Earth: A meta-review and implications for environmental
424 governance. Global Environ Chang. 52, 201-211.
425 Bates, D., Maechler, M., Bolker, B., Walker, S. 2015. Fitting linear mixed-effects models using
426 lme4. J Stat Softw 67, 1-48.

427 Black, S.A., Groombridge, J.J., Jones, C.G. 2011. Leadership and conservation effectiveness:
428 Finding a better way to lead. Conserv. Lett. 4, 329–339.
429 Bekkers, V., Van Duivenboden, H., Thaens, M., 2006. Public innovation and information and
430 communication technology: Relevant backgrounds and concepts, in: Information and
431 Communication, Technology and Public Innovation: Assessing the ICT-Driven
432 Modernization of Public Administration. IOS Press, Amsterdam, pp. 3–21.
433 Bell, S., Marzano, M., Cent, J., Kobierska, H., Podjed, D., Vandzinskaite, D., Reinert, H.,
434 Armaitiene, A., Grodzińska-Jurczak, M., Muršič, R., 2008. What counts? Volunteers and
435 their organisations in the recording and monitoring of biodiversity. Biodivers. Conserv.
436 17, 3443–3454.
437 Bruyere, B.L., 2015. Giving direction and clarity to conservation leadership. Conserv. Lett. 8,
438 378–382.
439 Bruyere, B., Rappe, S., 2007. Identifying the motivations of environmental volunteers. J.
440 Environ. Plan. Manag. 50, 503–516.
441 Bryce, R., Oliver, M.K., Davies, L., Gray, H., Urquhart, J., Lambin, X., 2011. Turning back the
442 tide of American mink invasion at an unprecedented scale through community
443 participation and adaptive management. Biol. Conserv. 144, 575–583.
444 Chapron, G., 2015. Wildlife in the cloud: A new approach for engaging stakeholders in
445 wildlife management. Ambio 44, 550–556.
446 Dickinson, J.L., Zuckerberg, B., Bonter, D.N., 2010. Citizen science as an ecological research
447 tool: challenges and benefits. Annu. Rev. Ecol. Evol. Syst. 41, 149–172.
448 Dietz, J.M., Aviram, R., Bickford, S., Douthwaite, K., Goodstine, A., Izursa, J.L., Kavanaugh, S.,
449 MacCarthy, K., O'Herron, M., Parker, K. 2004. Defining leadership in conservation: A

450 view from the top. Conserv. Biol. 18, 274–278.
451 Druschke, C.G., Seltzer, C.E., 2012. Failures of engagement: Lessons learned from a citizen
452 science pilot study. Appl. Environ. Educ. Commun. 11, 178–188.
453 Fereday, J., Muir-Cochrane, E., 2006. Demonstrating rigor using thematic analysis: A hybrid
454 approach of inductive and deductive coding and theme development. Int. J. Qual.
455 methods 5, 80–92.
456 Galán-Díaz, C., Edwards, P., Nelson, J.D., Van der Wal, R., 2015. Digital innovation through
457 partnership between nature conservation organisations and academia: A qualitative
458 impact assessment. Ambio 44, 538–549.
459 Gallo, T., Waitt, D., 2011. Creating a successful citizen science model to detect and report
460 invasive species. Bioscience 61, 459–465.
461 Hajer, M.A., van den Brink, M., Metze, T., 2006. Doing discourse analysis: coalitions,
462 practices, meaning. Netherlands Geogr. Stud. (ISSN 0169-4839).
463 Jordan, R.C., Ballard, H.L., Phillips, T.B., 2012. Key issues and new approaches for evaluating
464 citizen-science learning outcomes. Front. Ecol. Environ. 10, 307–309.
465 Jørgensen, M.W., Phillips, L.J., 2002. Discourse analysis as theory and method. Sage.
466 Kelling, S., Fink, D., La Sorte, F.A., Johnston, A., Bruns, N.E., Hochachka, W.M., 2015. Taking a
467 'Big Data'approach to data quality in a citizen science project. Ambio 44, 601–611.
468 Kobori, H., Dickinson, J.L., Washitani, I., Sakurai, R., Amano, T., Komatsu, N., Kitamura, W.,
469 Takagawa, S., Koyama, K., Ogawara, T., 2016. Citizen science: A new approach to
470 advance ecology, education, and conservation. Ecol. Res. 31, 1–19.
471 Kremen, C., Ullman, K.S., Thorp, R.W., 2011. Evaluating the quality of citizen-scientist data
472 on pollinator communities. Conserv. Biol. 25, 607–617.

473 Mace, G.M., 2014. Whose conservation? Science. 345, 1558–1560.
474 McCroskey, L.L., McCroskey, J.C., Richmond, V.P., 2005. Applying organizational
475 orientations. theory to employees of profit and non-profit organizations. Commun. Q.
476 53, 21–40.
477 Melero, Y., Robinson, E., Lambin, X., 2015. Density-and age-dependent reproduction
478 partially compensates culling efforts of invasive non-native American mink. Biol.
479 Invasions 17, 2645–2657.
480 Miller-Rushing, A., Primack, R., Bonney, R., 2012. The history of public participation in
481 ecological research. Front. Ecol. Environ. 10, 285–290.
482 Newman, G., Wiggins, A., Crall, A., Graham, E., Newman, S., Crowston, K., 2012. The future
483 of citizen science: emerging technologies and shifting paradigms. Front. Ecol. Environ.
484 10, 298–304.
485 Pagès, M., Fischer, A., Van der Wal, R., 2018. The dynamics of volunteer motivations for
486 engaging in the management of invasive plants: Insights from a mixed-methods study
487 on Scottish seabird islands. J. Environ. Plan. Manag. 61, 904–923.
488 Pagès, M., Van der Wal, R., Lambin, X., Fischer, A. 2019. Empowered communities or “cheap
489 labour”? Engaging volunteers in the rationalised management of invasive alien species
490 in Great Britain. J. Environ. Manage. 229, 102-111.
491 Pruden, H.O., 1973. The upward mobile, indifferent, and ambivalent typology of managers.
492 Acad. Manag. J. 16, 454–464.
493 Sauermann, H., Franzoni, C., 2015. Crowd science user contribution patterns and their
494 implications. Proc. Natl. Acad. Sci. 112, 679–684.
495 Siguaw, J.A., Simpson, P.M., Enz, C.A., 2006. Conceptualizing innovation orientation: A

framework for study and integration of innovation research. J. Prod. Innov. Manag. 23, 556–574.

Stein, L.D., 2008. Towards a cyberinfrastructure for the biological sciences: progress, visions and challenges. Nat. Rev. Genet. 9, 678.

Sullivan, B.L., Aycrigg, J.L., Barry, J.H., Bonney, R.E., Bruns, N., Cooper, C.B., Damoulas, T., Dhondt, A.A., Dietterich, T., Farnsworth, A., 2014. The eBird enterprise: An integrated approach to development and application of citizen science. Biol. Conserv. 169, 31–40.

Thomas, D.R., 2006. A general inductive approach for analyzing qualitative evaluation data. Am. J. Eval. 27, 237–246.

Tibbles, D., Richmond, V.P., McCroskey, J.C., Weber, K., 2008. Organizational orientations in an instructional setting. Commun. Educ. 57, 389–407.

Van der Wal, R., Sharma, N., Mellish, C., Robinson, A., Siddharthan, A., 2016. The role of automated feedback in training and retaining biological recorders for citizen science. Conserv. Biol. 30, 550–561.

Wald, D.M., Longo, J., Dobell, A.R., 2016. Design principles for engaging and retaining virtual citizen scientists. Conserv. Biol. 30, 562–570.

Wiersma, Y., 2010. Birding 2.0: Citizen science and effective monitoring in the Web 2.0. Avian Conserv. Ecol. 5, 1–9.

Will, D.J., Campbell, K.J., Holmes, N.D., 2015. Using digital data collection tools to improve overall cost-efficiency and provide timely analysis for decision making during invasive species eradication campaigns. Wildl. Res. 41, 499–509.

Table S1. AIC mode values per model. Model selection based on AIC for all nine models, best models were selected by ΔAIC < 2. The best model in each set is indicated by bold text.

Model	Explanatory variables	Response Variable		
		Number of records	Frequency of records	Batch Size
Control (A+C) vs Treatment (B+D)	Group * Coordinator	402.95	401.34	245.44
	Group + Coordinator	**396.74**	**359.02**	**212.34**
	Group	430.71	360.33	216.34
B vs. C	Group * Coordinator	289.21	410.11	279.04
	Group + Coordinator	**272.32**	**348.21**	**252.45**
	Group	277.53	354.32	257.01
B vs. D	Group * Coordinator	229.95	362.44	122.24
	Group + Coordinator	**197.28**	**233.01**	**118.74**
	Group	203.54	265.47	210.82

Table S2. Parameter estimates and their associated standard errors for variables included in the best model for each of the three proxies of volunteer submission behavior (number of records, frequency of records, and batch size), for three different subsets of volunteers: control (A+C group) versus treatment (B+D group), B vs. C, and B vs. D groups. For each model the intercept relates to that of Coordinator Tay and control (Control vs Treatment model) and Coordinator Tay and B (for the other two models), respectively.

		Number of records				**Frequency of records**				**Batch size**			
Model	**Variable**	Estimate	SE	z	P	Estimate	SE	z	P	Estimate	SE	z	P
Control (A+C) vs Treatment (B+D)	Intercept	**1.79**	**0.33**	**5.36**	**<0.001**	**1.28**	**0.32**	**3.95**	**<0.001**	**0.71**	**0.20**	**3.51**	**<0.001**
	Treatment (B+D)	0.13	0.35	0.37	0.71	0.18	0.34	0.54	0.59	**-0.45**	**0.22**	**-2.09**	**0.04**
	C-Highlands	0.62	0.36	1.73	0.08	0.47	0.35	1.36	0.17	**0.62**	**0.22**	**2.78**	**0.01**
	C-Aberdeenshire	**1.41**	**0.40**	**3.54**	**<0.001**	**1.11**	**0.38**	**2.94**	**<0.001**	**0.51**	**0.25**	**2.05**	**0.05**
	C-Cairngorms	**1.20**	**0.60**	**2.01**	**0.04**	1.02	0.57	1.80	0.07	0.35	0.38	0.93	0.36
B vs. C	Intercept	**2.41**	**0.34**	**7.00**	**<0.001**	2.02	0.56	-0.55	0.58	**0.25**	**0.43**	**0.09**	**0.05**
	Group C	**-1.21**	**0.45**	**2.66**	**0.01**	**-1.64**	**0.62**	**-2.62**	**0.008**	-0.46	0.47	-0.98	0.33
	C-Highlands	0.80	0.46	1.75	0.08	-1.59	0.32	1.74	0.08	**0.69**	**0.23**	**3.40**	**0.003**
	C-Aberdeenshire	**1.00**	**0.49**	**2.05**	**0.04**	0.64	0.36	1.77	0.07	0.50	0.27	1.80	0.07
	C-Cairngorms	0.72	0.63	1.15	0.25	0.47	0.52	0.90	0.37	0.36	0.40	0.89	0.38
B vs. D	Intercept	**2.34**	**0.33**	**7.08**	**<0.001**	2.03	0.56	-0.55	0.58	**0.26**	**0.43**	**0.09**	**0.05**
	Group D	**-1.14**	**0.38**	**3.00**	**<0.001**	**-1.59**	**0.58**	**-2.76**	**0.006**	-0.78	0.42	-1.68	0.08
	C-Highlands	**0.97**	**0.43**	**2.26**	**0.02**	-1.60	0.33	1.74	0.08	**0.70**	**0.24**	**3.40**	**0.003**
	C-Aberdeenshire	**1.10**	**0.45**	**2.45**	**0.01**	0.66	0.36	1.77	0.07	0.52	0.27	1.80	0.07
	C-Cairngorms	0.79	0.62	1.28	0.20	0.45	0.52	0.88	0.37	0.35	0.42	0.87	0.39