

Do monetary incentives encourage local communities to collect and upload mosquito sound data using smartphones? A case study in the Democratic Republic of the Congo

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Full Title:	Do monetary incentives encourage local communities to collect and upload mosquito sound data using smartphones? A case study in the Democratic Republic of the Congo
Short Title:	Incentives for citizen science data collection in the DRC
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Keywords:	Citizen science; Malaria; Ecological Monitoring; public health
Abstract:	<p>Malaria is one of the deadliest vector borne diseases affecting sub-Saharan Africa. A suite of systems are being used to monitor and manage malaria risk and disease incidence, with an increasing focus on technological interventions that allow private citizens to remotely record and upload data. However, data collected by citizen scientists must be standardised and consistent if it is to be used for scientific analysis. Studies that aim to improve data collection quality and quantity have often included incentivisation, providing citizen scientists with monetary or other benefits for their participation in data collection. We tested whether monetary incentives enhance participation and data collection in a study trialling an acoustic mosquito sensor. Working with the community in two health districts in the Democratic Republic of Congo, we measured data collection participation, completeness, and community responses. Our results showed mixed responses to the incentive, with more participants interested in the social status and monetary value of the technology used than the monetary incentive itself. The effect of incentives on data collection varied over the course of the trial, increasing participation in the start of the trial but with no effect in the latter half of the trial. Feedback from participants showed that opinions on technology, research objectives, and incentives varied between communities, and was associated with differences in data collection quantity and quality, suggesting that differences in community interest in data collection and the incentives may be more important than the incentive value itself. These results suggest that though there is an initial benefit, extrinsic motivations do not override differences in intrinsic motivations over time, and enhanced communication and dialogue with participants may improve citizen science participation and attitudes.</p>
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Response to Reviewers:	<p>Thank you for the opportunity to submit a revised draft of our manuscript titled “What incentives encourage local communities to collect and upload mosquito sound data using smartphones? A case study in the Democratic Republic of the Congo” to PLOS One. We appreciate the time you and the reviewers have taken to provide valuable feedback and insightful comments. We have made changes to incorporate most of the suggestions provided by reviewers and they are highlighted through the manuscript. Please find below the point-by-point responses and edits made to the paper in line with feedback.</p> <p>Journal Requirements: Comment 1: Please ensure that your manuscript meets PLOS ONE's style requirements, including those for file naming. Response: The manuscript has been amended to address the style and naming requirements.</p> <p>Comment 2: Please note that funding information should not appear in any section or other areas of your manuscript. We will only publish funding information present in the Funding Statement section of the online submission form. Please remove any funding-related text from the manuscript. Response: The manuscript has been amended to remove funding information from the manuscript.</p> <p>Comment 3: When completing the data availability statement of the submission form, you indicated that you will make your data available on acceptance. We strongly recommend all authors decide on a data sharing plan before acceptance, as the process can be lengthy and hold up publication timelines. Please note that, though access restrictions are acceptable now, your entire data will need to be made freely accessible if your manuscript is accepted for publication. This policy applies to all data except where public deposition would breach compliance with the protocol approved by your research ethics board. If you are unable to adhere to our open data policy, please kindly revise your statement to explain your reasoning and we will seek the editor's input on an exemption. Please be assured that, once you have provided your new statement, the assessment of your exemption will not hold up the peer review process. Response: All the raw data from our study is now publicly available at 10.6084/m9.figshare.27332124</p> <p>Comment 4: We note that Figure 2 in your submission contain map/satellite images which may be copyrighted. All PLOS content is published under the Creative Commons Attribution License (CC BY 4.0), which means that the manuscript, images, and Supporting Information files will be freely available online, and any third party is permitted to access, download, copy, distribute, and use these materials in any way, even commercially, with proper attribution. For these reasons, we cannot publish previously copyrighted maps or satellite images created using proprietary data, such as Google software (Google Maps, Street View, and Earth). For more information, see our copyright guidelines: http://journals.plos.org/plosone/s/licenses-and-copyright. Response: To comply with the rules regarding CC BY 4.0 the original data showing the health districts of the DRC from the Humanitarian Data Exchange (DRC health Data) was removed and replaced using Creative Commons Attribution Licensed data. The Democratic Republic of the Congo (DRC) GIS data from simplemaps, the GRID3 COD - Health Areas v4.0: Kwilu health areas (GeoPackage), and the GRID3 COD - Health Areas v4.0: Kinshasa health area (GeoPackage) are all accessible under existing CC BY 4.0 licenses. This change in data used in the map of the DRC has also been reflected in the addition of two references for the GeoPackages used, along with the statement of origin in the caption on Figure 2: Center for International Earth Science Information Network (CIESIN), Columbia University, Ministère de la Santé Publique, Hygiène et Prévention, Democratic Republic of the Congo, and GRID3. (2025). GRID3 COD - Health Areas v4.0: Kinshasa health areas (GeoPackage). New York: Columbia University. https://data.humdata.org/dataset/grid3-cod-health-areas-v4-0. Accessed April 3, 2025. Center for International Earth Science Information Network (CIESIN), Columbia University, Ministère de la Santé Publique, Hygiène et Prévention, Democratic Republic of the Congo, and GRID3. (2025). GRID3 COD - Health Areas v4.0: Kwilu</p>

health areas (GeoPackage). New York: Columbia University.
<https://data.humdata.org/dataset/grid3-cod-health-areas-v4-0>. Accessed April 3, 2025.

Comment 5: We note that Figure 3 and 4 includes an image of a participant in the study.

Response: These images have been removed from the manuscript.

Comment 6. Please review your reference list to ensure that it is complete and correct. If you have cited papers that have been retracted, please include the rationale for doing so in the manuscript text or remove these references and replace them with relevant current references. Any changes to the reference list should be mentioned in the rebuttal letter that accompanies your revised manuscript. If you need to cite a retracted article, indicate the article's retracted status in the References list and also include a citation and full reference for the retraction notice.

Response: The citation list has been reviewed and there were no instances of retracted papers. The reference list was amended with the GeoPackage references for the Kwilu and Kinshasa health districts (shown above), and the references were renumbered to reflect these additions.

Comments from Reviewer 1

Major comments

Comment 1: Lines 79-85: the introduction references the Tanzania study but does not clearly position this manuscript as a follow-up. It could strengthen the manuscript to explicitly state how this work builds on or how it differs from the Tanzania findings. It is recommended that the authors add a sentence explicitly linking the gaps identified in the Tanzania study (for instance, rural-only context) to the objectives of this work.

Response: This study is named directly as a second trial of the mosquito detection application with monetary incentives in line 187. Verbiage specifying the research's focus on the use of monetary extrinsic factors, and how the study builds on the study in Tanzania has been added in lines 205-206, stating: 'This study builds upon our previous work in Tanzania to fill gaps in understanding how monetary incentives alone influence the consistency and quality of audio data collection.'

Comment 2: Regarding the Focus Group Insights, lines 247-253, the discussion of Focus Group Discussions (FGD) results is useful but could benefit from additional depth. For example, higher persistence in Bandundu could be contextualized using participant quotes. A suggestion would be that the authors add representative quotes from FGDs to illustrate key themes and link them to the observed participation trends.

Response: Due to the lack of significant differences in pre-trial FGD responses between Kinshasa and Bandundu it does not feel appropriate to use a FGD response in this section of the results to highlight differences in the groups that were seen later in the trial (such as in the post-trial FGDs). Instead, a quote from a participant listing multiple motivation factors has been added in lines 373-377 to demonstrate how complex participant motivations were prior to trial participation.

Comment 3: The study's inclusion of Bandundu (rural) and Kinshasa (urban) appear to be an opportunity to explore how rural-urban differences influence participation. However, the manuscript does not fully address these dynamics or their potential implications. In lines 401-402, the authors note that differences in participation are not attributable to demographic factors but do not explore other potential influences, such as rural-urban dynamics that may be marked in the two setting of the study. This section could be expanded on to discuss e.g. infrastructure, community cohesion, and leadership differences between Bandundu and Kinshasa.

Response: This study was not aimed at specifically addressing urban versus rural factors for responses to incentivization, and the Kinshasa study sites were not located in the city but in rural parts of the health district (referred to as rural Kinshasa when first introduced in the manuscript, line 188). However, we acknowledge the potential role of proximity to urban areas and have now addressed this in the manuscript discussion lines 547-549, reading: 'These differences may be related to the proximity of the rural Kinshasa sites with the city of Kinshasa, though the access of participants to urban environments and differences in community cohesion were not specifically accounted for in our surveys.'

Minor comments:

Comment 4: Line 46: replace "effecting sub-Saharan Africa" with "affecting sub-Saharan Africa."

Response: This has now been amended in the manuscript.

Comment 5: Discussion: the authors acknowledge that the findings are context-specific but do not discuss how they might be generalised to other settings. The paper could benefit from expanding the discussion to include how differences in infrastructure, culture, or community norms might affect the scalability of the study's approach. Ethical considerations, such as phone retention, may also be under-discussed in terms of their potential impact on the findings or on the design of the study.

Response: To address the generalizability of this research we added a section in lines 702-714 stating: "Our findings show that mobile applications using hardware on budget smartphones can generate useful data with limited interventions and suggests that mobile application development should be more widely considered in citizen science data collection efforts. Future research on the role of incentivization for data collection that utilizes technology should consider how to further disambiguate the inherent benefits in participation related to technological access, such as social status or monetary benefit from retaining equipment. We suggest that with increased mobile phone ownership, this complexity may be overcome by utilizing current phone owners, rather than providing participants with hardware."

The focus group discussions did not include specific questions that would allow us to analyse differences in culture and community norms beyond the motivations participants stated before the trial or their experiences afterwards. Differences in attitude and community norms were addressed in the discussion lines 575-678, and we have added in lines 709-712 a call for more cross-sectional work that may generate the data necessary to analyse the effects of infrastructure and community norms.

Comment 6: Future Research Directions: the conclusion could benefit from a brief discussion of future research priorities, such as testing alternative incentive models, evaluating long-term engagement strategies, and/or assessing the usability of the acoustic mosquito sensors in the study context.

Response: Future research directions we have added a section to the discussion in lines 702-713: "Future research on the role of incentivization for data collection that utilizes technology should consider how to further disambiguate the inherent benefits in participation related to technological access, such as social status or monetary benefit from retaining equipment. We suggest that with increased mobile phone ownership, this complexity may be overcome by utilizing current phone owners, rather than providing participants with hardware. Additionally, as mobile phone use becomes more popular, opportunities for large scale studies will support more complex statistical approaches to account for the complex structures that underpin intrinsic motivators and responses to extrinsic motivators, such as proximity to urban areas which are potentially obscured by the inferential statistical methods used in this study."

Comment 7: Methodology improvement: the supplementary file provides detailed documentation of participant demographics and focus group questions, which supports the reproducibility of the study. Nevertheless, the modified random walk technique used for participant selection is not sufficiently explained in either the manuscript or the supplementary materials. While the inclusion of demographic comparisons and FGD protocols is quite valuable, the lack of detail about the recruitment method limits the transparency of the methodology. For instance, how were starting points for recruitment selected? Were any randomisation procedures applied to maintain the sampling unbiased? Additionally, minor gaps in the description of the design of text message reminders could also limit reproducibility. It is recommended that the authors provide additional detail or supplementary materials for these two aspects.

Response: Details for how random walks were carried out is included in the methodology in lines 247-249, with details on reducing bias added in line 248: "To reduce the bias of entry point selection, each household was approached sequentially along the street and asked if they wanted to participate, until the number of households required to participate at the site (n=37) was met."

Regarding the methodological details of the SMS reminders, those reminders were not a component of this study but were part of the first study in Tanzania.

Comment 8: Data availability seems to be in compliance with PLOS guidelines. Still, it is important to confirm that the repository cited by the authors includes raw data points

	<p>(such as the individual participation records and anonymised FGD transcripts), as I was not able to access it. The statistical methods used appear to be appropriate, but I would recommend consulting someone with higher expertise in this matter. The methodology is sufficiently detailed overall. However, minor gaps in the description of participant recruitment (e.g., modified random walk technique) and the design of text message reminders could be further improved.</p> <p>Response: The additional raw data is available now at 10.6084/m9.figshare.27332124.</p> <p>Comments from Reviewer 2</p> <p>This study has addressed an important question about the influence of monetary incentives on participation (data collection) in citizen research. The methodology and results have been excellently presented and discussed. The researchers have done an excellent job of using quantitative and qualitative methods to address their study questions. The manuscript is indeed of very high quality.</p> <p>Here are a couple of comments that I recommend that the authors consider:</p> <p>Comment 1: The topic of the study is not congruent with the study objective or question. The title “What incentives encourage local communities to collect and upload mosquito sound data by using smartphones? A case study in the Democratic Republic of the Congo” suggests that the study has evaluated different type of incentive while it has specifically assessed the influence of “monetary incentives” A title that would fit better with the study objective/question/scope could be “Do monetary incentives encourage local communities to collect and upload mosquito sound data by using smartphones? A case study in the Democratic Republic of the Congo”</p> <p>Response: The title of the manuscript has been adjusted to account for this suggestion.</p> <p>Comment 2: The researchers may have made efforts to adjust for and discuss confounding inherent on the research design but need to describe this more clearly in the report. Also, I recommend that authors highlight known limitations of the main inferential statistical approach used in comparative analysis.</p> <p>Response: A sentence has been added in the methods to address the use of post-hoc test to reduce risk of type 1 error in line 341.</p> <p>To address the limitation of inferential statistics, a section has been added to the discussion in lines 709-712, suggesting future studies use cross-sectional data that may allow for more complex modelling approaches in analysis.</p>
Additional Information:	
Question	Response
<p>Financial Disclosure</p> <p>Enter a financial disclosure statement that describes the sources of funding for the work included in this submission. Review the submission guidelines for detailed requirements. View published research articles from PLOS ONE for specific examples.</p> <p>This statement is required for submission and will appear in the published article if the submission is accepted. Please make sure it is accurate.</p>	<p>Yes</p>

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<p>Competing Interests</p> <p>Use the instructions below to enter a competing interest statement for this submission. On behalf of all authors, disclose any competing interests that could be perceived to bias this work—acknowledging all financial support and any other relevant financial or non-financial competing interests.</p> <p>This statement is required for submission and will appear in the published article if the submission is accepted. Please make sure it is accurate and that any funding sources listed in your Funding Information later in the submission form are also declared in your Financial Disclosure statement.</p>	<p>The authors have declared that no competing interests exist.</p>

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The University of Oxford have sponsored the study. This study was reviewed and approved by the Oxford Tropical Research Ethics Committee (OxTREC Reference 548-19) and approved by the Kinshasa School of Public Health (ESP/CE/91B/2021). Informed written consent was obtained from all interviewees prior to the focus group discussions and the quantitative feedback survey. Consent forms signed by all the participants included the release of summary findings and details of individual responses from this study. Potential participants were informed of the voluntary nature of the study and had at least 24 hours to consider taking part.

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The data underlying the results presented in the study are available from (include the name of the third party

Data and analysis files are available from figshare (10.6084/m9.figshare.27332124).

<p><i>and contact information or URL).</i></p> <ul style="list-style-type: none"> • This text is appropriate if the data are owned by a third party and authors do not have permission to share the data. <p>* typeset</p>	
Additional data availability information:	

Do monetary incentives encourage local communities to collect and upload mosquito sound data using smartphones? A case study in the Democratic Republic of the Congo

Short Title: Incentives for citizen science data collection in the DRC

Kieran E. Storer^{1*}, Jane P. Messina², Eva Herreros-Moya¹, Emery Metelo^{3,4¶}, Josué Zanga^{4¶}, Nono M. Mvuama^{4¶}, Soleil Muzinga^{4¶}, Rinita Dam^{5&}, Marianne Sinka^{1&}, Ivan Kiskin^{6&}, Josh Everett^{1&}, Yunpeng Li^{7&}, Stephen Roberts^{8&}, and Katherine J. Willis¹

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29

30 ¶ EM, JZ, NMM, and SM contributed equally to this work

31 & RD, MS, IK, JE, YL, and SR also contributed equally to this work

32

33 Attribution

34 KES contributed to data curation, formal analysis, methodology, visualization, and writing the original
35 draft. JPM contributed to formal analysis and visualization. EHM contributed to conceptualization,
36 investigation, methodology, project administration, supervision, visualization, and the review and
37 editing of the manuscript. EM, JZ, NMM, and SM contributed to conceptualization, investigation,
38 methodology, data collection, and review and editing of the manuscript. RD, MS, IK, JE, YL, and SR
39 contributed to conceptualization, methodology, and review and editing of the manuscript. KJW
40 contributed to funding acquisition, methodology, supervision, and the review and editing of the
41 manuscript.

42

43 Abstract

44 Malaria is one of the deadliest vector borne diseases affecting sub-Saharan Africa. A suite of systems
45 are being used to monitor and manage malaria risk and disease incidence, with an increasing focus on
46 technological interventions that allow private citizens to remotely record and upload data. However,
47 data collected by citizen scientists must be standardised and consistent if it is to be used for scientific
48 analysis. Studies that aim to improve data collection quality and quantity have often included
49 incentivisation, providing citizen scientists with monetary or other benefits for their participation in
50 data collection. We tested whether monetary incentives enhance participation and data collection in a

study trialling an acoustic mosquito sensor. Working with the community in two health districts in the Democratic Republic of Congo, we measured data collection participation, completeness, and community responses. Our results showed mixed responses to the incentive, with more participants interested in the social status and monetary value of the technology used than the monetary incentive itself. The effect of incentives on data collection varied over the course of the trial, increasing participation in the start of the trial but with no effect in the latter half of the trial. Feedback from participants showed that opinions on technology, research objectives, and incentives varied between communities, and was associated with differences in data collection quantity and quality, suggesting that differences in community interest in data collection and the incentives may be more important than the incentive value itself. These results suggest that though there is an initial benefit, extrinsic motivations do not override differences in intrinsic motivations over time, and enhanced communication and dialogue with participants may improve citizen science participation and attitudes.

Introduction

Mobile phone usage in sub-Saharan Africa reached 489 million users in 2023, with smartphones making up 51% of mobile phones due to improvements in mobile phone access and network connections [1–3]. With increasing smartphone ownership, their use for citizen science data collection has also increased in tandem, making use of the built-in camera, sensors, and GPS to generate and record data [4–7]. Citizen science projects have ranged widely, and have been increasingly used in healthcare settings, including for monitoring diseases such as malaria by tracking outbreaks, monitoring drug stocks, reminding patients of medical appointments, and recording mosquito larval habitats and populations [for examples see: 8–15]. As the amount and type of data collected by private citizens increases there are opportunities for developing high-resolution data repositories that widen citizen participation to include a greater range of demographic groups.

76 Previous research on citizen science data collection has shown that gathering data for research or
77 healthcare purposes can help to improve educational outcomes [16], make data collectors feel more
78 connected to their community [17], and improve health outcomes [18]. But how do researchers
79 motivate people to participate and collect high-quality data? Firstly, there is need to understand the
80 roles that intrinsic and extrinsic motivations play in citizen scientist participation and data collection
81 quality. Intrinsic motivation factors are 'people's spontaneous tendencies to be curious and interested,
82 to seek out challenges and to exercise and develop their skills and knowledge, even in the absence of
83 operationally separable rewards' [19]. Intrinsic motivation is influenced by local and regional cultures,
84 education, and familial values [20]. In contrast, extrinsic motivators are 'behaviours done for reasons
85 other than their inherent satisfactions' [21], such as monetary gain [22]. Efforts to improve data
86 collection typically target these different motivation factors. Studies have shown that monetary
87 incentives can be used in health care and ecological monitoring schemes to improve participation [23–
88 27] and that intrinsic factors can be harnessed to improve data collection participation and quality by
89 improving learning opportunities and using participant knowledge [28–31].

90

91 The complex spatiotemporal variability inherent to motivation factors [32,33] and the theoretical
92 potential for a trade-off between them [21] make understanding their influence essential to improving
93 data collection quality and scope while optimising resource allocation. To study participants'
94 motivations and assess the functionality of incentive applications to promote community involvement
95 in the collection of high-quality long-term biological data, we previously ran a data collection trial
96 using incentives and SMS text reminders for collecting mosquito audio data in Tanzania using the
97 HumBug tool [34]. This tool is a smartphone audio sensor combined with a modified bed net designed
98 to temporarily trap mosquitoes and guide them towards a budget smartphone running the MozzWear
99 app that records the flight tone of host seeking mosquitoes overnight to determine the abundance and

100 diversity of mosquitoes present using their sound [35] (Fig. 1).; For details on the Humbug tool, also
101 see [36–42].

102

103 *Fig. 1: HumBug Tool configuration, showing the data collection, upload, and analysis pipeline (reproduced*
104 *from Sinka et al., 2021).*

105

106 The smartphone app MozzWear used in the HumBug tool records mosquito flight tone data overnight
107 and provides a secure connection to a server at the University of Oxford where the data is uploaded
108 via the mobile or Wi-Fi data network. The data then runs through an algorithm pipeline that first detects
109 the mosquito flight tone from background noise and then identifies the mosquito species using their
110 acoustic signature [35–37,40]. As such, the HumBug tool is a good example of using smartphone
111 technologies to provide an accessible biological data collection methodology to identify and monitor
112 vectors of human disease - in this case, mosquitoes.

113

114 Previous work in Tanzania showed that providing homeowners with monetary incentives and SMS
115 reminders to record and upload mosquito data did not significantly increase the number of uploads
116 when compared to the control group [34]. Instead, the study found that other factors influenced data
117 collection efforts. However, it did not examine in detail what these other factors might be. To better
118 understand, therefore, how a monetary extrinsic factor may affect data collection practices in the use
119 of the HumBug tool, we ran a second data collection trial in a different community within two districts
120 of the Democratic Republic of the Congo: **Bandundu, and rural Kinshasa**. In this study we aimed to
121 test whether monetary extrinsic incentives encouraged: i) participant data collection activity during the
122 trial period; ii) participant effort (the number of uploads per participant made during the sampling
123 period, indicative of following trial protocols); and iii) the persistence of participation over time
124 (whether trial participants continued to upload data throughout the sampling period). To address these
125 questions, we compared participant activity (weeks active) and sampling effort (number of uploads)

126 over the sampling period to assess differences in participation associated with receiving incentives for
127 data collection. This study builds upon our previous work in Tanzania to fill gaps in understanding
128 how monetary incentives alone influence the consistency and quality of audio data collection.
129

130 **Methods**

131 The study ran from April to November of 2022 in two districts of the Democratic Republic of the
132 Congo (DRC): rural Kinshasa, and Bandundu. Our collaborators at the University of Kinshasa and the
133 University of Bandundu selected participants, conducted demographic surveys and pre- and post-trial
134 focus group discussions, and ran the study. Data analysis and writing of the manuscript were carried
135 out by the University of Oxford team. All leaders of communities, health zone officials, and
136 participants provided signed consent forms for the study, and the study was approved by the University
137 of Oxford Tropical Research Ethics Committee and the University of Kinshasa Public Health Ethics
138 Committee. Informed written consent was obtained from all interviewees prior to the focus group
139 discussions and the quantitative feedback survey. Consent forms signed by all the participants included
140 the release of summary findings and details of individual responses from this study. Potential
141 participants were informed of the voluntary nature of the study and had at least 24 hours to consider
142 taking part. Efforts were made to create a safe place for sharing experiences during the focus group
143 discussions.
144

145 **Study Locations**

146 Geographically, the DRC covers an area of approximately 2,345,409 km². The country is dominated
147 by the Congo River basin surrounded by high plateaus, resulting in high precipitation and thick tropical
148 forest within the basin and grassland in the plateaus above. In the DRC, malaria is a major cause of

149 illness and death. Worldwide, 12% of the total malaria cases occurred in the DRC in 2022, causing
150 60% of hospital visits in the country [43,44].

151

152 Kinshasa is the capital city of the DRC and the largest city in central Africa. With ~16 million
153 population it is the third largest mega-city on the continent. The Bandundu district has a total of
154 143,435 people and covers an area of 222 Km² (Figure 2). Participants in our research were from the
155 Bu and Mikondo health districts of Kinshasa, and the Trois Rivières and Caravane health districts of
156 Bandundu.

157

158 *Fig. 2: Map of the Democratic Republic of Congo, modified from simplemaps.com [45] and GRID3 COD -*
159 *Health Areas v4.0 [46,47] under CC BY 4.0 license, showing the location of study districts; Bandundu in red*
160 *and Kinshasa in blue. On the zoom inset, black points show the location of study sites. Mapping was carried*
161 *out using QGIS 3.30.0 [48].*

162

163 Each district in our study had two trial sites: a control site and an incentive site. The selection of
164 participants from our four trial sites took place from April 2 to June 30, 2022. In each health district,
165 authorities of the different Health Zones, the village chiefs, and heads of districts were contacted to
166 gain permission for the study and to involve local leadership. Meetings with local leaders were carried
167 out to plan the recruitment of households for the study, and to allocate which health districts would be
168 the control treatment (Trois Rivières in Bandundu and Bu in Kinshasa) and the incentive treatment
169 (Caravane in Bandundu and Mikondo in Kinshasa). These health districts will hereafter be referred to
170 as a trial sites for clarity.

171

172 Households were recruited using a modified random walk technique from an entry point chosen from
173 the main entrances to the village/street selected by local health district officials. To reduce the bias of
174 entry point selection, each household was approached sequentially along the street and asked if they

175 wanted to participate, until the number of households required to participate at the site (n=37) was met.
176 Trial participants were admissible if they were 18+ years old, owned or had access to a personal mobile
177 phone, were residents in Bandundu/Kinshasa throughout the study, and were willing and capable of
178 providing a signed consent form.

179

180 Ahead of the trial, training of the interviewers and moderators took place over a day in each of the trial
181 sites to teach local health officials and local leadership how to run interviews and support participants
182 in the trial. Demonstrators were also taught how to install and use the HumBug tool and MozzWear
183 App and were given a presentation of the trial objectives. Finally, interviewers were trained on how to
184 administer the demographic questionnaires to participants who agreed to take part in the trial (DHS
185 Phase 8 Questionnaire, S1 Appendix).

186

187 Moderators ran pre-trial focus group discussions (FGDs) to confirm that participants understood the
188 purpose of the study, how the study was designed, and how to operate the HumBug tool and MozzWear
189 application. The pre-trial FGDs were also used to discuss and understand the challenges that
190 participants may face, their motivations for taking part in the study, and what they thought the impact
191 would be on their lives. The pre- and post- trial FGD questions can be found in the S2 Appendix. The
192 reasons participants gave for joining the study were categorized into common themes of access to
193 electricity, financial incentive, use of a phone, provision of bed nets, contributing to health
194 improvements and malaria control, or gaining personal knowledge. Participant FGDs responses were
195 then structurally coded for analysis [49].

196

197 Control group participants were provided with the HumBug tool (a smartphone running the MozzWear
198 app and the HumBug bed net), and one dollar to pay for an internet connection. The incentive group
199 was provided with the HumBug tool and one dollar for an internet connection, and an additional ten

dollars each month paid via airtime to their mobile phones. Participants were instructed to place the smartphone with the MozzWear app in the HumBug net and start the record function at 18:00 hrs and turn it off at 06:00 hrs on their allocated weekly recording day during the trial period (16 weeks total). Recordings were split at one-hour intervals automatically in the MozzWear app to prepare recordings for algorithmic analysis. As such a complete recording effort would show 12 recordings. The recordings were then uploaded by participants to the remote server when they connected to the internet. Once participants were taught how to use the Humbug tool there was no contact between the research team and the participants.

208

The research team conducted post-trial FGDs to understand the participants' experience of using the HumBug tool and participating in the study. Questions included whether they liked using the MozzWear app, whether they liked using the HumBug net, how the trial personally affected them, what they would want to be different about the trial in the future, whether they would participate in the future, and if they received an incentive whether it was enough money. Data from the post-trial FGDs was coded for analysis by themes of response to questions as described for the pre-trial FGDs.

215

216 **Data Analysis**

To compare the effect of providing incentives to the participants to upload mosquito audio data, the number of active participants (participants who uploaded any data) and the number of uploads were counted during each trial week. Participant identification numbers were used to assess the upload counts and weekly activity by location (Kinshasa or Bandundu districts) and experimental group (control or incentive). Counts of uploads, weeks of participation, and the average number of participants each week were compared using Wilcoxon Rank Sum tests [50] and Kruskal-Wallis tests [51] with a post-hoc Dunn test [52] to assess if there was a significant difference in participation between the experimental groups/locations over the study period and reduce potential type 1 error

associated with multiple comparisons. The number of participant uploads was broken down for each week of the trial to assess whether incentives improved data collection persistence throughout the study and was also compared using Wilcoxon Rank Sum Tests. Data on income, sex, age, education, and profession were also evaluated as explanatory variables to explain variation in data collection between groups. Comparisons of the demographic data of each district, trial group, and combination of the two, were made using Wilcoxon Rank Sum tests and Chi-squared tests. The pretrial FGD data was analysed using Wilcoxon Rank Sum tests to compare differences in pre-trial motivations for participation. The post-trial FGD data was analysed using a Fisher's Exact Test to assess the correlation between district and trial groups on attendance for the post-trial FGD and whether participants would take part in a future trial, and phone return. All plots were produced using ggplot2 [53].

Data management

Personal data generated in the form of signed consent forms, personal mobile phone numbers, interviews, and/or focus group audio recordings, were stored following the 2018 Data Protection Act on a secure administrative database on a University of Oxford server.

Results

Pre-Trial Focus Group Discussions

Pre-trial focus group discussions (FGDs) were run in three groups of 12-13 participants in each trial site (37 people per trial site, 148 participants in total). In the pre-trial FGDs, themes identified for participant motivation were monetary benefit (63.5% of all participants), contributing to science/health (33.1%), having a phone (29.7%), electricity access (27.0%) (not a component of this study), the HumBug net (6.7%), and gaining personal knowledge (5.4%). Participants were typically motivated by multiple factors. As a participant in Bandundu describes ‘To do the job well, I have to be motivated,

in the sense that I have to have the material for the job first, and then I have to be paid a good payment so that I can do a good job”. There was no significant difference in the number of motives each participant listed at the start of the study between Bandundu and Kinshasa ($p > 0.05$).

Statistical comparisons using Wilcoxon Rank Sum Tests showed that trial site participants in Kinshasa mentioned electricity significantly more as a reason to participate in the trial compared to Bandundu trial site participants ($W = 3774$, $p\text{-value} < 0.001$). Comparing treatment groups across both districts, electricity access was mentioned more frequently in the control groups compared to the incentive groups ($W = 2072$, $p\text{-value} < 0.001$). Between the treatment groups in Bandundu, electricity was more frequently mentioned by the control group (control $n=6$, incentive $n=0$; $W = 795.5$, $p\text{-value} = 0.012$) and personal knowledge (on topics such as mosquito control and malaria prevention) was more commonly cited by the incentive group (control $n=0$, incentive $n=4$; $W = 610.5$, $p\text{-value} = 0.042$). In Kinshasa, the control group mentioned electricity (control $n = 23$, incentive $n = 11$; $W = 906.5$, $p\text{-value} = 0.005$) and contributing to science/health (control $n = 15$, incentive $n = 6$; $W = 851$, $p\text{-value} = 0.022$) significantly more than the incentive group. There were no other significant differences between districts, trial groups, or the trial groups within districts ($p\text{-value} > 0.05$).

Demographic Survey

Demographic survey data were assessed to identify if they contributed to differences in recording ability between districts, treatment groups, and treatment groups within districts. There were significantly more adults in the homes of participants in the Kinshasa district sites compared to the Bandundu district sites ($W = 1680$, $p\text{-value} = 0.017$). Between the treatment groups in both districts, there were no significant differences in any demographic response variables. Within Kinshasa, there was significantly less water scarcity in the control group (29% experiencing water scarcity), and compared to the incentive group (45% experiencing water scarcity) (odds ratio = 0.09, $p\text{-value} = 0.021$).

and there was a significant difference in the method of home lighting, with significantly more homes in the control group using a rechargeable flashlight, torch, or lantern ($p\text{-value} = 0.016$). Within Bandundu there were significantly more children in the incentive group compared to the control group ($W = 675$, $p\text{-value} = 0.024$), with one more child per house in the study on average. Additionally, there was a significant difference in toilet types between the Bandundu trial groups ($p\text{-value} = 0.033$). These were the only cases out of 88 comparisons that were significantly different between districts and trial groups (S3 Table).

281

282 **Comparing Districts and Trial Groups**

Some participants decided to withdraw from the trial during its course and others failed to upload data, resulting in overall participation of 33 from the control group and 31 from the incentive group in the Kinshasa districts ($n=64$), and 33 from the control group and 35 from the incentive group in Bandundu districts ($n=68$), totalling 132 participants. The withdrawal rate from the study was 7.4% from the control sites and 10.4% from incentive sites across both districts. The reasons cited for formal withdrawal from the trial were lack of monetary benefit, unplanned move from the trial area, and loss of the smartphone. Comparisons in participation between trial districts using Wilcoxon Continuity tests showed that Bandundu participants uploaded data more weeks of the trial period ($W = 1589$, $p < 0.001$) and had more total uploads ($W = 1825.5$, $p = 0.009$), than participants in Kinshasa, shown in Figure 3.

293

Fig. 3: Comparison of a) the total number of uploads per participant in Bandundu and Kinshasa and b) the number of weeks that each participant was active in Bandundu and Kinshasa. Bandundu is shown in red, and Kinshasa is shown in blue. Boxes show the interquartile range (IQR), with whiskers showing the upper and lower 25% of the data, and points showing the outliers.

298

299 Comparing treatment groups across both districts there was no difference in participation between the
300 control group and the incentive group for either total uploads (W = 2409.5, p-value = 0.88), or
301 participation weeks (W = 2510.5, p-value= 0.79). Within Kinshasa there was no significant difference
302 between treatment groups in either uploads (W = 418.5, p-value = 0.057) or weeks of activity (W =
303 428, p-value = 0.073). In Bandundu, there were significantly more total uploads in the control group
304 compared to the incentive group (W = 845.5, p-value = 0.026) but no significant difference in the
305 average number of active weeks of each participant (W = 777, p-value = 0.13) (Table 1). There were
306 no significant relationships found between in the demographic variables that were captured in the
307 demographic questionnaire survey and the number of uploads or weeks of activity.

309 *Table 1: Results of the Mann Whitney-U Tests for the trial group comparisons, with * to denote significance,*
310 *p-value < 0.05 *, p-value<0.01 **.*

Comparison		Response Variable	Group	Mann-Witney U	Median	IQR	P-Value
District	Uploads		Kinshasa	W=1825.5	117.5	79.75-161.75	0.009486****
			Bandundu		160	107-186	
	Weeks		Kinshasa	W=1589	11	8-14.25	0.0002879***
			Bandundu		15	12-16	
Treatment	Uploads		Control	W=2409.5	136	73-186	0.8822
			Incentive		140	94.5-172.5	
	Weeks		Control	W = 2510.5	13	7-16	0.7852
			Incentive		13	10-15	
Bandundu	Treatment	Uploads	Control	W=845.5	180	122.25-193.5	0.02643*

Kinshasa	Treatment	Incentive		149.5	91-177.75	0.1307
		Weeks	Control	16	12-16	
			Incentive	13.5	11.5-16	
		Uploads	Control	99	62-164	
			Incentive	140	96.5-160	
		Weeks	Control	11	6-14	
			Incentive	12	10-14.5	0.07298

Activity and Effort over Time

Activity Persistence

The percentage of active participants was catalogued weekly to assess whether the monetary incentive affected persistence in data collection over the trial period (Fig. 4). At the start of the trial, the Kinshasa incentive group had the highest participation (87.1%), followed by the Bandundu incentive (83.3%), Bandundu control (80.5%), and Kinshasa control (70.3%). Participation was approximately stable for the first half of the trial before declining from week 8. At the end of the trial both the Kinshasa control and Kinshasa incentive group had dropped to 30-35% participation, Bandundu incentive dropped to 50% participation, and Bandundu control maintained 77.7% participation.

Fig. 4: The percentage of participants that activated the MozzWear app in each trial group during each week in the trial. The coloured lines coordinate with trial groups, showing Bandundu control in orange, Bandundu incentive in green, Kinshasa control in pink, and Kinshasa incentive in blue. Lines were fitted using locally

326 *estimated scatterplot smoothing (LOESS), with the 95% confidence interval for each treatment group indicated*
327 *in grey.*

328

329 **Data Collection Effort**

330 Data collection effort over the trial showed that in the first week the Kinshasa incentive group had the
331 highest average uploads per active participant (12.26) followed by the Bandundu control (11.69),
332 Bandundu incentive (10.83), and Kinshasa control (10.54). Data collection effort declined at around
333 week seven, and at the end of the trial, the upload effort dropped for all groups, finishing in descending
334 order with Bandundu control (11.29), Bandundu incentive (10.39), Kinshasa incentive (10.8), and
335 Kinshasa control (9.23). Over the course of the study, Bandundu had significantly more uploads per
336 participant compared to Kinshasa ($W = 1825.5$, $p\text{-value} = 0.009$), and the Bandundu control group had
337 higher data collection effort than the incentive group ($W=845.5$, $p\text{-value} = 0.026$). but there was no
338 significant difference between the control and incentive groups overall or within Kinshasa. Figure 5
339 below shows the weekly comparisons in data collection effort over the course of the trial between the
340 trial districts, treatment types, and treatments within districts. Bandundu had a trend of higher uploads
341 in weeks 2-4, 8, and 11 ($p\text{-value} < 0.1$), and significantly higher uploads in weeks 9, 10, and 12-16 ($p\text{-value} < 0.05$) compared to the Kinshasa groups. Comparisons of the treatment groups showed that the
342 control groups had higher participation than the incentive groups in the final three weeks of the trial
343 ($p\text{-value} < 0.05$). Within Bandundu, the control group had higher participation in weeks 14 and 16 of
344 the trial compared to the incentive group ($p\text{-value} < 0.05$), and within Kinshasa, the control group had
345 trends of lower participation than the incentive group in weeks 1 and 9 of the trial ($p\text{-value} < 0.1$)

347

348 *Fig. 5: Week-to-week comparisons of collection effort between the trial districts, and incentive and control*
349 *groups overall and within Kinshasa and Bandundu. The magnitude of the bars shows the difference in uploads*
350 *per person from the first group in panel subtitle relative to the second. Non-significant differences are shown*
351 *in grey; trends are shown in green ($p\text{-value} < 0.1$), significant results in yellow ($p\text{-value} < 0.05$), and highly*

352 *significant differences are shown in red (p -value < 0.001). The whiskers around each bar show the standard*
353 *error.*

354

355 **Post-Trial Focus Group Discussions**

356 The focus group discussions after the trial were attended by 27 participants from Kinshasa and 26 from
357 Bandundu equating to ~35% of the original trial participants. In comparison to the 12 pre-trial FGDs,
358 only 6 post-trial FGDs were run. Post-trial FGD attendance was lower in the Kinshasa incentive group
359 compared to other groups ($n = 8$, p -value = 0.098, 95% CI: [0.0995, 1.2767] odds ratio: 0.368). All
360 returning participants indicated that they had positive experiences with the HumBug sensor and a
361 positive experience with the HumBug bed nets. When asked about the effect of the trial on their life,
362 a respondent from the Bandundu incentive site said, "I was doing this work without someone to
363 command me (...) it gave me the sense of responsibility."

364

365 There was a lower interest in future participation for control groups ($n=12$) compared to the incentive
366 groups ($n=25$), and lower interest in future participation in Kinshasa (44.4% of respondents) compared
367 to Bandundu (96.2% of respondents). Both district and trial group were significantly associated with
368 participants interest in future participation (p -value < 0.001, 95% CI: [1.801, 5.468], odds ratio: 3.102),
369 showing that in Bandundu the control group was 10% less likely to say they would participate in the
370 future than the Bandundu incentive group, and in Kinshasa the control group was 60% less likely to
371 participate in the future compared to the Kinshasa incentive group.

372

373 When asked about challenges or things they wanted to change in the trial, electricity access was
374 mentioned more frequently in the Kinshasa incentive group ($W = 32$, p -value = 0.007) and the
375 Bandundu control group ($W = 129$, p -value = 0.008) compared to the other trial group in their
376 respective districts. Financial compensation/increased compensation was mentioned by 17

377 respondents, but did not vary significantly between trial groups. When queried on how to improve the
378 study, a respondent indicated a desire for more interaction and information, "When we send the data,
379 on your part, we need a sign to know if the data has arrived or not (...) until the end, we had no
380 communication."

381

382 Finally, only participants in the Kinshasa control group mentioned wanting to keep the smartphone
383 (n=12). Despite not being discussed in other post-trial FGDs, phone retention was an issue at the end
384 of the study. In total, there were 33 phones retained by participants across the districts, with a higher
385 likelihood for the Kinshasa incentive group and for the Bandundu control group to retain phones,
386 compared to the other trial group in their district (p-value=0.00516, 95% CI [1.567, 74.361], odds
387 ratio: 9.177). Additionally, nine phones were reported as lost or stolen by the end of the trial period.
388 As one participant phrased it from the control trial group in Kinshasa, "I want to be left with the phones
389 because we will be laughed at (...) if you take them away from us, they will say that we participated
390 in vain."

391

392 **Discussion**

393 Our results demonstrate that in the DRC there was no significant difference in the number of audio
394 recordings uploaded or the number of weeks that participants were active between the groups receiving
395 financial incentives and the groups that did not. The previous HumBug study in Tanzania similarly
396 showed no significant effect of incentives (monetary incentives, text message reminders, or their
397 combination) on the total audio recordings uploaded [34]. We found there was no significant effect of
398 demographics such as age, sex, or income on the number of uploads or participation weeks, nor were
399 there significant differences in these demographic traits between the districts, trial groups, or trial
400 groups within districts. The only significant effect on the number of uploads and active weeks was
401 study location which showed that participation was overall higher in Bandundu compared to Kinshasa,

402 and a difference between the control and treatment group uploads in Bandundu due to a higher
403 recording effort of the control group. This suggests that differences between the districts are not
404 attributable to demographic effects, and instead, there may be other differences, such as intrinsic
405 motivations or community leadership, resulting in higher numbers of uploads in Bandundu compared
406 to the Kinshasa sites. These differences may be related to the proximity of the rural Kinshasa sites with
407 the city of Kinshasa, though the access of participants to urban environments and differences in
408 community cohesion were not specifically accounted for in our surveys.

409

410 Our study results also show that incentivisation did not significantly affect audio uploads or activity
411 within Kinshasa and showed that the control group had more audio uploads in Bandundu compared to
412 the incentive group. Previous studies have shown that if incentivised actions align with social norms,
413 incentives can bolster desired behaviours [54], however, incentives can also weaken participants'
414 intrinsic motivations—a phenomenon known as the 'crowding out' effect. This occurs when the
415 anticipated intrinsic benefits of participation, such as the satisfaction of contributing, are diminished
416 by the introduction of external incentives [55]. The lack of response to incentives in our study suggests
417 that incentives were neither supporting intrinsic motivations nor diminishing them. Notably, for
418 logistical reasons this trial used individual health districts as trial groups. Differences in response to
419 incentives may be more strongly attributed to local culture and attitudes than treatment group. In the
420 future, a randomised control trial that assesses participants' existing motivations could more effectively
421 capture variations both among and within localities engaged in data collection. Additionally, further
422 work is needed to understand what the tipping points are for incentives to significantly motivate
423 participation, and what behaviours may either be unaffected by incentivisation or diminished by it.

424

425 Although incentives did not affect the overall number of data uploads across districts, there were
426 differences in the persistence of data collection participation and effort. The participation persistence

427 of the trial groups showed that the Bandundu control group had approximately the same amount of
428 participation from the start to the end of the trial, but that the other three trial groups experienced
429 significant declines in the latter half of the trial. A review paper of citizen science studies found that
430 studies that provided long term training and contact with organisers were the most successful at
431 engaging participants [56]. The declines in robust participation towards the end of the trial in our study
432 may be attributed to the lack of engagement with participants that was necessary to test the usability
433 of the data collection methodology with low intervention. The low contact resulted in several post-trial
434 focus group respondents indicating they would have liked more contact, despite all participants saying
435 the sensor and application were easy to use. Although participants had positive attitudes regarding the
436 data collection and responsibility (supporting results from other studies [57]) access to data and
437 collaborators may further improve participants' feelings about their participation and their
438 contributions [58].

439

440 Participant-researcher contact may be why our previous trial in Tanzania found that text reminders,
441 both alone and paired with an incentive, positively affected persistence in data collection, despite the
442 monetary incentive alone not showing a significant effect in that study system [34]. The declines in
443 participation persistence and effort seen in this study support this previous finding that incentives alone
444 are not enough to motivate participation. The tipping point in the middle of the study where
445 participation dropped suggests that participants do not need further encouragement or motivation in
446 the short term to collect Humbug data. In longer term contexts however, consistent contact and
447 communication may be necessary to continue to motivate participants, and we have found that
448 monetary incentives do not accomplish this, and in fact appear to only increase participation in the
449 early phases of the study.

450

451 The differences in upload effort between our trial groups did not follow patterns relating to
452 incentivisation. The data collection effort in Bandundu shows that the control group performed
453 similarly to the incentive group for most of the trial, with the control group performing significantly
454 better in the final couple of weeks. This appears to be due to a continued high level of data collection
455 persistence and effort on the part of the Bandundu control group, which seems to be attributable to
456 some intrinsic difference in this site compared to the other sites. In Kinshasa, incentivisation improved
457 data collection efforts in the early parts of the trial compared to the control group, suggesting that at
458 the time when participants were overall the most active, the incentive did improve the completeness
459 of data collection efforts. However, this higher level of data collection effort by Kinshasa's incentive
460 group dropped approximately halfway through the trial, after which there was not a significant
461 difference between the control and incentive groups. This mirrors the results for participant activity,
462 which showed that participation significantly dropped off halfway through. The decline in data
463 collection efforts shows that even those who are continuing to participate are not collecting data for
464 the entire time period (6 pm to 6 am) as requested in the data collection methodology. This may be in
465 part due to the design of our incentives, which were given regardless of activity and were not scaled
466 for completeness of participation. This result shows that despite incentivisation initially appearing to
467 motivate complete data collection in one of our districts, the diminishing interest and effort over time
468 are not overcome by incentivisation.

469

470 Our post-trial FGDs gave insight into issues surrounding incentives, including compensation and
471 technology. Over half of the participants in the trial did not return for the post-trial FGDs. The reasons
472 cited by the DRC team were a desire to keep the smartphone and the lack of payment at the control
473 sites, though there were more post-trial FGD attendees from the control groups than the incentive
474 groups. This compensation issue was emphasised by a refusal to return the phones by some participants
475 in trial groups in both districts. The Bandundu control group exhibited higher phone retention

476 compared to the Bandundu incentive group, and the Kinshasa incentive group showed higher phone
477 retention in contrast to the Kinshasa control group. There was no significant difference in the number
478 of participants that named phone retention as a motive for participation between the districts, the trial
479 groups, or between the trial groups within districts, showing that previously held values were not
480 associated with phone retention. Instead, the pattern of phone retention mirrored the activity levels of
481 each trial group, perhaps indicating that the more active participants felt a stronger entitlement to
482 keeping the phones. However, phone retention was related to the relative effort in each district, rather
483 than the overall effort. For example, the Bandundu incentive and the Kinshasa incentive had similar
484 activity levels and total uploads, yet the Kinshasa incentive group retained twice the number of phones.
485 As far as we are aware, participants in each district and trial group did not know the participation rates
486 of the other groups, and therefore, did not know their relative participation. This indicates that
487 individuals' participation might be influenced by their perception of effort.

488

489 The phone retention and refusal to return at the end of the study is an example of how citizen science
490 projects can deviate from planned outcomes. In this context, participants effectively provided
491 themselves with an incentive (or supplementary incentive) by refusing to return phones, despite study
492 agreements and information about compensation ahead of the trial. A study on citizen science with
493 specially designed video games found that game design can diminish citizen science outcomes and
494 enhance the odds of cheating and cutting corners, depending on the ability to do so [59]. It is important
495 to consider how incentive application design therefore may influence study outcomes and
496 participation. The incentive group in this case received payment regardless of participation, which may
497 have opened this study system to cutting corners (e.g., reduced activity and upload effort at the end of
498 the study period). As an alternative, incentives given in response to data collection activity close this
499 loophole and effectively encourage data collection persistence. Additionally, the post-trial survey in
500 this study was not incentivised, and therefore participants gained more from refusing to return phones

501 than they did from attending. Balancing incentive value with requests and alternatives is necessary for
502 incentives to operate as intended, and as seen in this study, some individuals will not follow
503 prescriptive actions if they feel they can benefit in other ways.

504

505 Our post-trial FGDs revealed that despite there not being a significant or differential response to
506 incentivisation, there were significant contrasting attitudes between the study groups in Bandundu and
507 those in Kinshasa. Bandundu exhibited a significantly higher overall participation rate in FGDs
508 compared to Kinshasa, and a greater proportion of Bandundu participants expressed willingness to
509 partake in the trial again, irrespective of incentivisation (25 out of 26 post-trial FGD attendees). Out
510 of 27 post-trial FGD attendees from Kinshasa, only 12 indicated a willingness to participate again.
511 Additionally, there appear to be differences in values between the two districts. Among the 16
512 participants who identified knowledge as their motive for future participation, only one was from
513 Kinshasa. Conversely, among Kinshasa participants who expressed willingness to participate again,
514 the majority cited incentives as their driving factor. Further research is needed to understand how
515 community and culture interact with incentive application, but in this case, despite differing
516 motivations for participation, incentives did not have any significant effects on overall participation in
517 the study.

518

519 The biggest issues cited by participants who took part in the trial were access to electricity to charge
520 the smartphone sensor and internet connection. Interestingly, the groups that mentioned access to
521 electricity significantly more were also the groups that performed best for data collection activity and
522 effort in each district. It could be that the practicality of it was more apparent to the groups that put
523 more effort in, and practical difficulties may be part of the reason people felt they should have been
524 compensated better for the study. Of the incentive group participants who attended the focus group,
525 over half said they felt they had not been given enough money for the study (14/22). This

526 dissatisfaction may have been due to the unexpected cost of transferring money, which reduced the
527 originally stated compensation (from \$10 to \$9). In pre-trial FGDs, there were only six cases when
528 participants who cited money as their motivation asked for a monetary value at or below the incentive
529 value given in the study, suggesting that the incentive potentially fell below common expectations.

530

531 Despite the sentiment that the money was not enough, incentive group participants were more likely
532 to say they would participate in the future than control group participants, and although bed nets were
533 one of the least cited reasons for participating in the study, almost all participants mentioned the bed
534 nets as a benefit they experienced in the trial, perhaps improving their desire to continue participation.
535 Considering that all phones were turned on and collected data at least once during the study period, it
536 appears useability was not a limiting factor of the study, and indeed all participants apart from one said
537 that they felt the MozzWear app was easy to use. Due to the lack of practical issues with the study, our
538 results highlight the importance of scaling expectations of citizen science and matching the value of
539 incentives with the effort and length of trials to improve participation and satisfaction.

540

541 Our findings show that mobile applications using hardware on budget smartphones can generate useful
542 data with limited interventions and suggests that mobile application development should be more
543 widely considered in citizen science data collection efforts. Future research on the role of
544 incentivization for data collection that utilizes technology should consider how to further disambiguate
545 the inherent benefits in participation related to technological access, such as social status or monetary
546 benefit from retaining equipment. We suggest that with increased mobile phone ownership, this
547 complexity may be overcome by utilizing current phone owners, rather than providing participants
548 with hardware. Additionally, as mobile phone use becomes more popular, opportunities for large scale
549 studies will support more complex statistical approaches to account for the complex structures that

550 underpin intrinsic motivators and responses to extrinsic motivators, such as proximity to urban areas
551 which are potentially obscured by the inferential statistical methods used in this study.

552

553

554 **Conclusions**

555 Results of this study show that in this study system incentives did not have significant effects on data
556 collection activity throughout the trial but did have some effect on data collection persistence and
557 effort, improving data collection effort during portions of the trial in one of our study districts. Our
558 results indicate that community differences are what drive the trends in participation in this study
559 system, and that more information is needed ahead of trials to assess how community differences may
560 impact participation in citizen science data collection. Participant engagement with researchers and
561 study organisers appears to improve data collection, particularly in longer studies. Communication
562 with participants is important for appropriately scaling incentives to account for citizen data collection
563 effort. Systems should be designed appropriately to maximise the alignment of incentives with active
564 data collection. Overall, the incentives tested do not appear to significantly improve data collection in
565 this study system, and in this case, increased engagement during data collection may have improved
566 outcomes. With technology becoming an increasingly used tool in citizen science, its application
567 should be considered in reference to existing infrastructure. Consideration should be made for the
568 value that the technology represents in reference to the overall value of the incentive being offered to
569 avoid issues with data sensor retention in response to changing attitudes towards incentive value.

570

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576

577

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Supplementary Information

S1 Appendix: The DHS Demographic Survey Administered to Participants

763 **S2 Appendix:** The focus group discussion questions administered pre-trial and post-trial.

764 **S3 Table:** A table of results from comparisons of the demographic survey between study districts, trial
765 groups overall, and trial groups within each district.

766

767

Figure 5

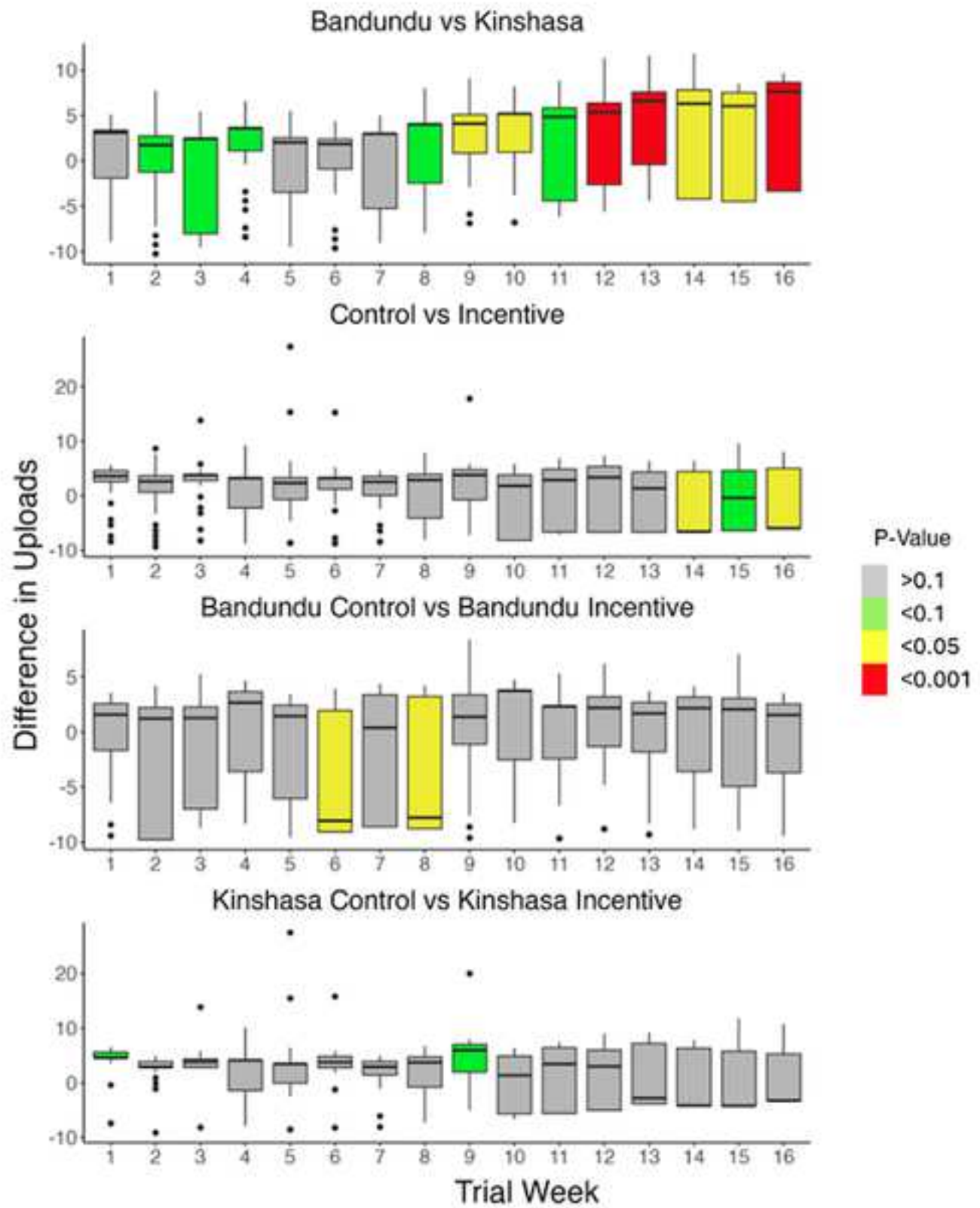


Figure 4

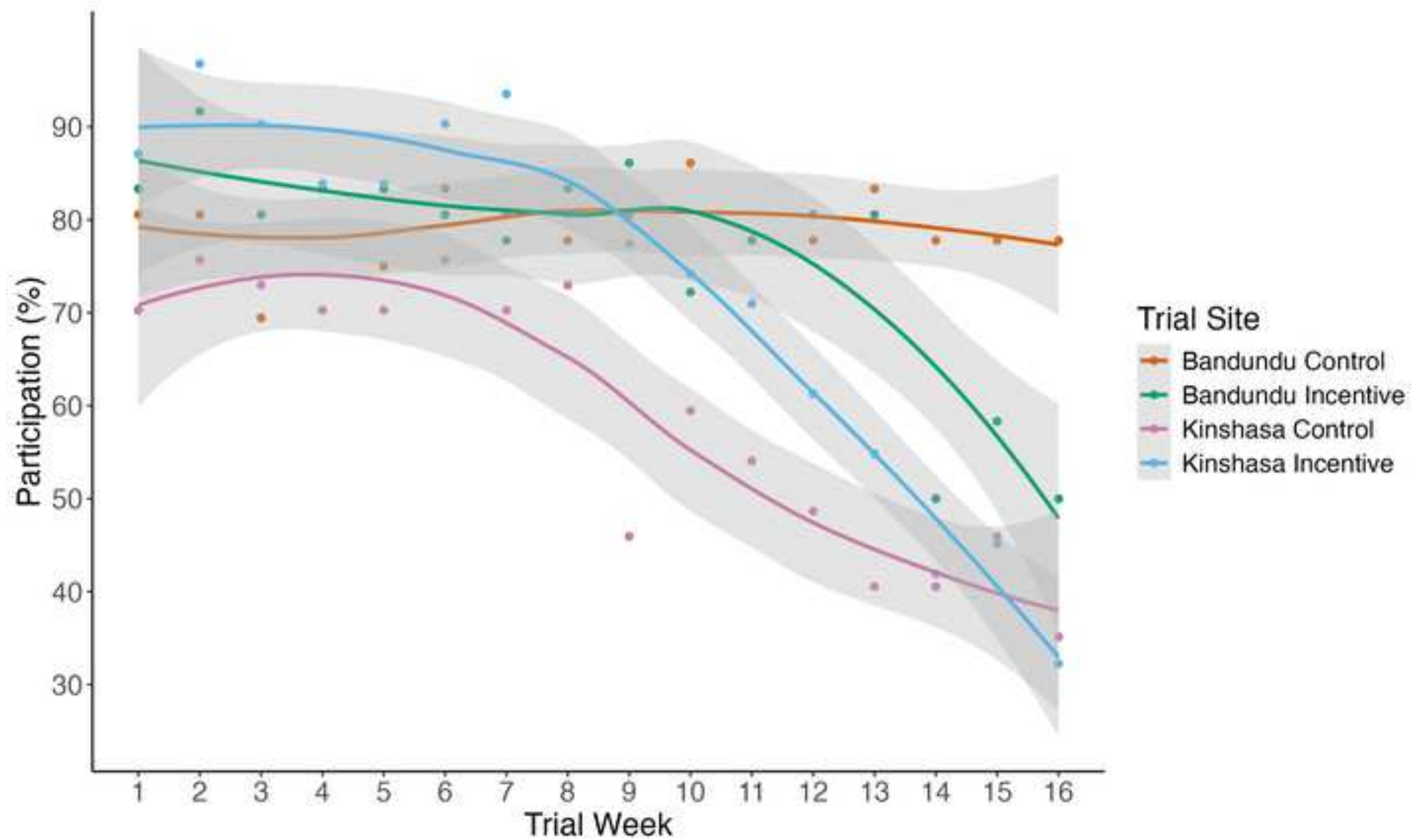


Figure 3

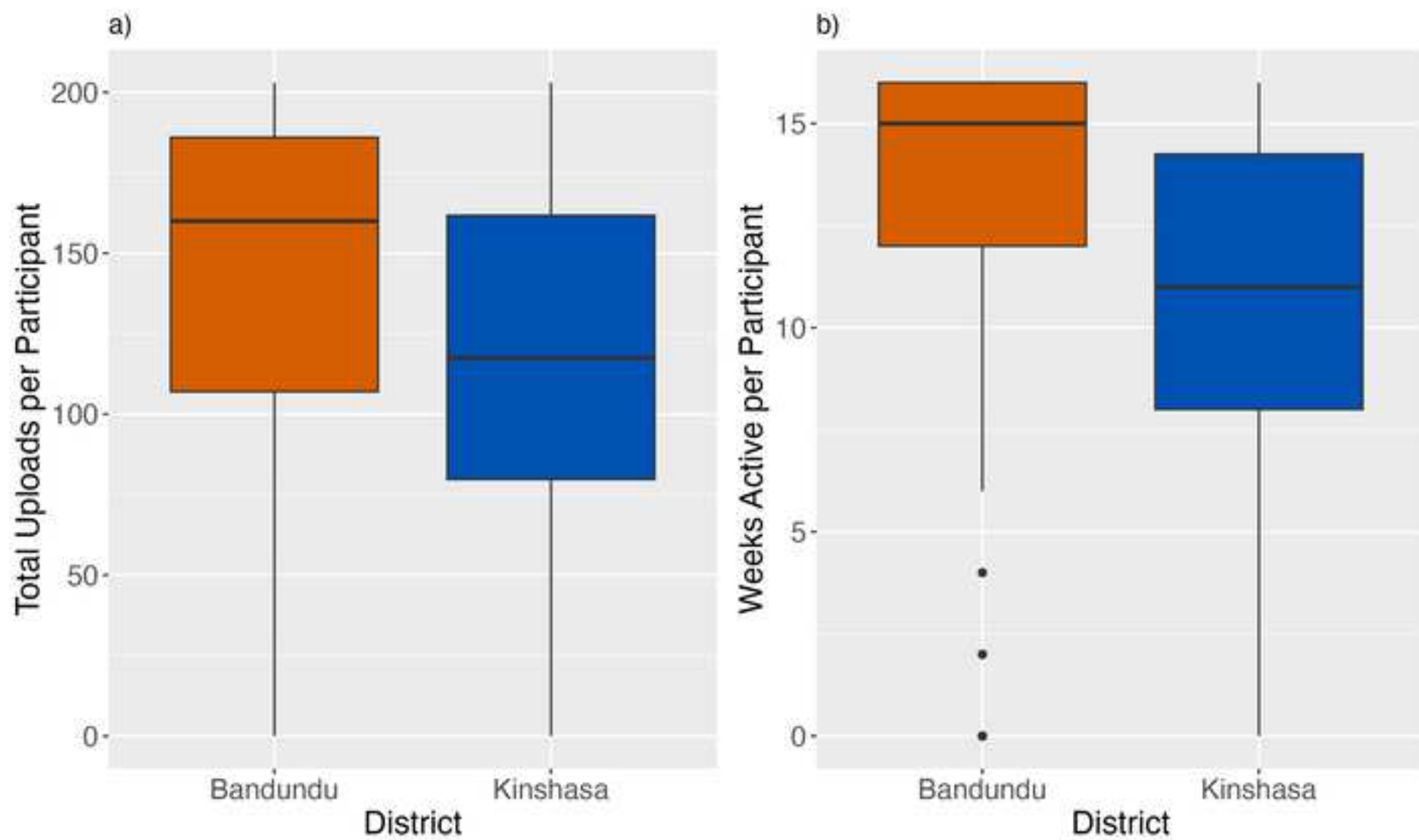
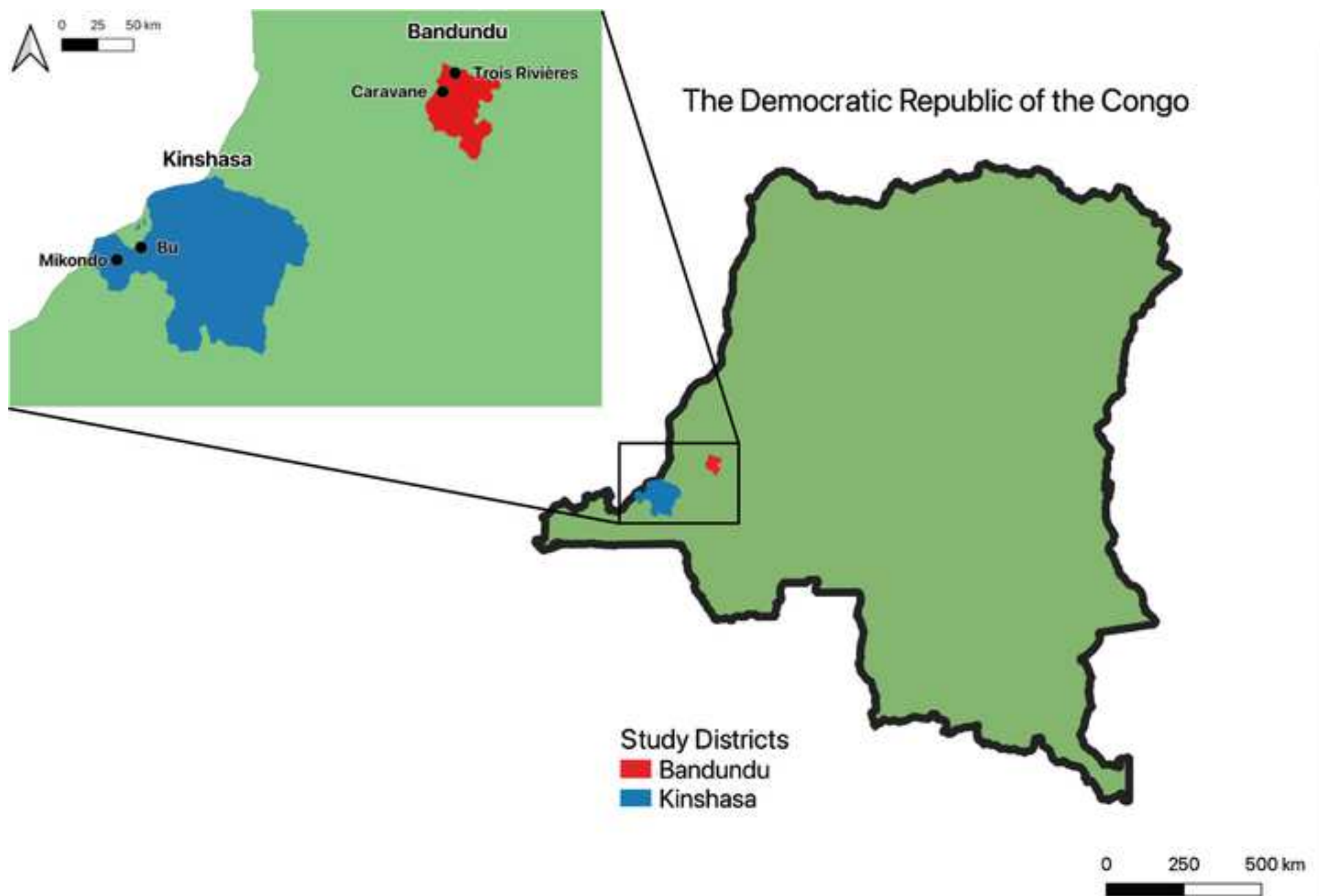
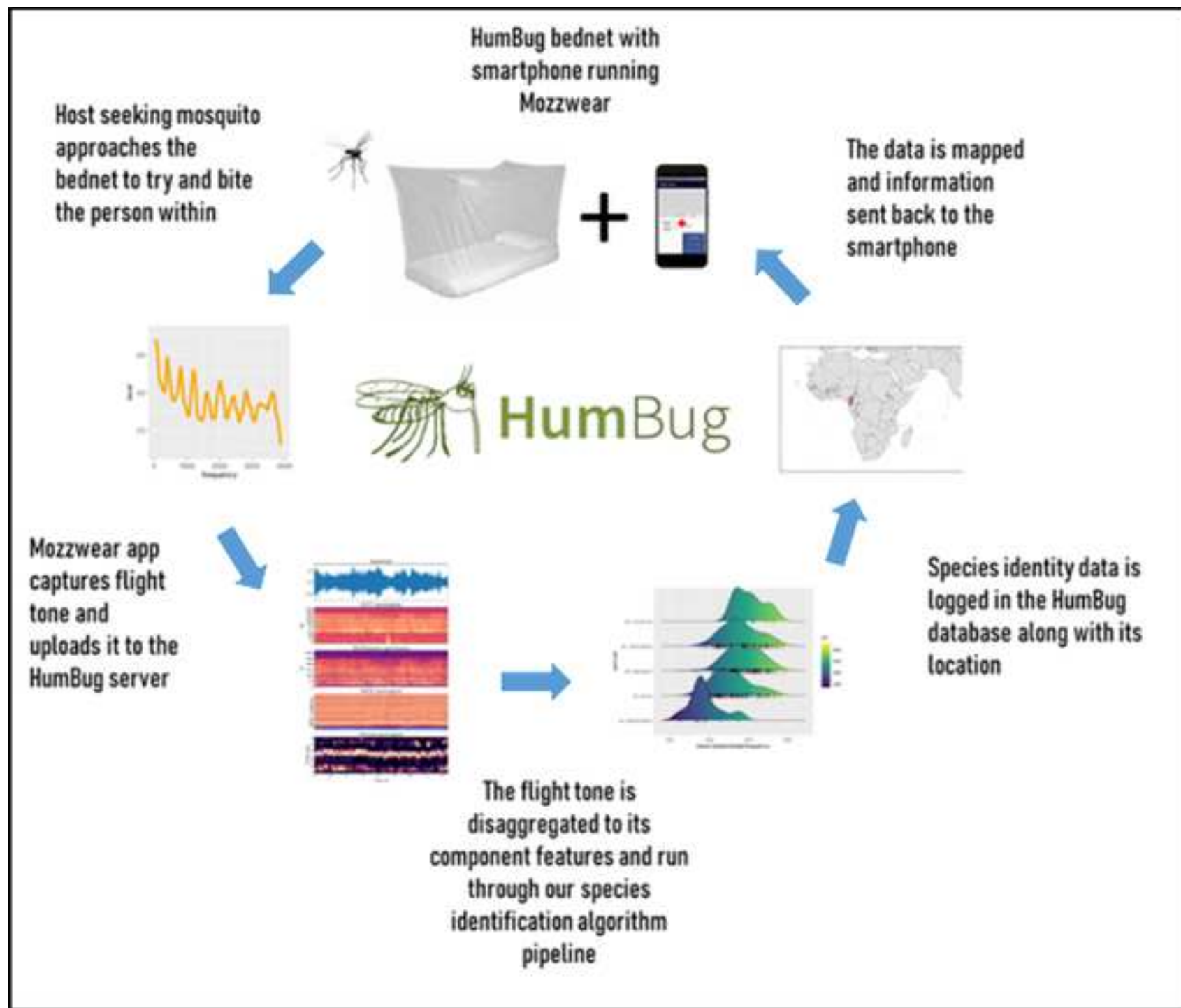
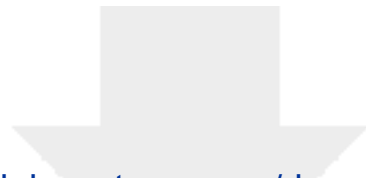


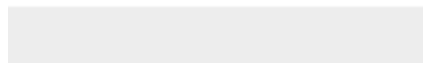
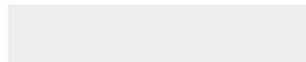
Figure 2







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Supporting Information
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1 ~~What-Do monetary~~ incentives encourage local communities to collect and upload
2 mosquito sound data ~~by~~ using smartphones? A case study in the Democratic
3 Republic of the Congo

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4
5 Short Title: Incentives for citizen science data collection in the DRC

6
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9 Li⁷, Stephen Roberts⁸, and Katherine J. Willis¹

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34 [&] RD, MS, IK, JE, YL, and SR also contributed equally to this work

35

36 Attribution

37 KES contributed to data curation, formal analysis, methodology, visualization, and writing the original
38 draft. JPM contributed to formal analysis and visualization. EHM contributed to conceptualization,
39 investigation, methodology, project administration, supervision, visualization, and the review and
40 editing of the manuscript. EM, JZ, NMM, and SM contributed to conceptualization, investigation,
41 methodology, data collection, and review and editing of the manuscript. RD, MS, IK, JE, YL, and SR
42 contributed to conceptualization, methodology, and review and editing of the manuscript. KJW
43 contributed to funding acquisition, methodology, supervision, and the review and editing of the
44 manuscript.

45

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Abstract

Malaria is one of the deadliest vector borne diseases affecting sub-Saharan Africa. A suite of systems are being used to monitor and manage malaria risk and disease incidence, with an increasing focus on technological interventions that allow private citizens to remotely record and upload data. However, data collected by citizen scientists must be standardised and consistent if it is to be used for scientific analysis. Studies that aim to improve data collection quality and quantity have often included incentivisation, providing citizen scientists with monetary or other benefits for their participation in data collection. We tested whether monetary incentives enhance participation and data collection in a study trialling an acoustic mosquito sensor. Working with the community in two health districts in the Democratic Republic of Congo, we measured data collection participation, completeness, and community responses. Our results showed mixed responses to the incentive, with more participants interested in the social status and monetary value of the technology used than the monetary incentive itself. The effect of incentives on data collection varied over the course of the trial, increasing participation in the start of the trial but with no effect in the latter half of the trial. Feedback from participants showed that opinions on technology, research objectives, and incentives varied between communities, and was associated with differences in data collection quantity and quality, suggesting that differences in community interest in data collection and the incentives may be more important than the incentive value itself. These results suggest that though there is an initial benefit, extrinsic motivations do not override differences in intrinsic motivations over time, and enhanced communication and dialogue with participants may improve citizen science participation and attitudes.

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Introduction

Mobile phone usage in sub-Saharan Africa reached 489 million users in 2023, with smartphones making up 51% of mobile phones due to improvements in mobile phone access and network connections [1–3]. With increasing smartphone ownership, their use for citizen science data

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76 collection has also increased in tandem, making use of the built-in camera, sensors, and GPS to
77 generate and record data ([4–7]). Citizen science projects have ranged widely, and have been
78 increasingly used in healthcare settings, including for monitoring diseases such as malaria by tracking
79 outbreaks, monitoring drug stocks, reminding patients of medical appointments, and recording
80 mosquito larval habitats and populations ([for examples see: 8–15]). As the amount and type of data
81 collected by private citizens increases there are opportunities for developing high-resolution data
82 repositories that widen citizen participation to include a greater range of demographic groups.

83
84 Previous research on citizen science data collection has shown that gathering data for research or
85 healthcare purposes can help to improve educational outcomes ([16]), make data collectors feel more
86 connected to their community ([17]), and improve health outcomes ([18]). But how do researchers
87 motivate people to participate and collect high-quality data? Firstly, there is need to understand the
88 roles that intrinsic and extrinsic motivations play in citizen scientist participation and data collection
89 quality. Intrinsic motivation factors are 'people's spontaneous tendencies to be curious and interested,
90 to seek out challenges and to exercise and develop their skills and knowledge, even in the absence of
91 operationally separable rewards' ([19]). Intrinsic motivation is influenced by local and regional
92 cultures, education, and familial values ([20]). In contrast, extrinsic motivators are 'behaviours done
93 for reasons other than their inherent satisfactions' ([21]), such as monetary gain ([22]). Efforts to
94 improve data collection typically target these different motivation factors. Studies have shown that
95 monetary incentives can be used in health care and ecological monitoring schemes to improve
96 participation ([23–27]) and that intrinsic factors can be harnessed to improve data collection
97 participation and quality by improving learning opportunities and using participant knowledge ([28–
98 31]).

99

The complex spatiotemporal variability inherent to motivation factors [32,33] and the theoretical potential for a trade-off between them [21] make understanding their influence essential to improving data collection quality and scope while optimising resource allocation. To study participants' motivations and assess the functionality of incentive applications to promote community involvement in the collection of high-quality long-term biological data, we previously ran a data collection trial using incentives and SMS text reminders for collecting mosquito audio data in Tanzania using the HumBug tool [34]. This tool is a smartphone audio sensor combined with a modified bed net designed to temporarily trap mosquitoes and guide them towards a budget smartphone running the MozzWear app that records the flight tone of host seeking mosquitoes overnight to determine the abundance and diversity of mosquitoes present using their sound [35] (Fig. 1); For details on the Humbug tool, also see [36–42].

Fig. 1: HumBug Tool configuration, showing the data collection, upload, and analysis pipeline (reproduced from Sinka et al., 2021).

The smartphone app MozzWear used in the HumBug tool records mosquito flight tone data overnight and provides a secure connection to a server at the University of Oxford where the data is uploaded via the mobile or Wi-Fi data network. The data then runs through an algorithm pipeline that first detects the mosquito flight tone from background noise and then identifies the mosquito species using their acoustic signature [35–37,40]. As such, the HumBug tool is a good example of using smartphone technologies to provide an accessible biological data collection methodology to identify and monitor vectors of human disease - in this case, mosquitoes.

Previous work in Tanzania showed that providing homeowners with monetary incentives and SMS reminders to record and upload mosquito data did not significantly increase the number of uploads when compared to the control group [34]. Instead, the study found that other factors influenced data

collection efforts. However, it did not examine in detail what these other factors might be. To better understand, therefore, how a monetary extrinsic factors may affect data collection practices in the use of the HumBug tool, we ran a second data collection trial in a different community within two districts of the Democratic Republic of the Congo: Bandundu, and rural Kinshasa. In this study we aimed to test whether monetary extrinsic incentives encouraged: i) participant data collection activity during the trial period; ii) participant effort (the number of uploads per participant made during the sampling period, indicative of following trial protocols); and iii) the persistence of participation over time (whether trial participants continued to upload data throughout the sampling period). To address these questions, we compared participant activity (weeks active) and sampling effort (number of uploads) over the sampling period to assess differences in participation associated with receiving incentives for data collection. This study builds upon our previous work in Tanzania to fill gaps in understanding how monetary incentives alone influence the consistency and quality of audio data collection.

Methods

The study ran from April to November of 2022 in two districts of the Democratic Republic of the Congo (DRC): rural Kinshasa, and Bandundu. Our collaborators at the University of Kinshasa and the University of Bandundu selected participants, conducted demographic surveys and pre- and post-trial focus group discussions, and ran the study. Data analysis and writing of the manuscript were carried out by the University of Oxford team. All leaders of communities, health zone officials, and participants provided signed consent forms for the study, and the study was approved by the University of Oxford Tropical Research Ethics Committee and the University of Kinshasa Public Health Ethics Committee. Informed written consent was obtained from all interviewees prior to the focus group discussions and the quantitative feedback survey. Consent forms signed by all the participants included the release of summary findings and details of individual responses from this study. Potential participants were informed of the voluntary nature of the study and had at least 24 hours to consider

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151 taking part. Efforts were made to create a safe place for sharing experiences during the focus group
152 discussions.

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154 **Study Locations**

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155 Geographically, the DRC covers an area of approximately 2,345,409 km². The country is dominated
156 by the Congo River basin surrounded by high plateaus, resulting in high precipitation and thick tropical
157 forest within the basin and grassland in the plateaus above. In the DRC, malaria is a major cause of
158 illness and death. Worldwide, 12% of the total malaria cases occurred in the DRC in 2022, causing
159 60% of hospital visits in the country ([43,44]).

161 Kinshasa is the capital city of the DRC and the largest city in central Africa. With ~16 million
162 population it is the third largest mega-city on the continent. The Bandundu district has a total of
163 143,435 people and covers an area of 222 Km² (Figure 2). Participants in our research were from the
164 Bu and Mikondo health districts of Kinshasa, and the Trois Rivières and Caravane health districts of
165 Bandundu.

167 *Fig. 2: Map of the Democratic Republic of Congo, modified from simplemaps.com [45] and GRID3 COD -*
168 *Health Areas v4.0 [46,47], under CC BY 4.0 license, -showing the provinces of the DRC (45), the location of the*
169 *trial districts (46) location of study districts: showing Bandundu in redpurple and Kinshasa in blueorange. On*
170 *the zoom inset, -with blackred points showing the location of study sites in the zoom inset. Mapping was*
171 *carried out, -all visualised using QGIS 3.30.0 ([48]).*

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173 Each district in our study had two trial sites: a control site and an incentive site. The selection of
174 participants from our four trial sites took place from April 2 to June 30, 2022. In each health district,
175 authorities of the different Health Zones, the village chiefs, and heads of districts were contacted to

gain permission for the study and to involve local leadership. Meetings with local leaders were carried out to plan the recruitment of households for the study, and to allocate which health districts would be the control treatment (Trois Rivières in Bandundu and Bu in Kinshasa) and the incentive treatment (Caravane in Bandundu and Mikondo in Kinshasa). These health districts will hereafter be referred to as a trial sites for clarity.

Households were recruited using a modified random walk technique from an entry point chosen from the main entrances to the village/street selected by local health district officials. To reduce the bias of entry point selection, each household was approached sequentially along the street ~~From the entry point, the selection group and~~ asked if they wanted to participate, progressed until the number of households required to participate at the site (n=37) was met. Trial participants were admissible if they were 18+ years old, owned or had access to a personal mobile phone, were residents in Bandundu/Kinshasa throughout the study, and were willing and capable of providing a signed consent form.

Ahead of the trial, training of the interviewers and moderators took place over a day in each of the trial sites to teach local health officials and local leadership how to run interviews and support participants in the trial. Demonstrators were also taught how to install and use the HumBug tool and MozzWear App and were given a presentation of the trial objectives. ~~(Figures 3 and 4)~~. Finally, interviewers were trained on how to administer the demographic questionnaires to participants who agreed to take part in the trial (DHS Phase 8 Questionnaire, S1 Appendix).

Fig. 3: Images of the DRC showing trial participants how to record and upload data using the Humbug tool.

Fig. 4: Meetings with the participants to show them how to set up the HumBug net.

201 Moderators ran pre-trial focus group discussions (FGDs) to confirm that participants understood the
202 purpose of the study, how the study was designed, and how to operate the HumBug tool and MozzWear
203 application. The pre-trial FGDs were also used to discuss and understand the challenges that
204 participants may face, their motivations for taking part in the study, and what they thought the impact
205 would be on their lives. The pre- and post- trial FGD questions can be found in the S2 Appendix. The
206 reasons participants gave for joining the study were categorized into common themes of access to
207 electricity, financial incentive, use of a phone, provision of bed nets, contributing to health
208 improvements and malaria control, or gaining personal knowledge. Participant FGDs responses were
209 then structurally coded for analysis (498).

210
211 Control group participants were provided with the HumBug tool (a smartphone running the MozzWear
212 app and the HumBug bed net), and one dollar to pay for an internet connection. The incentive group
213 was provided with the HumBug tool and one dollar for an internet connection, and an additional ten
214 dollars each month paid via airtime to their mobile phones. Participants were instructed to place the
215 smartphone with the MozzWear app in the HumBug net and start the record function at 18:00 hrs and
216 turn it off at 06:00 hrs on their allocated weekly recording day during the trial period (16 weeks total).
217 Recordings were split at one-hour intervals automatically in the MozzWear app to prepare recordings
218 for algorithmic analysis. As such a complete recording effort would show 12 recordings. The
219 recordings were then uploaded by participants to the remote server when they connected to the internet.
220 Once participants were taught how to use the Humbug tool there was no contact between the research
221 team and the participants.

222
223 The research team conducted post-trial FGDs to understand the participants' experience of using the
224 HumBug tool and participating in the study. Questions included whether they liked using the
225 MozzWear app, whether they liked using the HumBug net, how the trial personally affected them,

226 what they would want to be different about the trial in the future, whether they would participate in
227 the future, and if they received an incentive whether it was enough money. Data from the post-trial
228 FGDs was coded for analysis by themes of response to questions as described for the pre-trial FGDs.
229

230 Data Analysis

231 To compare the effect of providing incentives to the participants to upload mosquito audio data, the
232 number of active participants (participants who uploaded any data) and the number of uploads were
233 counted during each trial week. Participant identification numbers were used to assess the upload
234 counts and weekly activity by location (Kinshasa or Bandundu districts) and experimental group
235 (control or incentive). Counts of uploads, weeks of participation, and the average number of
236 participants each week were compared using Wilcoxon Rank Sum tests ~~(5049)~~ and Kruskal-Wallis
237 tests ~~(510)~~ with a post-hoc Dunn test ~~(524)~~ to assess if there was a significant difference in
238 participation between the experimental groups/locations over the study period and reduce potential
239 type 1 error associated with multiple comparisons. The number of participant uploads was broken
240 down for each week of the trial to assess whether incentives improved data collection persistence
241 throughout the study and was also compared using Wilcoxon Rank Sum Tests. Data on income, sex,
242 age, education, and profession were also evaluated as explanatory variables to explain variation in data
243 collection between groups. Comparisons of the demographic data of each district, trial group, and
244 combination of the two, were made using Wilcoxon Rank Sum tests and Chi-squared tests. The pretrial
245 FGD data was analysed using Wilcoxon Rank Sum tests to compare differences in pre-trial motivations
246 for participation. The post-trial FGD data was analysed using a Fisher's Exact Test to assess the
247 correlation between district and trial groups on attendance for the post-trial FGD and whether
248 participants would take part in a future trial, and phone return. All plots were produced using ggplot2
249 ~~(532)~~.

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Data management

Personal data generated in the form of signed consent forms, personal mobile phone numbers, interviews, and/or focus group audio recordings, were stored following the 2018 Data Protection Act on a secure administrative database on a University of Oxford server.

Results

Pre-Trial Focus Group Discussions

Pre-trial focus group discussions (FGDs) were run in three groups of 12-13 participants in each trial site (37 people per trial site, 148 participants in total). In the pre-trial FGDs, themes identified for participant motivation were monetary benefit (63.5% of all participants), contributing to science/health (33.1%), having a phone (29.7%), electricity access (27.0%) (not a component of this study), the HumBug net (6.7%), and gaining personal knowledge (5.4%). Participants were typically motivated by multiple factors. As a participant in Bandundu describes ‘To do the job well, I have to be motivated, in the sense that I have to have the material for the job first, and then I have to be paid a good payment so that I can do a good job’. There was no significant difference in the number of motives each participant listed at the start of the study between Bandundu and Kinshasa ($p > 0.05$).

Statistical comparisons using Wilcoxon Rank Sum Tests showed that trial site participants in Kinshasa mentioned electricity significantly more as a reason to participate in the trial compared to Bandundu trial site participants ($W = 3774$, $p\text{-value} < 0.001$). Comparing treatment groups across both districts, electricity access was mentioned more frequently in the control groups compared to the incentive groups ($W = 2072$, $p\text{-value} < 0.001$). Between the treatment groups in Bandundu, electricity was more frequently mentioned by the control group (control $n=6$, incentive $n=0$; $W = 795.5$, $p\text{-value} = 0.012$) and personal knowledge (on topics such as mosquito control and malaria prevention) was more

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275 commonly cited by the incentive group (control n=0, incentive n=4; W = 610.5, p-value = 0.042). In
276 Kinshasa, the control group mentioned electricity (control n = 23, incentive n = 11; W = 906.5, p-value
277 = 0.005) and contributing to science/health (control n = 15, incentive n = 6; W = 851, p-value = 0.022)
278 significantly more than the incentive group. There were no other significant differences between
279 districts, trial groups, or the trial groups within districts (p-value>0.05).
280

281 **Demographic Survey**

282 Demographic survey data were assessed to identify if they contributed to differences in recording
283 ability between districts, treatment groups, and treatment groups within districts. There were
284 significantly more adults in the homes of participants in the Kinshasa district sites compared to the
285 Bandundu district sites (W = 1680, p-value = 0.017). Between the treatment groups in both districts,
286 there were no significant differences in any demographic response variables. Within Kinshasa, there
287 was significantly less water scarcity in the control group (29% experiencing water scarcity), and
288 compared to the incentive group (45% experiencing water scarcity) (odds ratio = 0.09, p-value = 0.021)
289 and there was a significant difference in the method of home lighting, with significantly more homes
290 in the control group using a rechargeable flashlight, torch, or lantern (p-value = 0.016). Within
291 Bandundu there were significantly more children in the incentive group compared to the control group
292 (W = 675, p-value = 0.024), with one more child per house in the study on average. Additionally, there
293 was a significant difference in toilet types between the Bandundu trial groups (p-value = 0.033). These
294 were the only cases out of 88 comparisons that were significantly different between districts and trial
295 groups (S3 Table).
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Comparing Districts and Trial Groups

Some participants decided to withdraw from the trial during its course and others failed to upload data, resulting in overall participation of 33 from the control group and 31 from the incentive group in the Kinshasa districts (n=64), and 33 from the control group and 35 from the incentive group in Bandundu districts (n=68), totalling 132 participants. The withdrawal rate from the study was 7.4% from the control sites and 10.4% from incentive sites across both districts. The reasons cited for formal withdrawal from the trial were lack of monetary benefit, unplanned move from the trial area, and loss of the smartphone. Comparisons in participation between trial districts using Wilcoxon Continuity tests showed that Bandundu participants uploaded data more weeks of the trial period ($W = 1589$, $p < 0.001$) and had more total uploads ($W = 1825.5$, $p = 0.009$), than participants in Kinshasa, shown in Figure 35.

Fig. 35: Comparison of a) the total number of uploads per participant in Bandundu and Kinshasa and b) the number of weeks that each participant was active in Bandundu and Kinshasa. Bandundu is shown in red, and Kinshasa is shown in blue. Boxes show the interquartile range (IQR), with whiskers showing the upper and lower 25% of the data, and points showing the outliers.

Comparing treatment groups across both districts there was no difference in participation between the control group and the incentive group for either total uploads ($W = 2409.5$, $p\text{-value} = 0.88$), or participation weeks ($W = 2510.5$, $p\text{-value} = 0.79$). Within Kinshasa there was no significant difference between treatment groups in either uploads ($W = 418.5$, $p\text{-value} = 0.057$) or weeks of activity ($W = 428$, $p\text{-value} = 0.073$). In Bandundu, there were significantly more total uploads in the control group compared to the incentive group ($W = 845.5$, $p\text{-value} = 0.026$) but no significant difference in the average number of active weeks of each participant ($W = 777$, $p\text{-value} = 0.13$) (Table 1). There were no significant relationships found between in the demographic variables that were captured in the demographic questionnaire survey and the number of uploads or weeks of activity.

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324 Table 1: Results of the Mann Whitney-U Tests for the trial group comparisons, with * to denote significance,
325 $p\text{-value} < 0.05$ *, $p\text{-value} < 0.01$ **.

<u>Comparison</u>		<u>Response Variable</u>	<u>Group</u>	<u>Mann-Witney U</u>	<u>Median</u>	<u>IQR</u>	<u>P-Value</u>
<u>District</u>		<u>Uploads</u>	<u>Kinshasa</u>	<u>W=1825.5</u>	<u>117.5</u>	<u>79.75-161.75</u>	<u>0.009486***</u>
			<u>Bandundu</u>		<u>160</u>	<u>107-186</u>	
		<u>Weeks</u>	<u>Kinshasa</u>	<u>W=1589</u>	<u>11</u>	<u>8-14.25</u>	<u>0.0002879***</u>
			<u>Bandundu</u>		<u>15</u>	<u>12-16</u>	
<u>Treatment</u>		<u>Uploads</u>	<u>Control</u>	<u>W=2409.5</u>	<u>136</u>	<u>73-186</u>	<u>0.8822</u>
			<u>Incentive</u>		<u>140</u>	<u>94.5-172.5</u>	
		<u>Weeks</u>	<u>Control</u>	<u>W = 2510.5</u>	<u>13</u>	<u>7-16</u>	<u>0.7852</u>
			<u>Incentive</u>		<u>13</u>	<u>10-15</u>	
<u>Bandundu</u>	<u>Treatment</u>	<u>Uploads</u>	<u>Control</u>	<u>W=845.5</u>	<u>180</u>	<u>122.25-193.5</u>	<u>0.02643*</u>
			<u>Incentive</u>		<u>149.5</u>	<u>91-177.75</u>	
		<u>Weeks</u>	<u>Control</u>	<u>W=777</u>	<u>16</u>	<u>12-16</u>	<u>0.1307</u>
			<u>Incentive</u>		<u>13.5</u>	<u>11.5-16</u>	
<u>Kinshasa</u>	<u>Treatment</u>	<u>Uploads</u>	<u>Control</u>	<u>W=418.5</u>	<u>99</u>	<u>62-164</u>	<u>0.05705</u>
			<u>Incentive</u>		<u>140</u>	<u>96.5-160</u>	
		<u>Weeks</u>	<u>Control</u>	<u>W=428</u>	<u>11</u>	<u>6-14</u>	<u>0.07298</u>
			<u>Incentive</u>		<u>12</u>	<u>10-14.5</u>	

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Comparison		Response Variable	Group	Mann-Witney U	Median	IQR	P-Value
District	Uploads		Kinshasa	W=1825.5	117.5	79.75-161.75	0.009486***
			Bandundu		160	107-186	
	Weeks		Kinshasa	W=1589	11	8-14.25	0.0002879***
			Bandundu		15	12-16	
Treatment	Uploads		Control	W=2409.5	136	73-186	0.8822
			Incentive		140	94.5-172.5	
	Weeks		Control	W = 2510.5	13	7-16	0.7852
			Incentive		13	10-15	
Bandundu	Treatment	Uploads	Control	W=845.5	180	122.25-193.5	0.02643*
			Incentive		149.5	91-177.75	
	Weeks		Control	W=777	16	12-16	0.1307
			Incentive		13.5	11.5-16	
Kinshasa	Treatment	Uploads	Control	W=418.5	99	62-164	0.05705
			Incentive		140	96.5-160	
	Weeks		Control	W=428	11	6-14	0.07298
			Incentive		12	10-14.5	

327

328

329 Activity and Effort over Time

330 Activity Persistence

331 The percentage of active participants was catalogued weekly to assess whether the monetary incentive
332 affected persistence in data collection over the trial period (Fig. 46). At the start of the trial, the
333 Kinshasa incentive group had the highest participation (87.1%), followed by the Bandundu incentive
334 (83.3%), Bandundu control (80.5%), and Kinshasa control (70.3%). Participation was approximately
335 stable for the first half of the trial before declining from week 8. At the end of the trial both the Kinshasa

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control and Kinshasa incentive group had dropped to 30-35% participation, Bandundu incentive dropped to 50% participation, and Bandundu control maintained 77.7% participation.

Fig. 46: The percentage of participants that activated the MozzWear app in each trial group during each week in the trial. The coloured lines coordinate with trial groups, showing Bandundu control in orange, Bandundu incentive in green, Kinshasa control in pink, and Kinshasa incentive in blue. Lines were fitted using locally estimated scatterplot smoothing (LOESS), with the 95% confidence interval for each treatment group indicated in grey.

Data Collection Effort

Data collection effort over the trial showed that in the first week the Kinshasa incentive group had the highest average uploads per active participant (12.26) followed by the Bandundu control (11.69), Bandundu incentive (10.83), and Kinshasa control (10.54). Data collection effort declined at around week seven, and at the end of the trial, the upload effort dropped for all groups, finishing in descending order with Bandundu control (11.29), Bandundu incentive (10.39), Kinshasa incentive (10.8), and Kinshasa control (9.23). Over the course of the study, Bandundu had significantly more uploads per participant compared to Kinshasa ($W = 1825.5$, $p\text{-value} = 0.009$), and the Bandundu control group had higher data collection effort than the incentive group ($W=845.5$, $p\text{-value} = 0.026$). but there was no significant difference between the control and incentive groups overall or within Kinshasa. Figure 57 below shows the weekly comparisons in data collection effort over the course of the trial between the trial districts, treatment types, and treatments within districts. Bandundu had a trend of higher uploads in weeks 2-4, 8, and 11 ($p\text{-value} < 0.1$), and significantly higher uploads in weeks 9, 10, and 12-16 ($p\text{-value} < 0.05$) compared to the Kinshasa groups. Comparisons of the treatment groups showed that the control groups had higher participation than the incentive groups in the final three weeks of the trial ($p\text{-value} < 0.05$). Within Bandundu, the control group had higher participation in weeks 14 and 16 of

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the trial compared to the incentive group (p-value <0.05), and within Kinshasa, the control group had trends of lower participation than the incentive group in weeks 1 and 9 of the trial (p-value < 0.1)

Fig. 57: Week-to-week comparisons of collection effort between the trial districts, and incentive and control groups overall and within Kinshasa and Bandundu. The magnitude of the bars shows the difference in uploads per person from the first group in panel subtitle relative to the second. Non-significant differences are shown in grey; trends are shown in green (p-value < 0.1), significant results in yellow (p-value < 0.05), and highly significant differences are shown in red (p-value < 0.001). The whiskers around each bar show the standard error.

Post-Trial Focus Group Discussions

The focus group discussions after the trial were attended by 27 participants from Kinshasa and 26 from Bandundu equating to ~35% of the original trial participants. In comparison to the 12 pre-trial FGDs, only 6 post-trial FGDs were run. Post-trial FGD attendance was lower in the Kinshasa incentive group compared to other groups (n = 8, p-value = 0.098, 95% CI: [0.0995, 1.2767] odds ratio: 0.368). All returning participants indicated that they had positive experiences with the HumBug sensor and a positive experience with the HumBug bed nets. When asked about the effect of the trial on their life, a respondent from the Bandundu incentive site said, "I was doing this work without someone to command me (...) it gave me the sense of responsibility."

There was a lower interest in future participation for control groups (n=12) compared to the incentive groups (n=25), and lower interest in future participation in Kinshasa (44.4% of respondents) compared to Bandundu (96.2% of respondents). Both district and trial group were significantly associated with participants interest in future participation (p-value < 0.001, 95% CI: [1.801, 5.468], odds ratio: 3.102), showing that in Bandundu the control group was 10% less likely to say they would participate in the

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386 future than the Bandundu incentive group, and in Kinshasa the control group was 60% less likely to
387 participate in the future compared to the Kinshasa incentive group.

388
389 When asked about challenges or things they wanted to change in the trial, electricity access was
390 mentioned more frequently in the Kinshasa incentive group ($W = 32$, $p\text{-value} = 0.007$) and the
391 Bandundu control group ($W = 129$, $p\text{-value} = 0.008$) compared to the other trial group in their
392 respective districts. Financial compensation/increased compensation was mentioned by 17
393 respondents, but did not vary significantly between trial groups. When queried on how to improve the
394 study, a respondent indicated a desire for more interaction and information, "When we send the data,
395 on your part, we need a sign to know if the data has arrived or not (...) until the end, we had no
396 communication."

397
398 Finally, only participants in the Kinshasa control group mentioned wanting to keep the smartphone
399 ($n=12$). Despite not being discussed in other post-trial FGDs, phone retention was an issue at the end
400 of the study. In total, there were 33 phones retained by participants across the districts, with a higher
401 likelihood for the Kinshasa incentive group and for the Bandundu control group to retain phones,
402 compared to the other trial group in their district ($p\text{-value}=0.00516$, 95% CI [1.567, 74.361], odds
403 ratio: 9.177). Additionally, nine phones were reported as lost or stolen by the end of the trial period.
404 As one participant phrased it from the control trial group in Kinshasa, "I want to be left with the phones
405 because we will be laughed at (...) if you take them away from us, they will say that we participated
406 in vain."

407

408 Discussion

409 Our results demonstrate that in the DRC there was no significant difference in the number of audio
410 recordings uploaded or the number of weeks that participants were active between the groups receiving

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411 financial incentives and the groups that did not. The previous HumBug study in Tanzania similarly
412 showed no significant effect of incentives (monetary incentives, text message reminders, or their
413 combination) on the total audio recordings uploaded (434). We found there was no significant effect
414 of demographics such as age, sex, or income on the number of uploads or participation weeks, nor
415 were there significant differences in these demographic traits between the districts, trial groups, or trial
416 groups within districts. The only significant effect on the number of uploads and active weeks was
417 study location which showed that participation was overall higher in Bandundu compared to Kinshasa,
418 and a difference between the control and treatment group uploads in Bandundu due to a higher
419 recording effort of the control group. This suggests that differences between the districts are not
420 attributable to demographic effects, and instead, there may be other differences, such as intrinsic
421 motivations or community leadership, resulting in higher numbers of uploads in Bandundu compared
422 to the Kinshasa sites. These differences may be related to the proximity of the rural Kinshasa sites with
423 the city of Kinshasa, though the access of participants to urban environments and differences in
424 community cohesion were not specifically accounted for in our surveys.

425
426 Our study results also show that incentivisation did not significantly affect audio uploads or activity
427 within Kinshasa and showed that the control group had more audio uploads in Bandundu compared to
428 the incentive group. Previous studies have shown that if incentivised actions align with social norms,
429 incentives can bolster desired behaviours (543), however, incentives can also weaken participants'
430 intrinsic motivations—a phenomenon known as the 'crowding out' effect. This occurs when the
431 anticipated intrinsic benefits of participation, such as the satisfaction of contributing, are diminished
432 by the introduction of external incentives (554). The lack of response to incentives in our study
433 suggests that incentives were neither supporting intrinsic motivations nor diminishing them. Notably,
434 for logistical reasons this trial used individual health districts as trial groups. Differences in response
435 to incentives may be more strongly attributed to local culture and attitudes than treatment group. In

436 the future, a randomised control trial that assesses participants' existing motivations could more
437 effectively capture variations both among and within localities engaged in data collection.
438 Additionally, further work is needed to understand what the tipping points are for incentives to
439 significantly motivate participation, and what behaviours may either be unaffected by incentivisation
440 or diminished by it.

441
442 Although incentives did not affect the overall number of data uploads across districts, there were
443 differences in the persistence of data collection participation and effort. The participation persistence
444 of the trial groups showed that the Bandundu control group had approximately the same amount of
445 participation from the start to the end of the trial, but that the other three trial groups experienced
446 significant declines in the latter half of the trial. A review paper of citizen science studies found that
447 studies that provided long term training and contact with organisers were the most successful at
448 engaging participants (565). The declines in robust participation towards the end of the trial in our
449 study may be attributed to the lack of engagement with participants that was necessary to test the
450 usability of the data collection methodology with low intervention. The low contact resulted in several
451 post-trial focus group respondents indicating they would have liked more contact, despite all
452 participants saying the sensor and application were easy to use. Although participants had positive
453 attitudes regarding the data collection and responsibility (supporting results from other studies (576))
454 access to data and collaborators may further improve participants' feelings about their participation
455 and their contributions (587).

456
457 Participant-researcher contact may be why our previous trial in Tanzania found that text reminders,
458 both alone and paired with an incentive, positively affected persistence in data collection, despite the
459 monetary incentive alone not showing a significant effect in that study system (34). The declines in
460 participation persistence and effort seen in this study support this previous finding that incentives alone

461 are not enough to motivate participation. The tipping point in the middle of the study where
462 participation dropped suggests that participants do not need further encouragement or motivation in
463 the short term to collect Humbug data. In longer term contexts however, consistent contact and
464 communication may be necessary to continue to motivate participants, and we have found that
465 monetary incentives do not accomplish this, and in fact appear to only increase participation in the
466 early phases of the study.

467

468 The differences in upload effort between our trial groups did not follow patterns relating to
469 incentivisation. The data collection effort in Bandundu shows that the control group performed
470 similarly to the incentive group for most of the trial, with the control group performing significantly
471 better in the final couple of weeks. This appears to be due to a continued high level of data collection
472 persistence and effort on the part of the Bandundu control group, which seems to be attributable to
473 some intrinsic difference in this site compared to the other sites. In Kinshasa, incentivisation improved
474 data collection efforts in the early parts of the trial compared to the control group, suggesting that at
475 the time when participants were overall the most active, the incentive did improve the completeness
476 of data collection efforts. However, this higher level of data collection effort by Kinshasa's incentive
477 group dropped approximately halfway through the trial, after which there was not a significant
478 difference between the control and incentive groups. This mirrors the results for participant activity,
479 which showed that participation significantly dropped off halfway through. The decline in data
480 collection efforts shows that even those who are continuing to participate are not collecting data for
481 the entire time period (6 pm to 6 am) as requested in the data collection methodology. This may be in
482 part due to the design of our incentives, which were given regardless of activity and were not scaled
483 for completeness of participation. This result shows that despite incentivisation initially appearing to
484 motivate complete data collection in one of our districts, the diminishing interest and effort over time
485 are not overcome by incentivisation.

486

487 Our post-trial FGDs gave insight into issues surrounding incentives, including compensation and
488 technology. Over half of the participants in the trial did not return for the post-trial FGDs. The reasons
489 cited by the DRC team were a desire to keep the smartphone and the lack of payment at the control
490 sites, though there were more post-trial FGD attendees from the control groups than the incentive
491 groups. This compensation issue was emphasised by a refusal to return the phones by some participants
492 in trial groups in both districts. The Bandundu control group exhibited higher phone retention
493 compared to the Bandundu incentive group, and the Kinshasa incentive group showed higher phone
494 retention in contrast to the Kinshasa control group. There was no significant difference in the number
495 of participants that named phone retention as a motive for participation between the districts, the trial
496 groups, or between the trial groups within districts, showing that previously held values were not
497 associated with phone retention. Instead, the pattern of phone retention mirrored the activity levels of
498 each trial group, perhaps indicating that the more active participants felt a stronger entitlement to
499 keeping the phones. However, phone retention was related to the relative effort in each district, rather
500 than the overall effort. For example, the Bandundu incentive and the Kinshasa incentive had similar
501 activity levels and total uploads, yet the Kinshasa incentive group retained twice the number of phones.
502 As far as we are aware, participants in each district and trial group did not know the participation rates
503 of the other groups, and therefore, did not know their relative participation. This indicates that
504 individuals' participation might be influenced by their perception of effort.

505

506 The phone retention and refusal to return at the end of the study is an example of how citizen science
507 projects can deviate from planned outcomes. In this context, participants effectively provided
508 themselves with an incentive (or supplementary incentive) by refusing to return phones, despite study
509 agreements and information about compensation ahead of the trial. A study on citizen science with
510 specially designed video games found that game design can diminish citizen science outcomes and

511 enhance the odds of cheating and cutting corners, depending on the ability to do so (528). It is
512 important to consider how incentive application design therefore may influence study outcomes and
513 participation. The incentive group in this case received payment regardless of participation, which may
514 have opened this study system to cutting corners (e.g., reduced activity and upload effort at the end of
515 the study period). As an alternative, incentives given in response to data collection activity close this
516 loophole and effectively encourage data collection persistence. Additionally, the post-trial survey in
517 this study was not incentivised, and therefore participants gained more from refusing to return phones
518 than they did from attending. Balancing incentive value with requests and alternatives is necessary for
519 incentives to operate as intended, and as seen in this study, some individuals will not follow
520 prescriptive actions if they feel they can benefit in other ways.

521
522 Our post-trial FGDs revealed that despite there not being a significant or differential response to
523 incentivisation, there were significant contrasting attitudes between the study groups in Bandundu and
524 those in Kinshasa. Bandundu exhibited a significantly higher overall participation rate in FGDs
525 compared to Kinshasa, and a greater proportion of Bandundu participants expressed willingness to
526 partake in the trial again, irrespective of incentivisation (25 out of 26 post-trial FGD attendees). Out
527 of 27 post-trial FGD attendees from Kinshasa, only 12 indicated a willingness to participate again.
528 Additionally, there appear to be differences in values between the two districts. Among the 16
529 participants who identified knowledge as their motive for future participation, only one was from
530 Kinshasa. Conversely, among Kinshasa participants who expressed willingness to participate again,
531 the majority cited incentives as their driving factor. Further research is needed to understand how
532 community and culture interact with incentive application, but in this case, despite differing
533 motivations for participation, incentives did not have any significant effects on overall participation in
534 the study.

535

536 The biggest issues cited by participants who took part in the trial were access to electricity to charge
537 the smartphone sensor and internet connection. Interestingly, the groups that mentioned access to
538 electricity significantly more were also the groups that performed best for data collection activity and
539 effort in each district. It could be that the practicality of it was more apparent to the groups that put
540 more effort in, and practical difficulties may be part of the reason people felt they should have been
541 compensated better for the study. Of the incentive group participants who attended the focus group,
542 over half said they felt they had not been given enough money for the study (14/22). This
543 dissatisfaction may have been due to the unexpected cost of transferring money, which reduced the
544 originally stated compensation (from \$10 to \$9). In pre-trial FGDs, there were only six cases when
545 participants who cited money as their motivation asked for a monetary value at or below the incentive
546 value given in the study, suggesting that the incentive potentially fell below common expectations.

547
548 Despite the sentiment that the money was not enough, incentive group participants were more likely
549 to say they would participate in the future than control group participants, and although bed nets were
550 one of the least cited reasons for participating in the study, almost all participants mentioned the bed
551 nets as a benefit they experienced in the trial, perhaps improving their desire to continue participation.
552 Considering that all phones were turned on and collected data at least once during the study period, it
553 appears useability was not a limiting factor of the study, and indeed all participants apart from one said
554 that they felt the MozzWear app was easy to use. Due to the lack of practical issues with the study, our
555 results highlight the importance of scaling expectations of citizen science and matching the value of
556 incentives with the effort and length of trials to improve participation and satisfaction.

557
558 Our findings show that mobile applications using hardware on budget smartphones can generate useful
559 data with limited interventions and suggests that mobile application development should be more
560 widely considered in citizen science data collection efforts. Future research on the role of

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561 incentivization for data collection that utilizes technology should consider how to further disambiguate
562 the inherent benefits in participation related to technological access, such as social status or monetary
563 benefit from retaining equipment. We suggest that with increased mobile phone ownership, this
564 complexity may be overcome by utilizing current phone owners, rather than providing participants
565 with hardware. Additionally, as mobile phone use becomes more popular, opportunities for large scale
566 studies will support more complex statistical approaches to account for the complex structures that
567 underpin intrinsic motivators and responses to extrinsic motivators, such as proximity to urban areas
568 which are potentially obscured by the inferential statistical methods used in this study.

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571 Conclusions

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572 Results of this study show that in this study system incentives did not have significant effects on data
573 collection activity throughout the trial but did have some effect on data collection persistence and
574 effort, improving data collection effort during portions of the trial in one of our study districts. Our
575 results indicate that community differences are what drive the trends in participation in this study
576 system, and that more information is needed ahead of trials to assess how community differences may
577 impact participation in citizen science data collection. Participant engagement with researchers and
578 study organisers appears to improve data collection, particularly in longer studies. Communication
579 with participants is important for appropriately scaling incentives to account for citizen data collection
580 effort. Systems should be designed appropriately to maximise the alignment of incentives with active
581 data collection. Overall, the incentives tested do not appear to significantly improve data collection in
582 this study system, and in this case, increased engagement during data collection may have improved
583 outcomes. With technology becoming an increasingly used tool in citizen science, its application
584 should be considered in reference to existing infrastructure. Consideration should be made for the

585 value that the technology represents in reference to the overall value of the incentive being offered to
586 avoid issues with data sensor retention in response to changing attitudes towards incentive value.
587

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592 Caravane, Bu and Mikondo for their support and participation in the study.
593

594 Ethics Approval and Consent

595 ~~The University of Oxford have sponsored the study. This study was reviewed by the Oxford Tropical~~
596 ~~Research Ethics Committee (OxTREC) and approved by the Kinshasa School of Public Health.~~
597 ~~Informed written consent was obtained from all interviewees prior to the focus group discussions and~~
598 ~~the quantitative feedback survey. Consent forms signed by all the participants included the release of~~
599 ~~summary findings and details of individual responses from this study. Potential participants were~~
600 ~~informed of the voluntary nature of the study and had at least 24 hours to consider taking part. Efforts~~
601 ~~were made to create a safe place for sharing experiences during the focus group discussions.~~
602

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790 **Supplementary Information**
791 **S1 Appendix:** The DHS Demographic Survey Administered to Participants
792 **S2 Appendix:** The focus group discussion questions administered pre-trial and post-trial.
793 **S3 Table:** A table of results from comparisons of the demographic survey between study districts, trial
794 groups overall, and trial groups within each district.
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Dear Dr. da Luz,

Thank you for the opportunity to submit a revised draft of our manuscript titled “*What incentives encourage local communities to collect and upload mosquito sound data using smartphones? A case study in the Democratic Republic of the Congo*” to *PLOS One*. We appreciate the time you and the reviewers have taken to provide valuable feedback and insightful comments. We have made changes to incorporate most of the suggestions provided by reviewers and they are highlighted through the manuscript. Please find below the point-by-point responses and edits made to the paper in line with feedback.

Journal Requirements:

Comment 1: *Please ensure that your manuscript meets PLOS ONE's style requirements, including those for file naming.*

Response: The manuscript has been amended to address the style and naming requirements.

Comment 2: *Please note that funding information should not appear in any section or other areas of your manuscript. We will only publish funding information present in the Funding Statement section of the online submission form. Please remove any funding-related text from the manuscript.*

Response: The manuscript has been amended to remove funding information from the manuscript.

Comment 3: *When completing the data availability statement of the submission form, you indicated that you will make your data available on acceptance. We strongly recommend all authors decide on a data sharing plan before acceptance, as the process can be lengthy and hold up publication timelines. Please note that, though access restrictions are acceptable now, your entire data will need to be made freely accessible if your manuscript is accepted for publication. This policy applies to all data except where public deposition would breach compliance with the protocol approved by your research ethics board. If you are unable to adhere to our open data policy, please kindly revise your statement to explain your reasoning and we will seek the editor's input on an exemption. Please be assured that, once you have provided your new statement, the assessment of your exemption will not hold up the peer review process.*

Response: All the raw data from our study is now publicly available at [10.6084/m9.figshare.27332124](https://doi.org/10.6084/m9.figshare.27332124)

Comment 4: *We note that Figure 2 in your submission contain map/satellite images which may be copyrighted. All PLOS content is published under the Creative Commons Attribution License (CC BY*

4.0), which means that the manuscript, images, and Supporting Information files will be freely available online, and any third party is permitted to access, download, copy, distribute, and use these materials in any way, even commercially, with proper attribution. For these reasons, we cannot publish previously copyrighted maps or satellite images created using proprietary data, such as Google software (Google Maps, Street View, and Earth). For more information, see our copyright guidelines: <http://journals.plos.org/plosone/s/licenses-and-copyright>.

Response: To comply with the rules regarding CC BY 4.0 the original data showing the health districts of the DRC from the Humanitarian Data Exchange (DRC health Data) was removed and replaced using Creative Commons Attribution Licensed data. The Democratic Republic of the Congo (DRC) GIS data from simplemaps, the GRID3 COD - Health Areas v4.0: Kwilu health areas (GeoPackage), and the GRID3 COD - Health Areas v4.0: Kinshasa health area (GeoPackage) are all accessible under existing CC BY 4.0 licenses. This change in data used in the map of the DRC has also been reflected in the addition of two references for the GeoPackages used, along with the statement of origin in the caption on Figure 2:

Center for International Earth Science Information Network (CIESIN), Columbia University, Ministère de la Santé Publique, Hygiène et Prévention, Democratic Republic of the Congo, and GRID3. (2025). GRID3 COD - Health Areas v4.0: Kinshasa health areas (GeoPackage). New York: Columbia University. <https://data.humdata.org/dataset/grid3-cod-health-areas-v4-0>. Accessed April 3, 2025.

Center for International Earth Science Information Network (CIESIN), Columbia University, Ministère de la Santé Publique, Hygiène et Prévention, Democratic Republic of the Congo, and GRID3. (2025). GRID3 COD - Health Areas v4.0: Kwilu health areas (GeoPackage). New York: Columbia University. <https://data.humdata.org/dataset/grid3-cod-health-areas-v4-0>. Accessed April 3, 2025.

Comment 5: *We note that Figure 3 and 4 includes an image of a participant in the study.*

Response: These images have been removed from the manuscript.

Comment 6. *Please review your reference list to ensure that it is complete and correct. If you have cited papers that have been retracted, please include the rationale for doing so in the manuscript text or remove these references and replace them with relevant current references. Any changes to the reference list should be mentioned in the rebuttal letter that accompanies your revised manuscript. If you need to cite a retracted article, indicate the article's retracted status in the References list and also include a citation and full reference for the retraction notice.*

Response: The citation list has been reviewed and there were no instances of retracted papers. The reference list was amended with the GeoPackage references for the Kwilu and Kinshasa health districts (shown above), and the references were renumbered to reflect these additions.

Comments from Reviewer 1

Major comments

Comment 1: *Lines 79-85: the introduction references the Tanzania study but does not clearly position this manuscript as a follow-up. It could strengthen the manuscript to explicitly state how this work builds on or how it differs from the Tanzania findings. It is recommended that the authors add a sentence explicitly linking the gaps identified in the Tanzania study (for instance, rural-only context) to the objectives of this work.*

Response: This study is named directly as a second trial of the mosquito detection application with monetary incentives in line 187. Verbiage specifying the research's focus on the use of monetary extrinsic factors, and how the study builds on the study in Tanzania has been added in lines 205-206, stating: 'This study builds upon our previous work in Tanzania to fill gaps in understanding how monetary incentives alone influence the consistency and quality of audio data collection.'

Comment 2: *Regarding the Focus Group Insights, lines 247-253, the discussion of Focus Group Discussions (FGD) results is useful but could benefit from additional depth. For example, higher persistence in Bandundu could be contextualized using participant quotes. A suggestion would be that the authors add representative quotes from FGDs to illustrate key themes and link them to the observed participation trends.*

Response: Due to the lack of significant differences in pre-trial FGD responses between Kinshasa and Bandundu it does not feel appropriate to use a FGD response in this section of the results to highlight differences in the groups that were seen later in the trial (such as in the post-trial FGDs). Instead, a quote from a participant listing multiple motivation factors has been added in lines 373-377 to demonstrate how complex participant motivations were prior to trial participation.

Comment 3: *The study's inclusion of Bandundu (rural) and Kinshasa (urban) appear to be an opportunity to explore how rural-urban differences influence participation. However, the manuscript does not fully address these dynamics or their potential implications. In lines 401-402, the authors note that differences in participation are not attributable to demographic factors but do not explore other potential influences, such as rural-urban dynamics that may be marked in the two setting of the study. This section could be expanded on to discuss e.g. infrastructure, community cohesion, and leadership differences between Bandundu and Kinshasa.*

Response: This study was not aimed at specifically addressing urban versus rural factors for responses to incentivization, and the Kinshasa study sites were not located in the city but in rural parts of the

health district (referred to as rural Kinshasa when first introduced in the manuscript, line 188). However, we acknowledge the potential role of proximity to urban areas and have now addressed this in the manuscript discussion lines 547-549, reading: 'These differences may be related to the proximity of the rural Kinshasa sites with the city of Kinshasa, though the access of participants to urban environments and differences in community cohesion were not specifically accounted for in our surveys.'

Minor comments:

Comment 4: Line 46: replace "effecting sub-Saharan Africa" with "affecting sub-Saharan Africa."

Response: This has now been amended in the manuscript.

Comment 5: Discussion: the authors acknowledge that the findings are context-specific but do not discuss how they might be generalised to other settings. The paper could benefit from expanding the discussion to include how differences in infrastructure, culture, or community norms might affect the scalability of the study's approach. Ethical considerations, such as phone retention, may also be under-discussed in terms of their potential impact on the findings or on the design of the study.

Response: To address the generalizability of this research we added a section in lines 702-714 stating: "Our findings show that mobile applications using hardware on budget smartphones can generate useful data with limited interventions and suggests that mobile application development should be more widely considered in citizen science data collection efforts. Future research on the role of incentivization for data collection that utilizes technology should consider how to further disambiguate the inherent benefits in participation related to technological access, such as social status or monetary benefit from retaining equipment. We suggest that with increased mobile phone ownership, this complexity may be overcome by utilizing current phone owners, rather than providing participants with hardware."

The focus group discussions did not include specific questions that would allow us to analyse differences in culture and community norms beyond the motivations participants stated before the trial or their experiences afterwards. Differences in attitude and community norms were addressed in the discussion lines 575-678, and we have added in lines 709-712 a call for more cross-sectional work that may generate the data necessary to analyse the effects of infrastructure and community norms.

Comment 6: Future Research Directions: the conclusion could benefit from a brief discussion of future research priorities, such as testing alternative incentive models, evaluating long-term engagement strategies, and/or assessing the usability of the acoustic mosquito sensors in the study context.

Response: Future research directions we have added a section to the discussion in lines 702-713: “Future research on the role of incentivization for data collection that utilizes technology should consider how to further disambiguate the inherent benefits in participation related to technological access, such as social status or monetary benefit from retaining equipment. We suggest that with increased mobile phone ownership, this complexity may be overcome by utilizing current phone owners, rather than providing participants with hardware. Additionally, as mobile phone use becomes more popular, opportunities for large scale studies will support more complex statistical approaches to account for the complex structures that underpin intrinsic motivators and responses to extrinsic motivators, such as proximity to urban areas which are potentially obscured by the inferential statistical methods used in this study.”

Comment 7: *Methodology improvement: the supplementary file provides detailed documentation of participant demographics and focus group questions, which supports the reproducibility of the study. Nevertheless, the modified random walk technique used for participant selection is not sufficiently explained in either the manuscript or the supplementary materials. While the inclusion of demographic comparisons and FGD protocols is quite valuable, the lack of detail about the recruitment method limits the transparency of the methodology. For instance, how were starting points for recruitment selected? Were any randomisation procedures applied to maintain the sampling unbiased? Additionally, minor gaps in the description of the design of text message reminders could also limit reproducibility. It is recommended that the authors provide additional detail or supplementary materials for these two aspects.*

Response: Details for how random walks were carried out is included in the methodology in lines 247-249, with details on reducing bias added in line 248: “To reduce the bias of entry point selection, each household was approached sequentially along the street and asked if they wanted to participate, until the number of households required to participate at the site (n=37) was met.”

Regarding the methodological details of the SMS reminders, those reminders were not a component of this study but were part of the first study in Tanzania.

Comment 8: *Data availability seems to be in compliance with PLOS guidelines. Still, it is important to confirm that the repository cited by the authors includes raw data points (such as the individual participation records and anonymised FGD transcripts), as I was not able to access it. The statistical methods used appear to be appropriate, but I would recommend consulting someone with higher expertise in this matter. The methodology is sufficiently detailed overall. However, minor gaps in the description of participant recruitment (e.g., modified random walk technique) and the design of text message reminders could be further improved.*

Response: The additional raw data is available now at [10.6084/m9.figshare.27332124](https://doi.org/10.6084/m9.figshare.27332124).

Comments from Reviewer 2

This study has addressed an important question about the influence of monetary incentives on participation (data collection) in citizen research. The methodology and results have been excellently presented and discussed. The researchers have done an excellent job of using quantitative and qualitative methods to address their study questions. The manuscript is indeed of very high quality.

Here are a couple of comments that I recommend that the authors consider:

Comment 1: *The topic of the study is not congruent with the study objective or question. The title “What incentives encourage local communities to collect and upload mosquito sound data by using smartphones? A case study in the Democratic Republic of the Congo” suggests that the study has evaluated different type of incentive while it has specifically assessed the influence of “monetary incentives” A title that would fit better with the study objective/question/scope could be “Do monetary incentives encourage local communities to collect and upload mosquito sound data by using smartphones? A case study in the Democratic Republic of the Congo”*

Response: The title of the manuscript has been adjusted to account for this suggestion.

Comment 2: *The researchers may have made efforts to adjust for and discuss confounding inherent on the research design but need to describe this more clearly in the report. Also, I recommend that authors highlight known limitations of the main inferential statistical approach used in comparative analysis.*

Response: A sentence has been added in the methods to address the use of post-hoc test to reduce risk of type 1 error in line 341.

To address the limitation of inferential statistics, a section has been added to the discussion in lines 709-712, suggesting future studies use cross-sectional data that may allow for more complex modelling approaches in analysis.

In addition to the above comments, all spelling and grammatical errors pointed out by the reviewers have been corrected. We look forward to hearing from you regarding our submission and to respond to any further questions and comments you may have.

Sincerely,

Kieran E. Storer

Kieran Jones

22/April/2025



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http://figshare.com/articles/dataset/Raw_data_and_R_code_on_participant_data_collection_in_study_in_the_DRC_characterizing_the_effects_of_monetary_incentives_on_data_collection_/27332124