MAMBO

MODERN APPROACHES TO THE MONITORING OF BIODIVERSITY

D1.1 Report on stakeholder needs

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D1.1 Report on stakeholder needs.

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1 Preface

This document is a deliverable report prepared for the Modern Approaches to the Monitoring of BiOdiversity (MAMBO) project, funded by the EU Horizon Europe Research and Innovation Action grant (No. 101060639). The MAMBO project aims to support EU biodiversity policy and address knowledge gaps by providing solutions to biodiversity monitoring through the design and development of novel tools and technologies.

This project report presents an overview of WP1's plans to assess the needs of stakeholders over the course of the project. It is organised as three main sections; the first, presents a theory of change to achieve MAMBO's overarching goal and an assessment of how stakeholder engagement and user needs assessments will help reach this. The second section synthesizes outcomes of stakeholder interactions carried out by MAMBO WP leads, and the final section presents results of an online questionnaire with biodiversity monitors which forms an initial phase in MAMBO's on-going user needs assessment.

List of abbreviations

App(s)	Application(s)
eDNA	Environmental De-oxyribonucleic Acid
EU	European Union
EUNIS	The European University Information Systems organisation
GBIF	The Global Biodiversity Information Facility
LiDAR	Light Detection And Ranging
MAMBO	Modern Approaches to the Monitoring of BiOdiversity
NA	Not Applicable
ODK	Open Data Kit
PEDR	Plan for Exploitation and Dissemination of Results
RI	Research Infrastructure
RS	Remote Sensing
Tech.	Technology/technologies
ToC	Theory of Change
UREAD	University of Reading
WP	Work package

2 Executive Summary

Engaging with stakeholders to understand their needs, and collaborating with them in the co-design of new biodiversity monitoring tools and technologies are core aims of the MAMBO project. This process will support the achievement of MAMBO's overarching goal of developing useful and user-friendly biodiversity monitoring tools and technologies that will assist with collecting data on species and habitats and filling data gaps which contribute to conservation issues.

This report presents the first stages in understanding stakeholder needs, which will be continuously assessed over the course of the project as MAMBO. It is structured as three main sections (i) a **Theory of Change**, which outlines key activities that will feed outputs to achieve effective change in biodiversity monitoring, (ii) **a synthesis of stakeholder engagement activities** carried out by MAMBO researchers which have yielded vital information on their needs, and finally, (iii) **the results of a scoping survey with biodiversity monitors** to identify current monitoring methods, assess their use of novel tools and establish their motivations, challenges and incentives which impact their use or uptake of modern approaches to monitoring biodiversity.

Key Messages

Consider the type and expertise of the monitor involved – stakeholders from different sectors have different abilities to adopt novel tools and technologies. Our survey also revealed that incentives and challenges also vary depending on the type of biodiversity to be monitored.

Barriers to uptake vary amongst stakeholders – financial reasons are the most important challenge for adopting novel tools and technologies. Time-investment to learn and implement new tools, insufficient reliability and quality of data (in terms of geographic coverage, and taxonomic resolution), and a lack of awareness are also as important barriers to adoption for some monitors.

Free to access novel tools and technologies is preferred – a general exception to this are molecular methods which monitors expect and are willing to pay for. Species monitors are more likely to pay upfront for monitoring equipment such as acoustic- and camera- systems, but payment preferences varied between monitor types and across technologies.

Training by experts is required – stakeholders may require support for the analyses of data produced by modern monitoring tools and technology.

Ownership is critical – to ensure uptake and continued use of novel tools and technologies increasing users' ownership is important.

Communication is key – stakeholders are often unaware what is available, or possible to achieve using novel tools and technologies, often leading to disappointment and disillusion with modern monitoring techniques. Open communication and clear guidance is needed. Contact with developers at certain times during development is important to increase the uptake of novel tools and technologies.

3 Introduction

The Modern Approaches to the Monitoring of BiOdiversity (MAMBO) project will support EU biodiversity policy by developing tools and technologies to assist with species and habitat monitoring. Providing data solutions is an integral first step in addressing the biodiversity crisis, and MAMBO researchers will deliver these by addressing monitoring issues that often lead to fragmented, taxonomically biased and segregated data. Stakeholder involvement is a priority for MAMBO with several engagement activities planned over the duration of the project that will champion co-design and user needs.

An important step in achieving MAMBO's goal of designing and testing monitoring tools and technologies is gathering data on what users need. Individuals and organisations that will adopt and use MAMBO outputs comprise a key target stakeholder group for the project, and as such, the terms *'stakeholder', 'user' and 'end-user'* are used interchangeably and synonymously throughout this report. The stakeholders included in this user needs assessment are primarily made up of biodiversity monitors as they comprise a target group which may adopt and utilise MAMBO tools and technologies to gather biodiversity data. We use a broad definition for biodiversity monitor and include those who gather biodiversity data (species and/or habitats) for a diverse range of reasons from policy requirements, academic research, interest in natural history, and citizen scientists.

Stakeholder needs assessments provide context for a problem and should guide MAMBO's work to ensure tools and technologies being developed can provide solutions to common biodiversity monitoring issues by a seamless uptake by end-users. Through this process, primary end-users can be identified, their use of novel tools and technologies can be explored, any bottlenecks or barriers that could impede uptake can be documented early, and motivations or incentives can be identified and understood.

The aim of this report is to describe the initial phase of an on-going evaluation of stakeholder needs carried out by MAMBO's 'User needs and co-development' work package (WP 1). MAMBO researchers will identify and engage with key stakeholders over the course of the project to ensure MAMBO's outputs are developed with end-users in mind. To achieve a comprehensive and relevant user needs assessment, engagement activities will be designed in collaboration with WP and task leads across MAMBO and tailored to the tools and technologies being developed.

4 Section I: Theory of Change

Stakeholder needs will be continuously assessed for a range of MAMBO outputs and activities, which are at different stages of development, over the entire course of the project. To do this effectively, it is important to establish a strategy early and for this reason a theory of change (ToC) approach was undertaken. The aim of this ToC was to explore and identify how stakeholder needs fit within MAMBO's different WPs and feed outputs which will ensure MAMBO's overarching goal is reached in time (Fig 1). ToCs are flexible frameworks that can be read as logic maps of what needs to happen in order to reach a desired goal (Rice et al., 2020). They comprise a series of organised building blocks, in our case; inputs, activities,

outputs, outcomes, impacts and goals, that facilitate change through checkpoints (outputs, outcomes and impacts) with causal links drawn between inputs and activities that should result in measurable progress and eventual change.

The ToC presented in this report has been produced with MAMBO's overarching aim of developing tools and technologies to help monitor biodiversity and habitats that are effective, useful, user-friendly and that can feed EU policy needs, in mind. This ToC was not designed as an exhaustive list of MAMBO tasks and outputs, but rather focuses on four main workstreams (i) habitat assessments (conditions and extent), (ii) species monitoring (acoustic and image-based), (iii) data use and availability (through integration to relevant research infrastructures (RIs) and (iv) the underlying stakeholder engagement and co-design elements that are required to deliver on the first three workstreams.

Whilst the ToC provides an overarching framework underpinning MAMBO's goal, this report will focus on specific key components related to stakeholder needs and which have already been completed or are in-progress. These are highlighted with a white border in Fig 1. Key lessons learned are presented from relevant stakeholder engagement that has already been carried out by MAMBO researchers (Section II) and has involved several key activities identified in the ToC (surveys, semi-structured interviews, focus groups). Section III provides a more in-depth analysis of a recent online survey carried out by WP1 to assess biodiversity monitors use of novel tools and technologies and an initial assessment of their needs. We also present some initial data on barriers and incentives that impact uptake of novel tools. This analysis will be further developed through semi-structured interviews and will form D1.6 Report on incentives and barriers to adoption of technology, due in month 46 of the project. Some other activities included in the ToC are reported elsewhere, for example, a survey carried out with habitat conditions monitors in February 2023 contributed to D4.1 Review of habitat conditions metrics used across the EU, suitable for remote sensing (Gerard, F. *et al.,* 2023).

The ToC will be shared with MAMBO project members, it will be held on the project SharePoint in WP1's folder, and presented at MAMBO's AGM in September 2024. It is hoped that it will provide a useful framework to identify activities and inputs needed to achieve key milestones over the course of the project and ensure that stakeholder engagement and input are recognised throughout MAMBO's work.

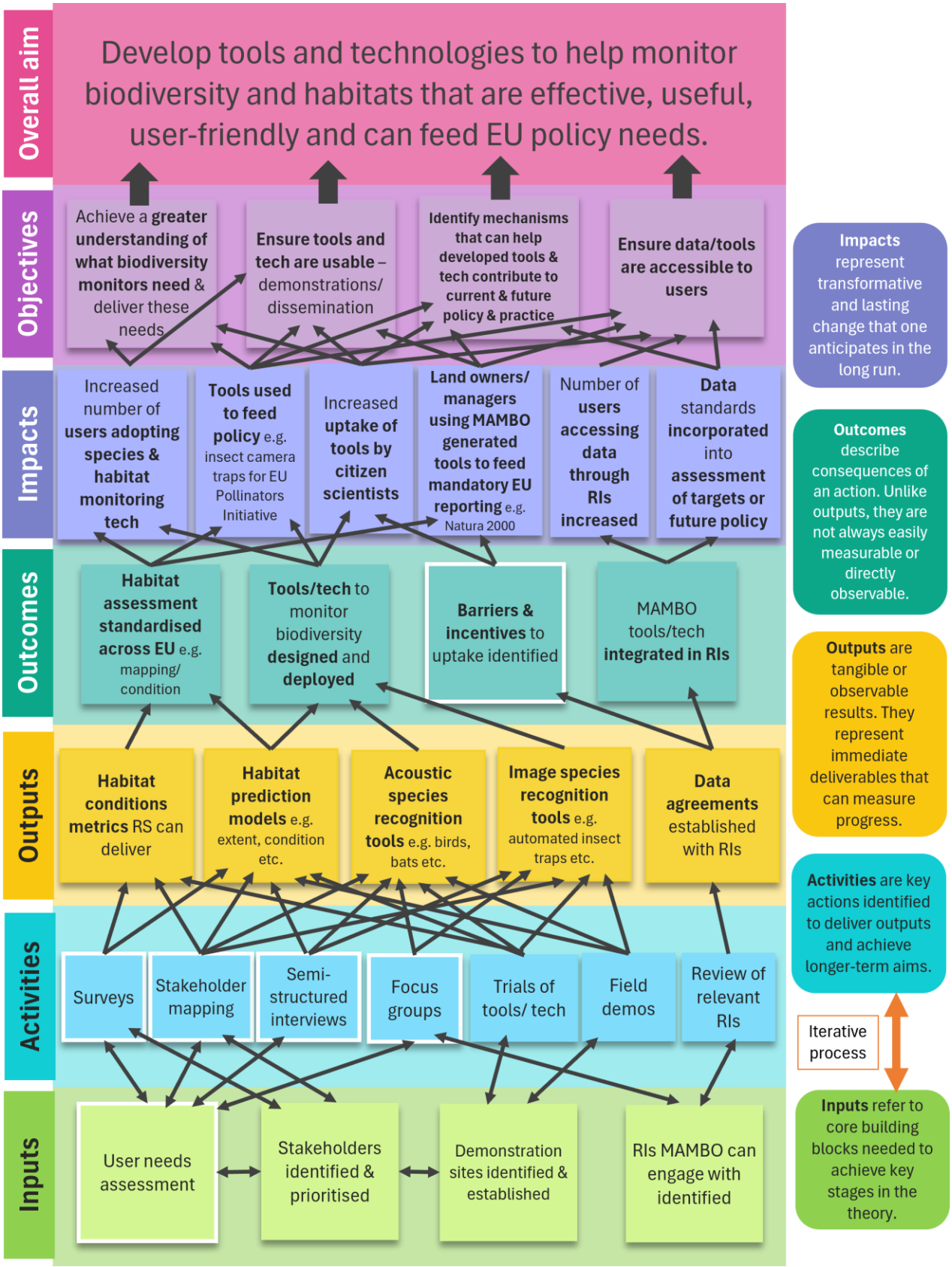

Figure 1 A theory of change to outline the steps necessary to achieve MAMBO's overarching aim of developing tools and technologies to help monitor biodiversity and habitats that are effective, useful, user-friendly and which can ultimately feed EU policy needs. Links are identified to signify pathways. Components of the ToC are organised under inputs, activities, outputs, outcomes, impacts, objectives and an overall aim, which are defined to the right hand side of the figure. Elements included in this report are highlighted with a white border.

5 Section II: Relevant Stakeholder Engagement To-Date

MAMBO WP and task leads have engaged with relevant stakeholders and continue to do so on a regular basis - many of these interactions have already yielded valuable information in terms of understanding their needs and influencing workflows for MAMBO outputs (see Fig 2). In some cases, engagement activities occurred prior to the commencement of the MAMBO project, but since outcomes of these connections will benefit and guide MAMBO research activities, they have been included in this report.

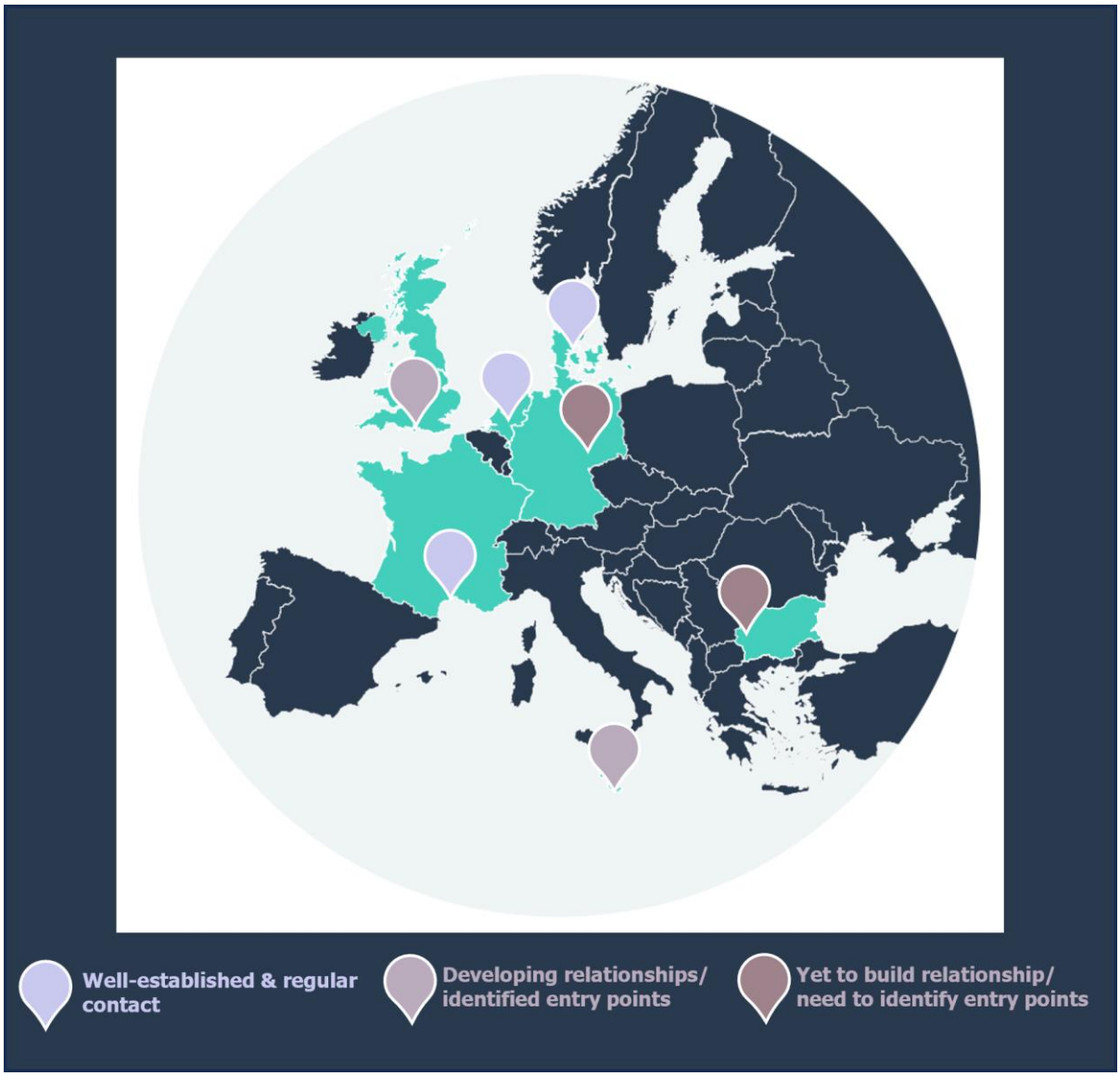

Figure 2 Map of MAMBO partner countries and their relationships with stakeholders.

To gather information on relevant stakeholder engagement, in a systematic way, a document was circulated amongst MAMBO WP leads in May 2023 (See Annex 12.1), to act as framework to summarise any relevant interactions to date and document relevant data. Responses were provided by seven individuals, covering activities related to WP 3 – Ground-based recording and monitoring tools, WP 4 – Remote sensing for habitat assessment and WP 5 – Equipment

and demonstration on sites and in targeted regions. The level of interaction between MAMBO project members and stakeholders is variable (Fig 2), with some being in regular contact with stakeholders and having already completed user needs assessments for specific tasks (e.g. T3.1 – AI based image recognition for European animals), others have identified key individuals/organisations and identified entry points for engagement and future assessments of their needs. It remains unclear whether any stakeholders and/or entry points for engagement have been identified for two of MAMBO's partner countries, Bulgaria and Germany (Fig 2) and this will be checked and could become a focus during MAMBOs stakeholder mapping exercise (T1.3 – Stakeholder mapping and network analysis).

As several members of the MAMBO project work on biodiversity-related projects which include stakeholder interactions, they have already learned key information about their needs which is relevant to MAMBO. Others have already built networks of stakeholders with which they have regular contact, and which has also yielded valuable understanding of their needs and expectations. These data have been collected through discussion groups, semi-structured interviews, email communication, and field demonstrations.

A summary of the key lessons/outcomes of relevant stakeholder engagement carried out by **MAMBO researchers** can be found below.

Communication is key – MAMBO researchers have learnt that stakeholders often do not know what tools or technologies are available, or what is possible for the habitats or species they monitor. This problem is sometimes compounded by inflated expectations of what novel tools can deliver based on promotion of the *possibilities* of cutting-edge technologies that are still under development. This can lead to stakeholders becoming disappointed or disillusioned with new technologies. Two-way communication can provide a potential solution to this, where users can understand what is available, what is being developed and soon to be available and developers can manage stakeholders' expectations through clear explanation of what current tools can deliver and identify needs that can be solved through the use of novel tools and technologies. This strategy will be encouraged by WP1 over the course of the MAMBO project.

The type of monitor is important to consider – stakeholders from different sectors have different abilities to adopt novel tools and technologies. For example, independent and private-sector users might have a greater capacity to invest and adapt to new technologies. On the other hand, depending on their scale of operation, managers of public spaces might be tied to certain reporting codes of practice and species/habitat standards that make it more difficult for them to adapt to new technologies due to a greater number of interdependencies. To overcome this, MAMBO researchers will utilise international standards in the development of their tools and technologies including standardising species names based on GBIF taxonomy and EUNIS habitat classifications.

Barriers to uptake vary amongst stakeholders – stakeholders have expressed their readiness to adopt new tools and technologies to assist with their monitoring but still need to overcome several obstacles and barriers in order to do so. Stakeholders have listed financial cost, time to learn and implement new tools and technologies, an insufficient level of reliability and quality of data (in terms of geographic range/resolution) as primary barriers

to adaptation. MAMBO will continue to engage with stakeholders in demonstration countries (and beyond) to ensure that the tools being developed provide data at an appropriate resolution for users.

Quality is key – stakeholders wish to monitor changes in their environment more accurately (in space and time) but feel that novel tools may not offer the quality of data necessary to improve their assessments. This is something that MAMBO can work on improving by continuing to engage with stakeholders in demonstration countries and ensuring that the tools developed provide data at an appropriate resolution for users.

Time is precious – stakeholders identify a key benefit to novel tools is their ability to provide biodiversity data more efficiently enabling them to speed up or extend the spatial scope of their work. However, the time investment necessary to adopt new tools is an important consideration. MAMBO will try to overcome this through demonstrations of new tools and technologies with stakeholders by developers.

Ownership is important – to ensure uptake and continued use of novel tools and technologies increasing users' ownership is important. Those MAMBO researchers with strong foundations with stakeholders including regular contact sustained over multiple years have found that this is a key point to consider.

Novel tools/technology might be a double-edged sword – while stakeholders are convinced of the benefits of new technologies to meet their monitoring needs, some fear their work (particularly fieldwork) will be reduced through their implementation.

6 Section III: Survey on Stakeholder Needs for Biodiversity Monitoring

An initial assessment of the user needs of biodiversity monitors, who study either species or habitats, was conducted through an online survey, created, and hosted using Qualtrics software (Qualtrics, Provo, UT). MAMBO WP leads were consulted during the design of the survey to ensure useful questions were posed that would gather information relevant to the breadth of MAMBO research. Prior to its launch, ethics clearance was obtained from the University of Reading's Ethics board who reviewed the full survey contents, plans for distribution and data analysis and storage. The online survey was open for four weeks in July 2023. A combination of social media and bespoke invitations was used to share the survey and ensure a constant response level was maintained over the sampling period. Data from incomplete surveys were excluded from analysis, and in total, 119 respondents submitted completed questionnaires by the closing date. A full list of survey questions can be found in Annex 12.2.

Data collected through this survey represent knowledge of species and habitat monitoring in 54 countries worldwide (Fig 3). No limits were placed on the taxa or habitats that could be included in this assessment, and participants were invited to achieve a diversity of both. The highest representation occurred for Spain [21] and the United Kingdom [20]. Some participants reported non-country-specific geographic ranges such as Europe [6], Mediterranean [2], Borneo [1], North America [1], Baltic Sea [1], North-east Atlantic [1] and Africa [1], these have not been included in the map below. As MAMBO's aim is to develop novel tools and technologies that will improve biodiversity monitoring in Europe, European representation was a key aim for this exercise. This was achieved as 38 European countries were represented. Those who were not reflected in results of this survey may be useful to include in targeted future stakeholder activities.

The following sections present results of this survey and are organised under three main themes, (i) a summary of the type of monitoring carried out by respondents, their methods and motivations, (ii) the use of novel tools and technologies, and finally (iii) an exploration of challenges and incentives that may impact on the uptake of novel tools. They represent data from biodiversity monitors who primarily identified as data collectors (Fig, 4), an important group as they may be end-users of MAMBO project outputs. Fourteen respondents selected "other" to best describe their relationship with biodiversity data, but most of these chose a combination of suggested terms. Nine stated they would select all (data collector, analyser, user, provider, holder), a further two said they collect and analyse data and three said they played a coordination/management role for monitoring activities.

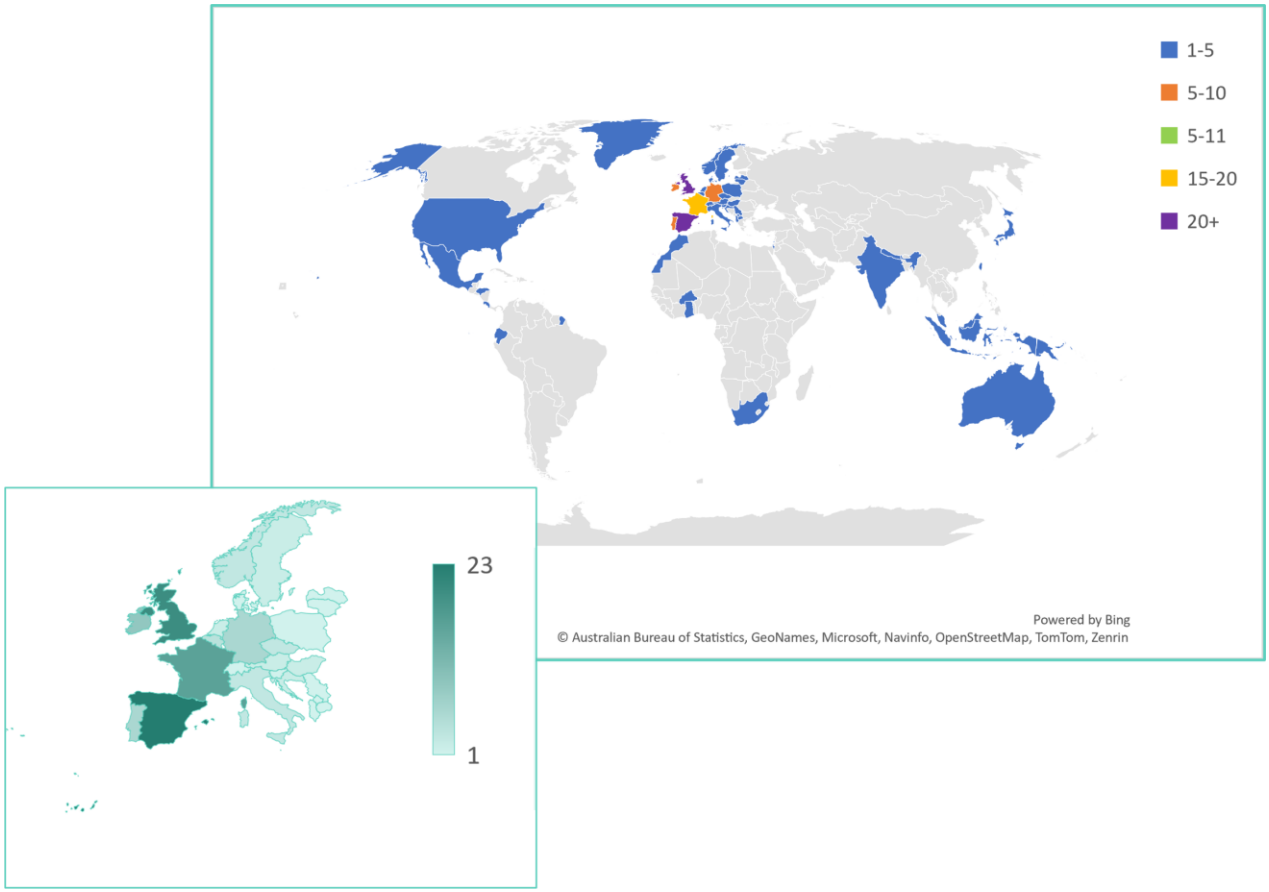

Figure 3 Map showing geographic coverage of participants, colour-coded by the number of participants representing each country. Inset map shows coverage of European participants, with a colour ramp to represent the number of respondents from each country.

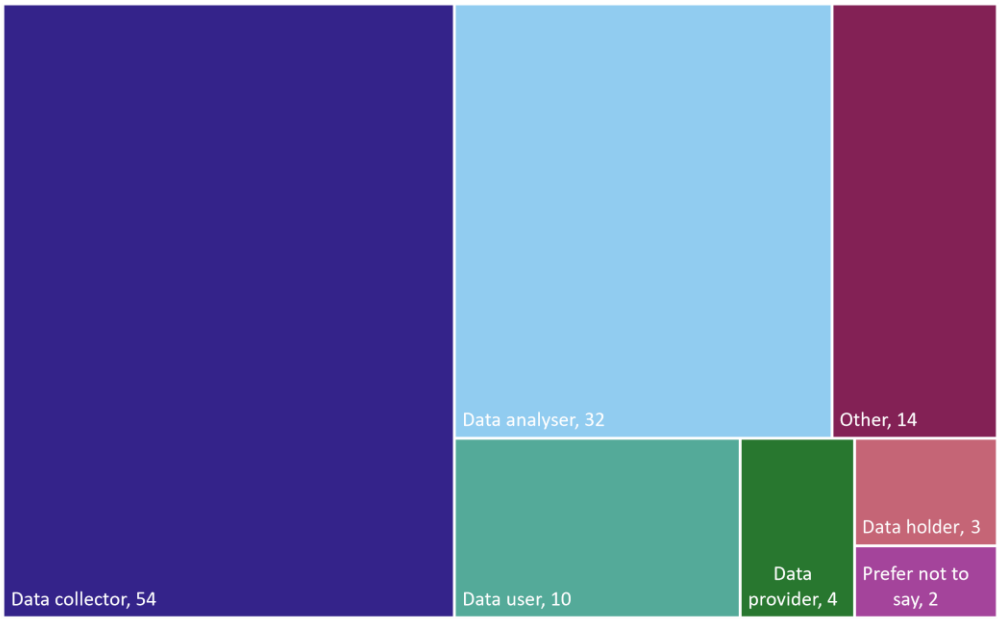

Figure 4 Number of respondents according to their relationship with data. The 119 participants were asked which term best described them.

6.1 Current methods and motivations for biodiversity monitoring

The aim of the first section of the survey was to gather some baseline data on the types of monitoring being undertaken and the primary motivations behind these. Of the 119 respondents, 57 stated they carry out species monitoring only, 7 carry out habitat monitoring only and the remaining 55 monitor both species and habitats (Fig 5). Where appropriate, results of the survey are split according to these monitoring types.

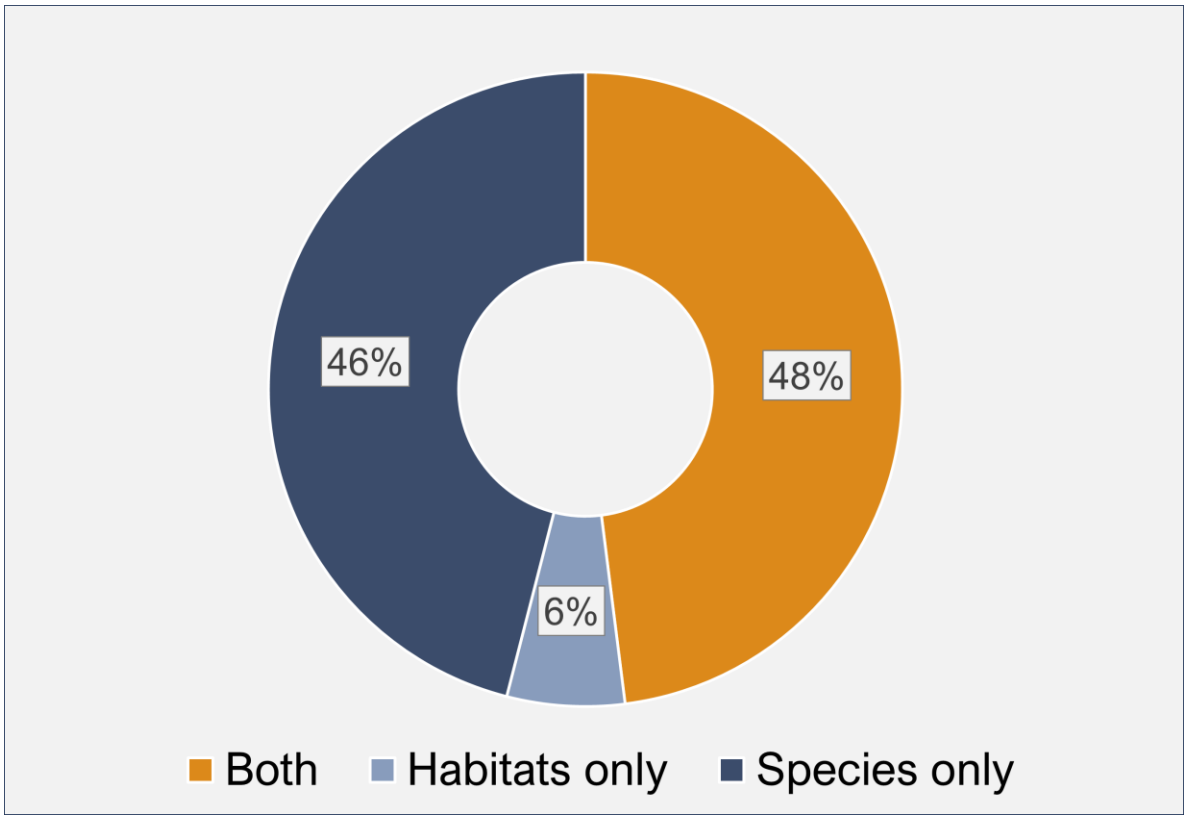

Figure 5 Proportion of respondents who carry out species-only monitoring (dark blue), habitats-only monitoring (pale blue) and both species and habitat monitoring (orange).

The majority of species monitors study insects [60] and plants [53], but overall, the data gathered reflect monitoring of a diverse range of taxa (Fig 6). While the majority of habitat monitors focus their efforts on forests and other woodlands (Fig 7), 18 respondents chose "Other" for habitat type. These included *temporary ponds/pools* [4], *riverbanks* [1], *agricultural or farmlands* [4], *wetlands* [3], *urban habitats* [3], *offshore marine habitats* [2], *lakes* [1], *alpine* [1] and *snow beds* [1].

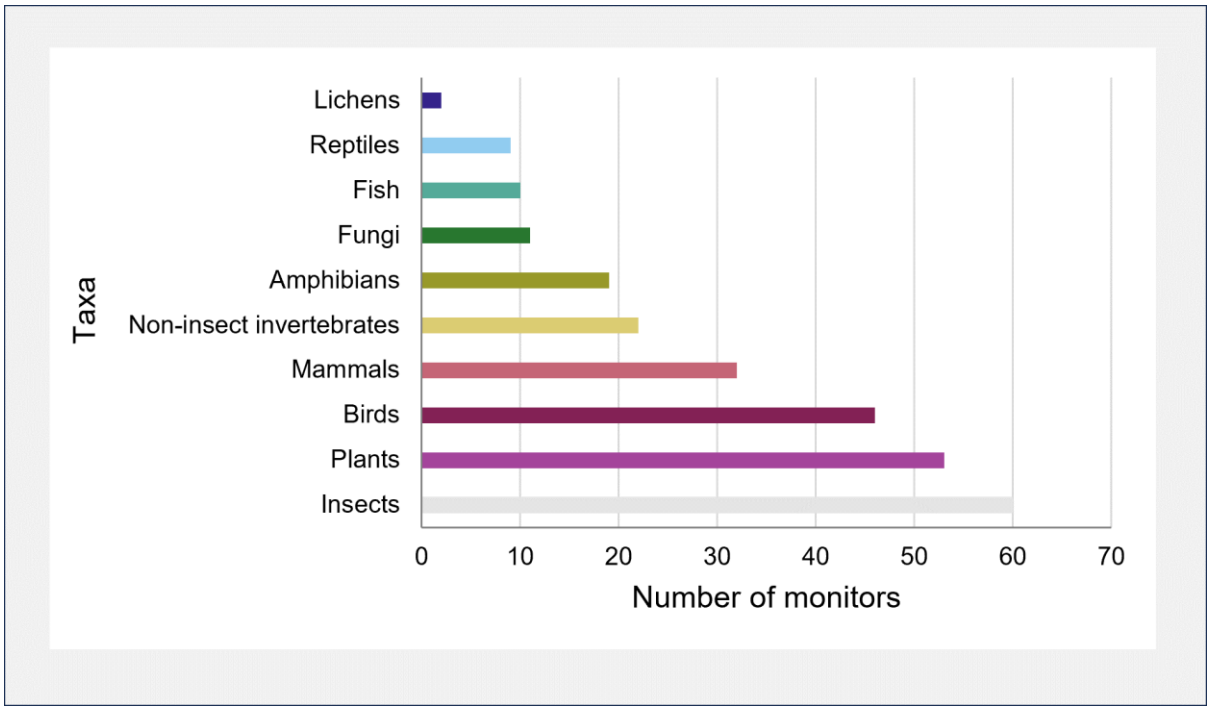

Figure 6 The number of respondents who monitor species by different taxa.

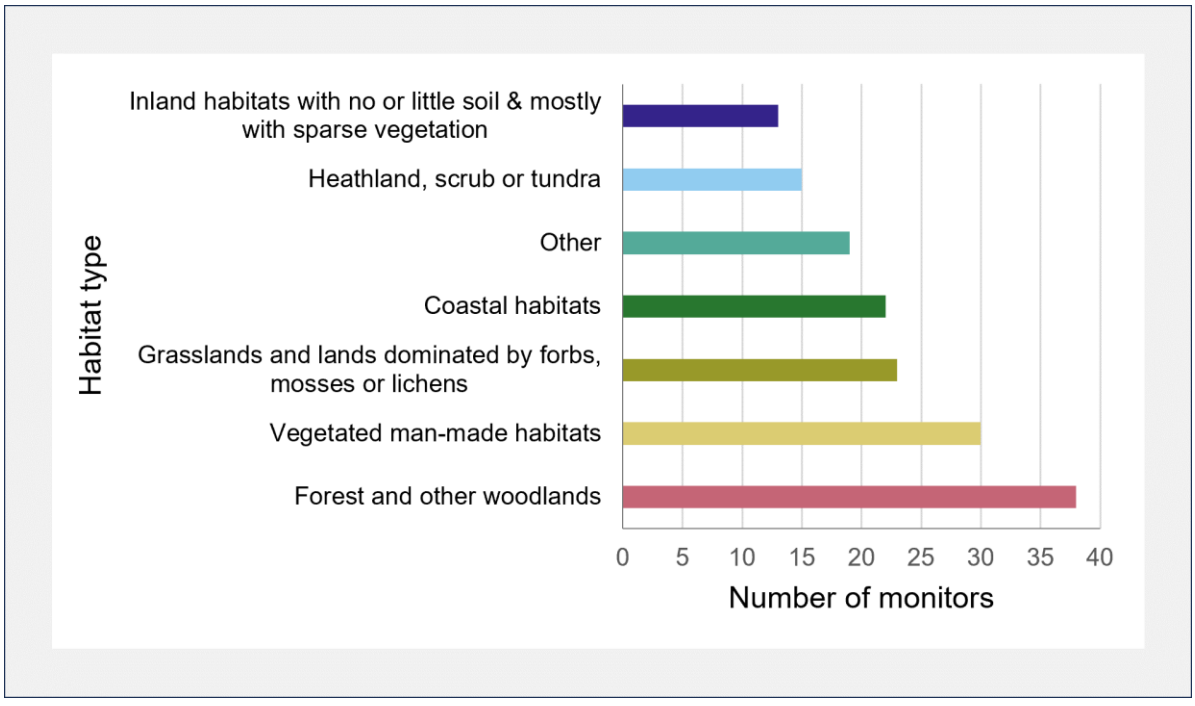

Figure 7 The number of respondents who monitor habitats by different habitat type.

Most monitors record biodiversity data for academic research and the conservation of habitats and species. Respondents were asked to select their primary motivations behind collecting biodiversity data and were allowed to select multiple options. Most respondents cited academic research [88] and biodiversity conservation [84] as their

main motivations (Fig 8). Many respondents also listed citizen science [36], land management [35] and interest in natural history [31] as also being important reasons for monitoring biodiversity. Policy requirements were also indicated as motivations, with national policy requirements selected 30 times and EU policy requirements chosen 28 times. Other motivations listed by participants included *Pest control, Monitoring species recovery and updating policies for better habitat protection, Fisheries stock assessment, Public health risk assessment, Mining rehabilitation, Developing metrics for biodiversity credits, and Health*.

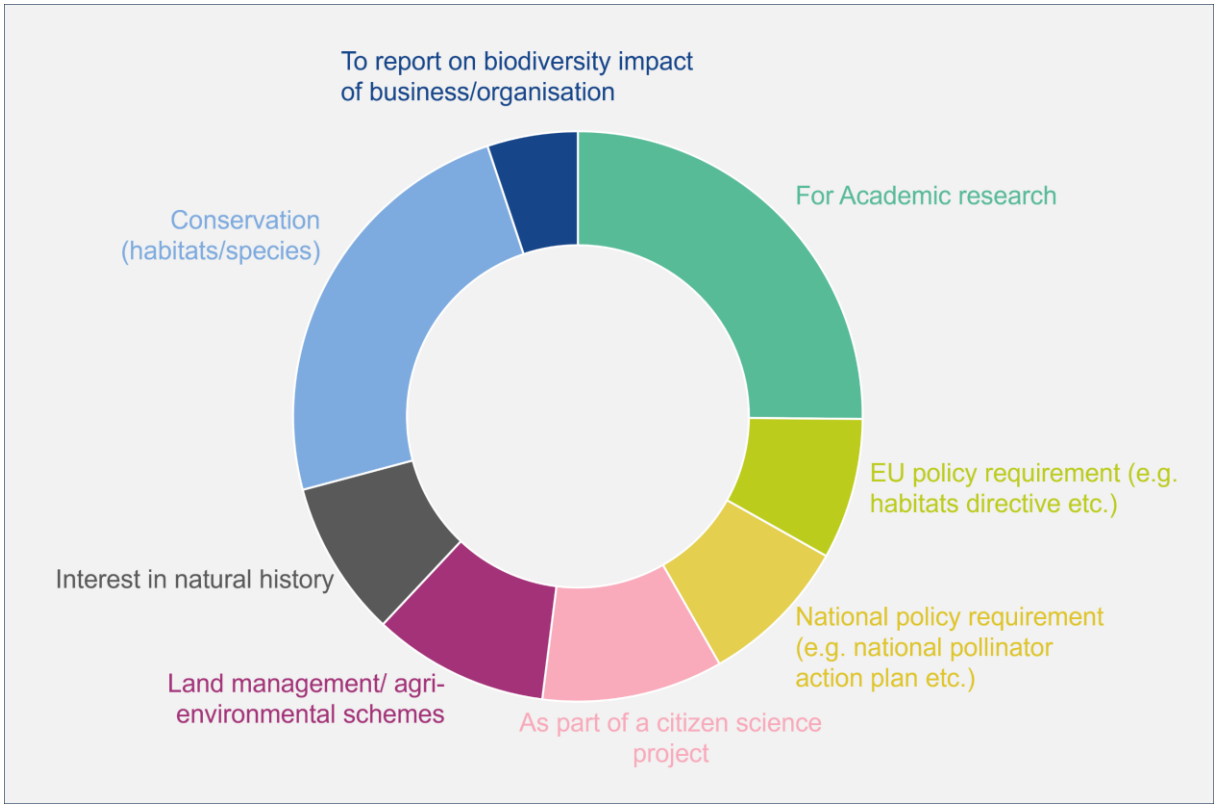

Figure 8 Motivations behind carrying out biodiversity monitoring according to 119 survey respondents.

Our survey revealed that most biodiversity monitors still rely on traditional field surveys to obtain their data. The majority of respondents listed traditional field surveys as a current method of gathering biodiversity data (97% of species monitors and 81% of habitat monitors, Fig 9, Fig 10). Twenty-seven species monitors listed "other" methods which included molecular methods (barcoding and eDNA), trapping such as pitfall, light and modified traps, radio tagging, port sampling and other apps which do not automatically identify species such as field guides and citizen science apps. Other methods enlisted by habitat monitors includes the use of ecoacoustics, Open Data Kit (ODK) apps, soil samples and temperature loggers.

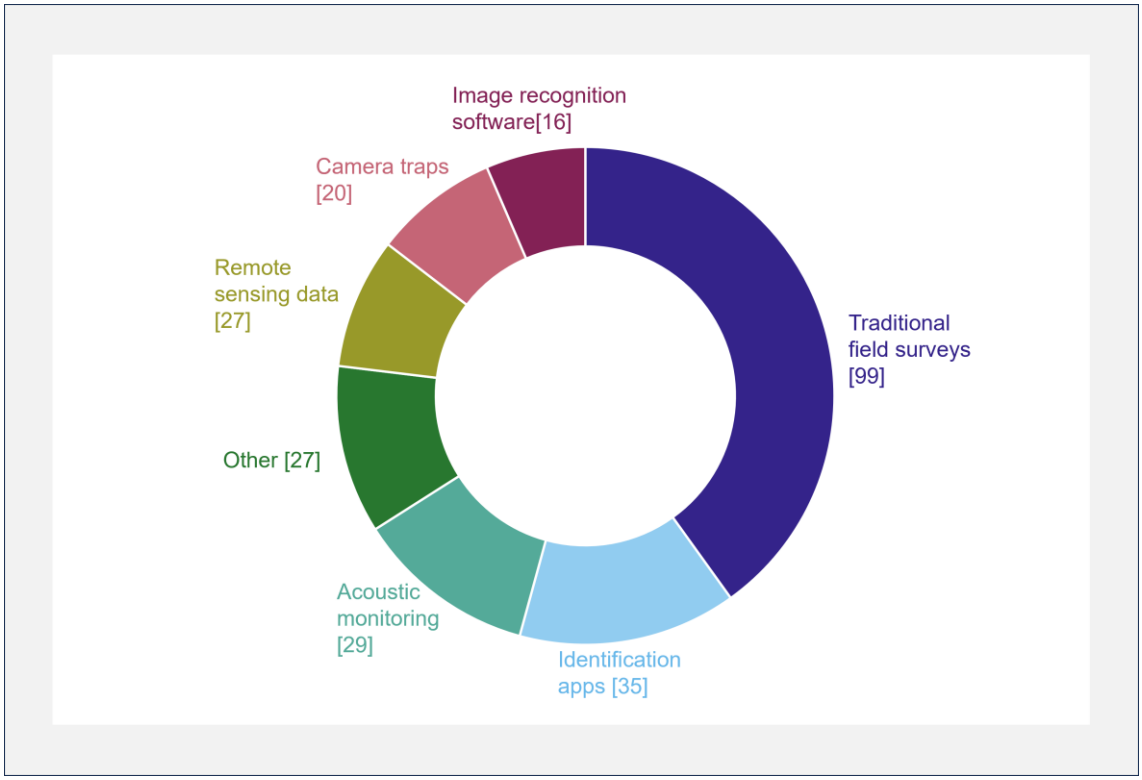

Figure 9 Methods used to collect species monitoring data based on 102 species monitors. Numbers in square brackets represent the number of monitors who stated they currently use each monitoring method. Respondents could choose multiple selections to reflect their monitoring activities.

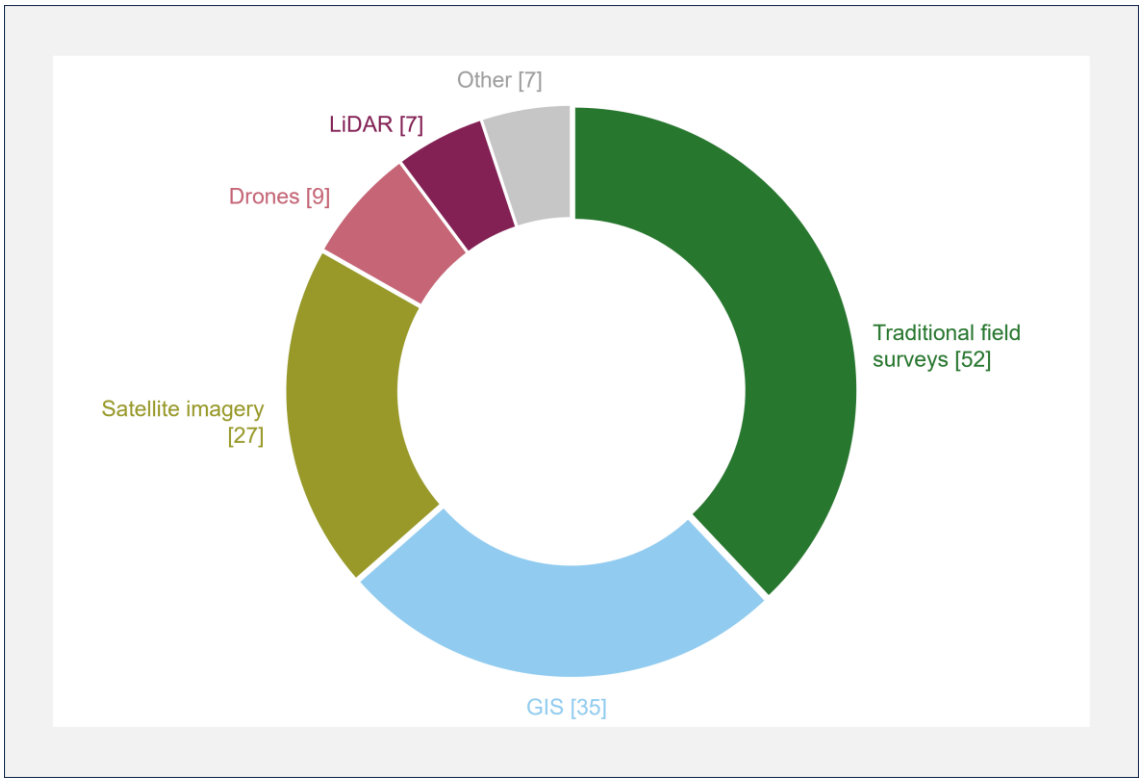

Figure 10 Methods used to collect habitat monitoring data based on responses from 64 habitat monitors. Numbers in square brackets represent the number of monitors who stated they currently use each monitoring method. Respondents could choose multiple selections to reflect their monitoring activities.

The majority of biodiversity monitors feel they are monitoring their target species and habitats often enough using their current methods. Monitors varied in how often they carry out their assessments (Table 1), with most species monitors collecting multiple samples per year [67 recorders] and most habitat monitors carrying out annual assessments [20]. Both groups felt their frequency of monitoring was adequate, however a higher proportion of habitat monitors felt they do not monitor often enough (46%). Whilst only 39% of species monitors felt they weren't monitoring often enough.

Table 1 How frequently biodiversity monitors carry out their assessments and the proportion which feel they are monitoring often enough compared to those who feel they are not monitoring often enough according to type of monitoring (species or habitats).

Type of monitoring	Frequency	No. of recorders	I feel I am monitoring often enough	I do not monitor often enough
Species	Multiple samples per year	31	22	9
	Annually	25	13	12
	Seasonally	8	6	2
	Less frequently	10	4	6
	Overall species monitors	**74**	**45**	**29**
Habitats	Monthly	6	5	1
	Quarterly - every 3 months	5	3	2
	Seasonally	8	4	4
	Every 6-12 months	2	2	0
	Annually	20	8	12
	Every 1-5 years	12	9	3
	Less frequently	10	3	7
	Overall habitat monitors	**63**	**34**	**29**

6.2 The use of novel tools for biodiversity monitoring

Novel tools are most commonly used by species monitors, but many still use traditional survey methods. The majority of survey respondents reported they use novel tools and/or technology for species monitoring only (36% of respondents, Fig 11). However, a further 35% of participants reported that they *do not currently use any novel tools or technologies* for biodiversity monitoring (Fig 11). If advances in monitoring technology are to address biodiversity data gaps efforts must be made to increase uptake, or understand why monitors still rely on established, low-tech monitoring.

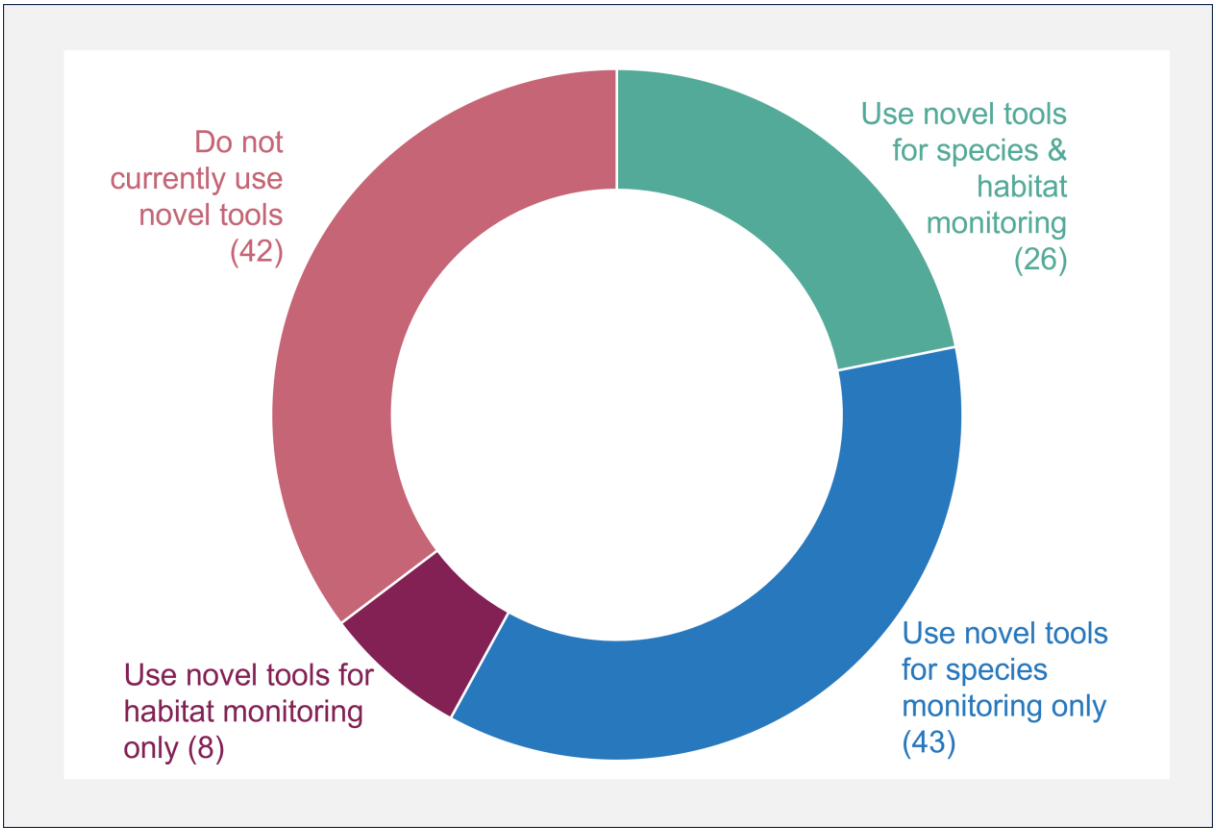

Figure 11 Stakeholder use of novel tools and technologies, numbers indicate the number of respondents that chose each option.

Monitors have a good understanding of the novel tools available for biodiversity monitoring. When asked about their use and familiarity of modern approaches to monitoring biodiversity, very few expressed an unfamiliarity with them (Fig 12). Applications to collect structured field data (such as ODK) was the least known amongst participants, overall, 14% of participants indicated they weren't familiar with this type of tool. It is possible, however, that monitors who already engage with modern tools were more likely to respond to this survey than those who do not, further investigation will be necessary to determine if this is the case.

Mobile apps are a popular method of species identification. Of the 119 survey respondents, 44% reported currently using image-based species identification apps and a 26% use acoustic species identification apps (Fig 12). A further 22% and 21% of overall monitors would like to use image-based and acoustic-based species ID apps, respectively, suggesting that apps are a popular method of obtaining biodiversity data.

Our survey revealed that many biodiversity monitors want to use drone imagery to obtain biodiversity data. While only 25% of overall respondents currently use drone imagery for monitoring species or habitats, a further 44% indicated that they would like to use this technology (Fig 12). This is encouraging as MAMBO researchers will be exploring the applications of drone imagery for deriving habitat conditions metrics (T4.2 – develop habitat conditions metrics).

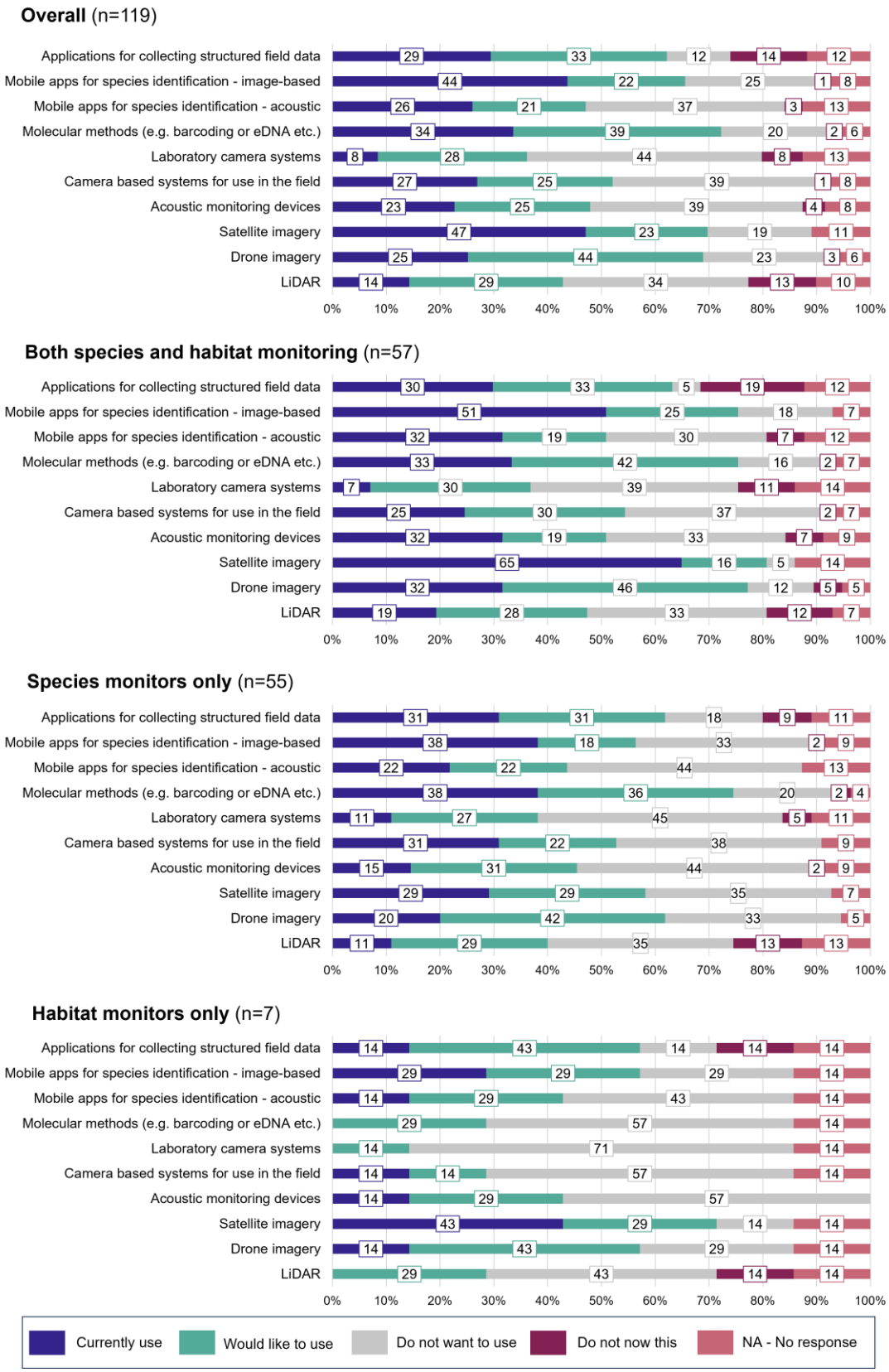

Figure 12 A summary of the use of novel tools and technologies by overall respondents (top panel, n=119), those that monitor species and habitats (n=57), species-only monitors (n=55) and habitat-only monitors (n=7). Respondents were asked to indicate which tool/tech they currently use, would like to use, do not want to use,

and those they are unfamiliar with. Data labels represent the percentage of respondents that chose each corresponding option.

6.3 Barriers and incentives that affect uptake of novel tools and technologies

As outlined in section 7.2, many biodiversity monitors do not currently use novel tools and technologies to collect species and habitat data despite appreciating their value and expressing a desire to. Recent technological advances in artificial intelligence, remote sensing and sound and image species recognition software can provide benefits such as sampling automation, increased accuracy and standardised approaches over larger geographic areas (Buckland and Johnston, 2017; Reddy et al., 2021). Despite these benefits which could complement traditional survey methods and make monitoring more efficient (Beng and Corlett, 2020), cost-effective (Stephenson, 2020) and ease habitat identification (He et al., 2015), uptake remains relatively low. A key component of MAMBO's stakeholder needs assessment is to identify factors that impact adoption, both negatively and positively. To explore this, we asked our survey respondents to rate any challenges and/or barriers that impede uptake of novel tools, their willingness to pay and to identify solutions that could increase their use of novel tools and technologies. The following key messages are derived from data collected through the online survey, whilst some overlap exists with those lessons learned from more targeted stakeholder engagement carried out by MAMBO WP leads, both are presented as results if two independent assessments.

Most monitors perceive novel tools and technologies to be too expensive. Financial barriers came out as the most important challenge our respondents face that impact their ability to adopt new tools and technologies (Fig 13). This was rated most important across all monitor types (species, habitats and both).

Habitat monitors may not be aware of the tools and technologies that are available. Lack of awareness was rated as the second most important barrier to habitat monitors (Fig 13), this challenge came out as third most important when considering all 119 respondents overall. This should be taken into consideration through MAMBOs stakeholder engagement. A possible activity could include showcasing novel tools and technologies to habitat monitors and could be included in the project's Exploitation and Dissemination of Results (PEDR) to ensure MAMBOs habitat monitoring tools and technologies are communicated and promoted to habitat monitors.

Biodiversity monitors are confident in their ability to adapt to using novel tools and technologies. A lack of confidence in adopting new tools and technologies was consistently ranked as unimportant amongst our 119 survey respondents (Fig 13).

Monitors feel novel tools and technologies can't provide the appropriate taxonomic resolution or geographic coverage to meet their needs. These were ranked as important challenges by respondents and should be considered a priority when developing monitoring tools and technologies.

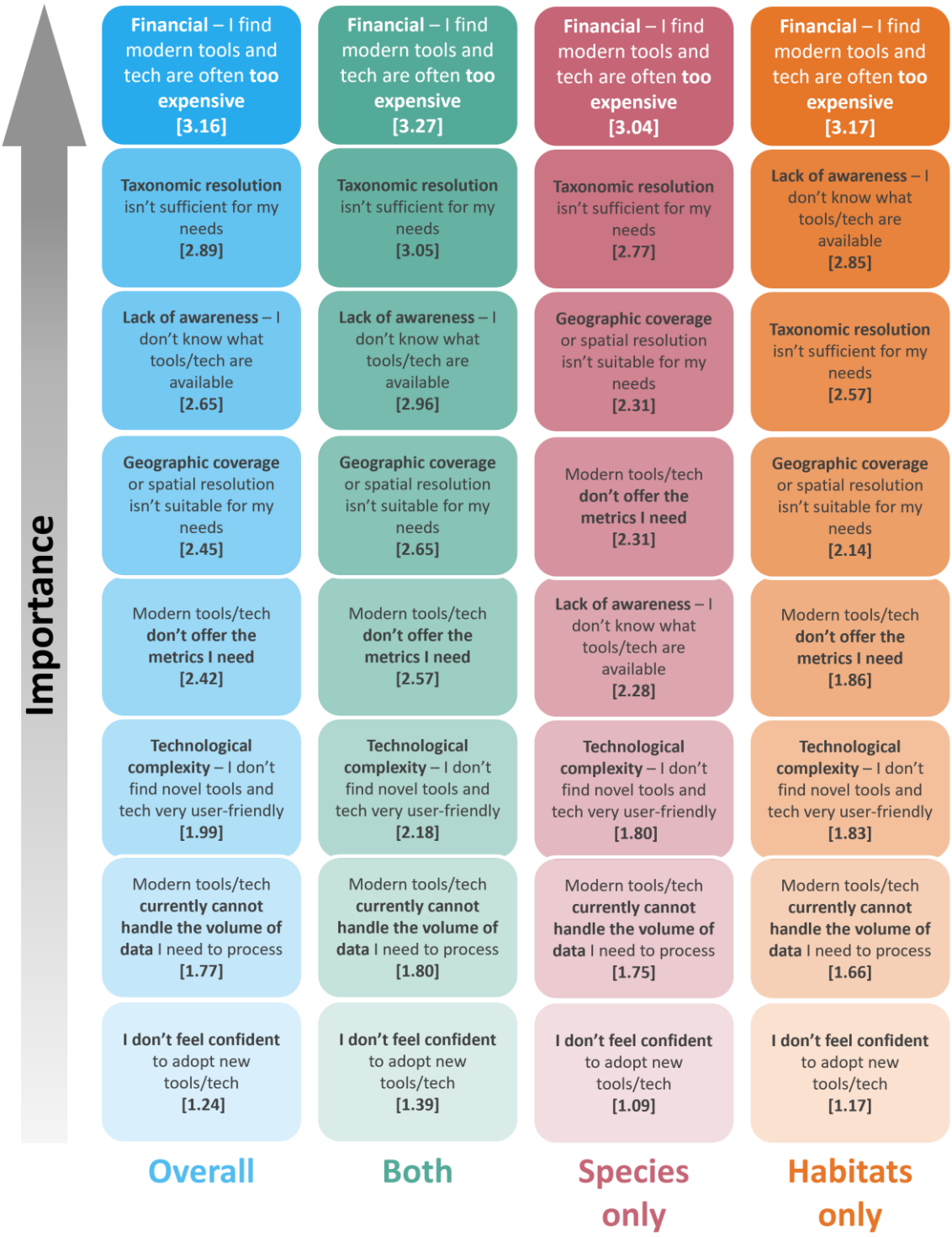

Figure 13 Challenges to the uptake of novel tools and technologies. Participants were asked to rate a set of predefined potential barriers to their use of novel tools/technologies on a scale of 0-5 where 0 indicates no impact and 5 indicates a strong impact. Mean impact scores are given in square brackets, and challenges have been arranged according to importance for each biodiversity monitoring group.

Most monitors are *not willing* to pay for novel tools and technologies (Fig 14). Financial barriers are commonly reported as reasons for low uptake of biodiversity

monitoring technologies. An exception to this relates to molecular methods, which biodiversity monitors are more inclined to pay for on a one-time basis (i.e. per sample).

Willingness to pay depends on the technology and the type of monitor. Habitat-only monitors are most likely to pay a subscription fee for apps to help collect structured field data but were generally more disinclined to pay for tools and technologies across the board. Monitors of both species and habitats are more willing to pay for tools and technologies, but expressed a general preference for once off payments followed by initial free trials with follow-up payment options.

Species-only monitors were found to be more inclined to pay for tools and technologies in general but preferred payment options varied according to technologies. On top of molecular methods, species monitors appear to be more likely to pay upfront for hardware such as camera systems [40%] and acoustic monitoring devices [35%] (Fig 15). Species monitors would also prefer not to pay upfront but have the option of premium paid-for features, for apps aimed at collecting structured field data [25%], image [25%] and acoustic [20%] species identification (Fig 14).

Finally, we explored incentives, and what could improve uptake of novel tools and technologies (Fig 15). **Overall, species-only, and habitats-only monitors stated that an improved level of accuracy, e.g. identification to species would increase their use of novel biodiversity monitoring tools.**

Stakeholders who monitor both species and habitats identified an increased geographic specificity as important to increasing their use of novel tools and technologies.

Having contact with the developer at certain times during development is important to increase the use of novel tools amongst habitat monitors. This was the second most important incentive identified by habitat-only monitors (Fig 15).

Stakeholders need support in processing and analysing data resulting from novel monitoring tools and technologies. Ease of analysis of data was the second most important factor that would increase the use of tools and tech by species-only monitors, while those monitors who study both species and habitats chose having tools to support the processing of data as second most important (Fig 15).

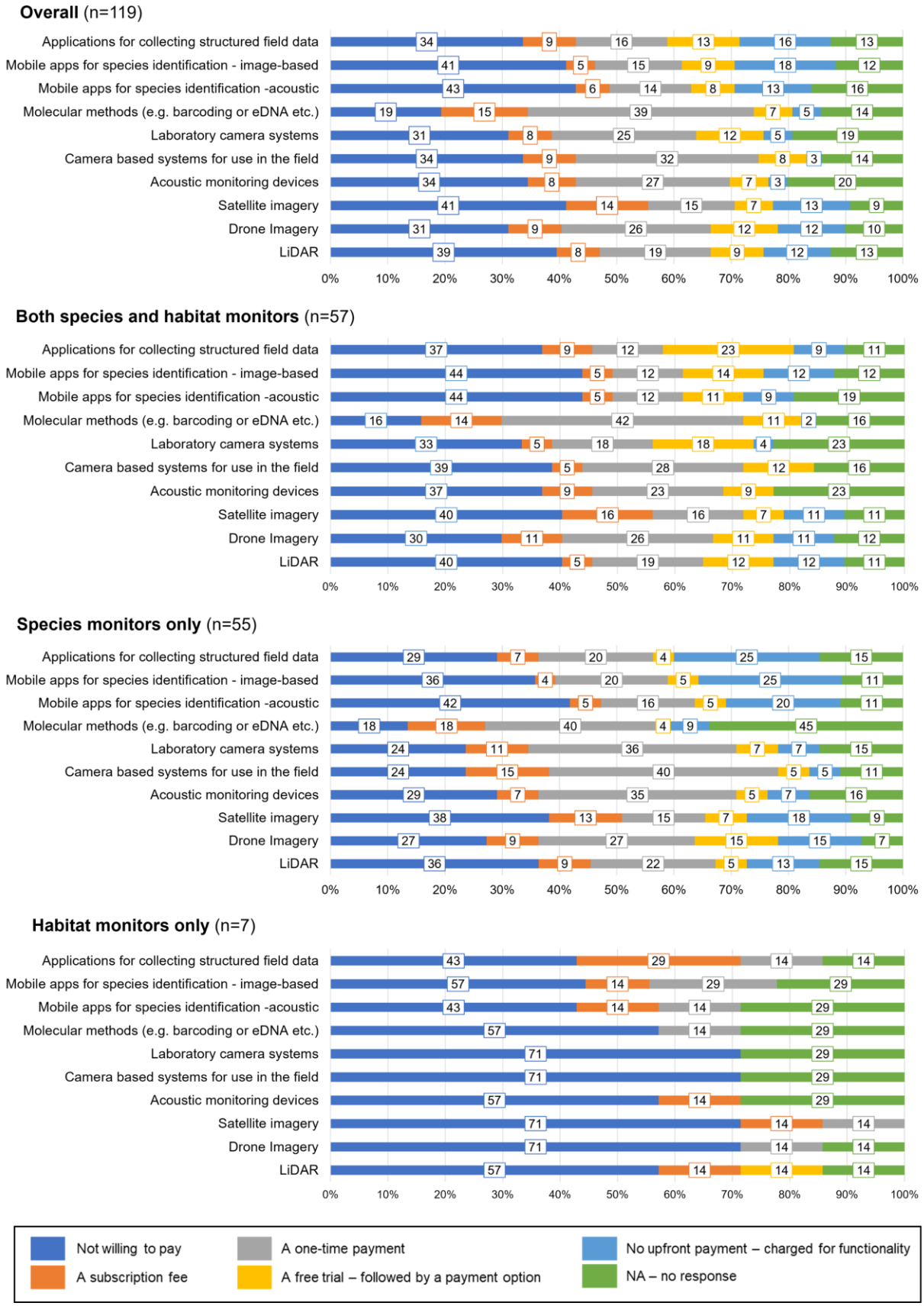

Figure 14 Willingness to pay for novel tools and technologies according to 119 biodiversity monitors. Participants were asked to indicate their payrment preference for a series of predefined novel tools/technologies, data labels indicate the percentage respondents that chose each payment option.

Figure 15 The number of participants who selected each iIncentive to use novel tools/technologies by monitoring type. .

7 Next steps in MAMBO's stakeholder needs assessments

Understanding stakeholder needs is a priority for MAMBO, and user-needs assessments will be carried out at key stages over the course of the project period. These will include various stages of development for the tools and technologies that MAMBO researchers are producing. The theory of change presented in this report will provide a framework of activities for this process.

A common outcome from MAMBO's interactions with stakeholders to-date (through engagement with researchers and the survey with biodiversity monitors) has been the importance of communication. This report has presented key information on stakeholder needs which will be useful for MAMBO researchers and beyond. Results will be communicated back to project members through follow-up correspondence and presentation at key project meetings.

It is evident that a strong foundation in stakeholder engagement exists amongst MAMBO researchers (Section II), who are in regular contact with key users. It will be increasingly important to actively engage with stakeholders as MAMBO tools and technology are realized. A strategic plan of stakeholder co-development activities (T1.4) will be vital to avoid stakeholder fatigue and to ensure gaps in stakeholder representation are addressed.

Through the survey with biodiversity monitors, we have developed new connections with stakeholders who have expressed interest in engaging with MAMBO in the future (Fig 16). Of the 119 respondents, 91 provided contact details and indicated they would be interested in future engagement with MAMBO researchers. Most expressed interest in being invited to attend demonstrations by key experts, participating in co-design of species monitoring tools and technologies and attending online webinars on MAMBO's work.

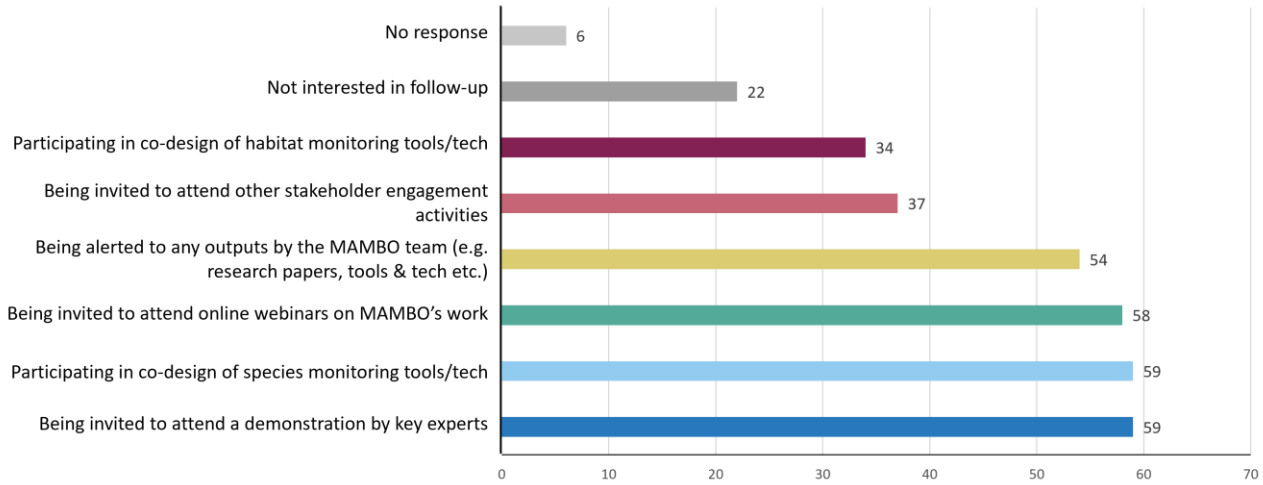

Figure 16 The number of survey participants who expressed interest in future engagement with MAMBO.

MAMBO's community of stakeholders will expand over the course of the project, through T1.3 – stakeholder mapping and network analysis and other interactions by MAMBO researchers. These will provide further data on the needs of a diverse group of users. Different

modes of assessments will be used, tailored to the diverse range of MAMBO tools and technologies and will include follow-up surveys, focus groups, workshops, webinars, semi-structured interviews and demonstrations by key experts.
Some key challenges faced by biodiversity monitors have been identified through this initial assessment but this will be expanded on through T1.6 – Identification of incentives and barriers to uptake of MAMBO tools and technology.

8 Acknowledgements

We wish to acknowledge the time and feedback MAMBO colleagues gave us in the initial concept and design of the questionnaire on biodiversity monitoring needs.
We thank our internal reviewer for providing useful feedback which helped develop this report.
We also appreciate those within MAMBO and colleagues at University of Reading who shared the survey with their extended colleagues and networks.
We extend a huge thank you to the 119 participants who provided valuable data on their experience and opinions on novel tools and technologies while monitoring species and habitat monitoring.
UREAD work on MAMBO is funded through Innovate UK Horizon Europe Guarantee reference number 10039023.

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Project partners

10 Annex

10.1 Framework to summarise relevant stakeholder interactions.

The following list of questions can be used as a guide to summarise any relevant stakeholder interactions you have had. It is important that we capture these data so that we ensure we are not carrying out redundant user-needs assessments and to avoid stakeholder fatigue. The list of questions should give you an idea of the kinds of information we need but it is not exhaustive so please feel free to add any other information you think might be relevant.
I will use information from these summaries to form a section of **D1.1 Report on stakeholder needs.** This is due August 31st.

1. **How have you engaged with stakeholders to-date?**
   i.e. conversations, formal/semi-structured interviews, questionnaires, focus groups, webinars etc.
2. **Who have you engaged with? What kind of stakeholders?**
   We do not need individual names but feel free to provide this information, if possible, an alternative is to name organisations or describe what type of stakeholder they represent- i.e. landowners, users of software, other researchers, citizens, recorders etc.
3. **Please provide a summary of outcomes.**
   What did you learn?
   How has this directed/impacted on your work/design/progress for MAMBO?
   ***Did you identify any specific needs** - in terms of what they want to be able to achieve using novel technologies or tools?*
   Did they mention any challenges/limitations that they face - in terms of their monitoring?
   Do you think novel tech/tools help with these?
   Are there any barriers that may impact their ability to adopt novel tech and tools?
   How has this impacted on your work in MAMBO – has it led to any changes in your design/metrics etc.?

4. **Are there any specific gaps in terms of user-needs that you think MAMBO should address?**

   This will not be included in the broad-brush user-needs survey, but may be useful in the design of future user-needs assessments such as focus groups, interviews etc.

5. **When did these interactions take place?**

   We are aware that some of these activities pre-date MAMBO, as you will work towards refining/improving tools/tech already established, however any user-needs/stakeholder engagement that you carried out in those initial phases may still be very relevant to MAMBO.

6. **Which WP(s)/Task(s) does this summary relate to.**

7. **Has your interactions with stakeholders led to any outputs (report, publication, questionnaire etc.) If so, please include a link or citation below.**

10.2 Online questionnaire to gather information from biodiversity monitors.

MAMBO
MODERN APPROACHES TO THE MONITORING OF BIODIVERSITY

Welcome to the MAMBO (Modern Approaches to the Monitoring BiOdiversity) project's survey on **biodiversity and habitat monitoring needs.**

Over the next three years, the MAMBO team will develop, test and implement modern tools and technologies to support the monitoring of species and habitats for which knowledge gaps still exist. You can learn more about this Horizon Europe funded project here.

To inform a key project deliverable on stakeholder needs, researchers from the University of Reading are running this survey to gather information from individuals who carry out species and/or habitat monitoring.

We will start by asking you about the type of monitoring you perform, and your motivations behind gathering these data. We will then gather information on your use of emerging technologies and tools and any barriers you might face in terms of adopting these novel technologies.

Information for Participants

This exercise involves a questionnaire which could take approximately 15 minutes to complete depending on your answers. We are seeking to gather information from individuals or organisations who carry out species and/or habitat monitoring across broad taxonomic and geographic ranges, from different sectors and career stages.

The survey will be open until August 1st 2023.

Your participation is entirely voluntary and very much appreciated. Incomplete survey data will not be used for analysis, once you click "submit" your responses will be entered into a database which will be stored on a secure password-protected University of Reading computer accessible only by Dr Lois Kinneen. Results will be shared with MAMBO project partners in an anonomous form and may also be made publicly available in this anonomous form.

If you have any questions or wish to withdraw your responses and data, you may do so by August 15th 2023 by email to Dr Lois Kinneen: l.kinneen@reading.ac.uk

To begin, please enter a **unique identifier** (for example today's date and time or a memorable word).
Please keep a record of this unique code as you can use it to contact us about your responses.

First, we will ask you some questions on the types of monitoring you currently perform.

Do you monitor species, habitats or both?
Please select all that apply.

- ☐ Species
- ☐ Habitats

Where do you carry out your species and/or habitat monitoring?
List all countries and/or regions that you currently carry out monitoring activites. Please use a semicolon (;) to separate entries.

What are your ***primary motivations or reasons*** for collecting species and/or habitat monitoring data?
Please select all that apply.

- ☐ EU policy requirement (e.g. birds directive, habitat directive etc.)
- ☐ National policy requirement (e.g. national pollinator action plan etc.)
- ☐ For academic research
- ☐ As part of a citizen science project
- ☐ To report on biodiversity impact of buisness/organisation
- ☐ Conservation (habitats/species)
- ☐ Land management/agri-environmental schemes
- ☐ Interest in natural history
- ☐ Other - please specify

Thinking about the species monitoring you perform.

What ***taxa*** do you currently monitor?
Please select all that apply, and use the text boxes to give further details if you wish.

- ☐ Amphibians
- ☐ Birds
- ☐ Fish
- ☐ Fungi
- ☐ Insects
- ☐ Non-insect invertebrates
- ☐ Mammals
- ☐ Plants
- ☐ Reptiles
- ☐ Other - please specify

How often do you carry out ***species*** monitoring?
Please select the most appropriate response, or use the text box to provide further details.

- ○ Multiple samples per year
- ○ Annually - every year
- ○ Seasonally - please specify
- ○ Less frequently - please specify

Do you feel you are ***monitoring species*** as often as is necessary to fulfill your needs?
Please select the most appropriate response. Yes if you feel you are monitoring species at a frequency that fits your needs, and no if you feel you would monitor more often.

Yes	No
○	○

What methods or tools do you currently use for your ***species monitoring***?
Please select all options that apply to you.

- ☐ Identification apps
- ☐ Remote sensing data
- ☐ Acoustic monitoring
- ☐ Camera traps
- ☐ Image recognition software
- ☐ Traditional field surveys
- ☐ Other - please specify

Thinking about the habitat monitoring you perform.

What type(s) of habitat do you monitor?
Please select all that apply and use the text boxes to give further details if you wish.

- ☐ Grasslands and lands dominated by forbs, mosses or lichens
- ☐ Coastal habitats
- ☐ Heathland, scrub or tundra
- ☐ Forest and other woodlands
- ☐ Inland habitats with no or little soil & mostly with sparse vegetation
- ☐ Vegetated man-made habitats
- ☐ Other - please specify

Which of the following **metric(s)** do you use to monitor habitat(s)?
Please select all that apply.

- ☐ **Presence of species - flora** (e.g. positive, negative, nutrient change, mowing/grazing)
- ☐ **Presence of species - fauna**
- ☐ **Presence (evidence)/ density of large herbivores** (e.g. trampling, vegetation bites, deer, dung etc.)
- ☐ **Presence (evidence)/density of smaller grazers/diggers** (e.g. rabbits, moles, geese etc.)
- ☐ **Graminoid:Forb ratio**
- ☐ **% Cover of vegetation communities/habitat**
- ☐ **% Cover of water bodies**
- ☐ **% Cover of bareground**
- ☐ **% Cover of stone, rock boulder**
- ☐ **% Cover of burnt area**
- ☐ **Forest structure: tree size distribution, understory**
- ☐ **Number of large trees/hollow broadleaved trees**
- ☐ **Coarse dead wood (presence/absence/density)**
- ☐ **Leaf litter** (presence/absence/density)
- ☐ **Herb, Grass: Dead material/litter** (presence/absence/% cover)
- ☐ **Presence/absence of dynamic stages** (water dynamics or other)
- ☐ **Forest: Light condition** (canopy cover/canopy gaps/glades)
- ☐ **Herb, Grass: Light condition** (Ellenberg L or other)
- ☐ **Nutrient level** (Ellenberg N or other)
- ☐ **Wetness** (Ellenberg F or other)
- ☐ **Fragmentation metrics**
- ☐ **Degradation, alterations:** evidence of drainage
- ☐ **Degradation, alterations:** linear features or areas with low vegetation due to traffic, digging etc.
- ☐ **Degradation, alterations:** evidence of stream/river regulation
- ☐ **Degradation, alterations:** change in micro-topography
- ☐ **Open landscapes:** vegetation height
- ☐ **Other** - please specify

How often do you carry out ***habitat*** monitoring?
Please select the most appropriate response, or use the text box to provide further details.

- ○ Monthly
- ○ Quarterly - every 3 months
- ○ Every 6-12 months
- ○ Annually - every twelve months
- ○ Every 1-5 years
- ○ Seasonally - please specify
- ○ Less frequently - please specify

Do you feel you are ***monitoring habitats*** as often as is necessary to fulfill your needs?
Please select the most appropriate response. Yes if you feel you are monitoring species at a frequency that fits your needs, and no if you feel you would monitor more often.

Yes ○ No ○

Which of the following do you use for ***habitat monitoring***?
Please select all options that apply.

- ☐ GIS
- ☐ LiDAR
- ☐ Drones
- ☐ Satellite imagery
- ☐ Traditional field surveys
- ☐ Other - Please specify

Finally, thinking about emerging tools/technologies for monitoring species and habitats.
Emerging tools and technologies include modern methods of biodiversity monitoring such as remote sensing, camera systems, acoustic monitoring and eDNA etc.

Do you currently use any **emerging technologies/tools** to assist with your species/habitat monitoring?
Please select the most appropriate option(s).

- ☐ Yes - for species monitoring
- ☐ Yes - for habitat monitoring
- ☐ Yes - for both species & habitat monitoring
- ☐ No

Considering the following modern biodiversity monitoring tools, please indicate which you; ***currently use***, ***would like to use***, ***don't want to use***, or ***are unfamiliar with.***
Please select the most appropriate option for each tool or technology.

	Currently use	Want to use	Do not want to use	Do not know this
LiDAR	○	○	○	○
Drone imagery	○	○	○	○
Satellite imagery	○	○	○	○
Acoustic monitoring devices	○	○	○	○
Camera based systems for use in the field (e.g. camera traps)	○	○	○	○
Camera based systems for lab use (e.g. to assist with counting specimens, measuring size etc.)	○	○	○	○
Molecular methods (e.g. barcoding or eDNA etc.).	○	○	○	○
Mobile apps for species identification - acoustic	○	○	○	○
Mobile apps for species identification - image-based	○	○	○	○
Applications for collecting structured field data	○	○	○	○

Are there **any other modern biodiversity monitoring tools/technologies** that you are aware of (not listed above).
Please list these below, separating each entry with a semicolon (;).

Would you be willing to pay for the following modern biodiversity monitoring tools? If so, which payment option would you find most appropriate?
Please select the most appropriate option for each tool or tech.

	Not willing to pay	A subscription fee	A one-time payment	A free trial - followied by a payment option	No upfront payment - charged for functionality (e.g. free app with premium paid-for features)
LiDAR	○	○	○	○	○
Drone imagery	○	○	○	○	○
Satellite imagery	○	○	○	○	○
Acoustic monitoring devices	○	○	○	○	○
Camera based systems for use in the field (e.g. camera traps)	○	○	○	○	○
Camera based systems for lab use (e.g. to assist with counting specimens, measuring size etc.)	○	○	○	○	○
Molecular methods (e.g. barcoding or eDNA etc.).	○	○	○	○	○
Mobile apps for species identification - acoustic	○	○	○	○	○
Mobile apps for species identification - image-based	○	○	○	○	○
Applications for collecting structured field data	○	○	○	○	○

Now considering the following **apps which can be used for idenfitication or data entry,** please indicate which you; ***currently use, have used in the past, are aware of, or are unaware of.***
Please select the most appropriate option for each app.

	Currently use	I have used it in the past but not currently	I am aware of this but don't use it	Never heard of this
iNaturalist	○	○	○	○
iBird	○	○	○	○
eBird	○	○	○	○
Pl@ntNet	○	○	○	○
Merlin Bird ID	○	○	○	○
Audubon bird guide	○	○	○	○
Flora incognita	○	○	○	○
iRecord	○	○	○	○
ObsIdentify	○	○	○	○
Biodiversity Data Capture (NBDC)	○	○	○	○
Plant Snap	○	○	○	○
Picture This	○	○	○	○
ChirpoMatic	○	○	○	○
PictureInsect	○	○	○	○
Leps	○	○	○	○
Survey123	○	○	○	○
EpiCollect	○	○	○	○
Google Open Data Kit	○	○	○	○
MyNature Animal Tracks	○	○	○	○
Arter.dk	○	○	○	○
naturbasen.dk	○	○	○	○
Danmarks svampeatlas	○	○	○	○
Nature Europe	○	○	○	○
seek	○	○	○	○
Birdseye	○	○	○	○
Anthos	○	○	○	○
Malta Flora & Fauna	○	○	○	○
The Jellyfish App	○	○	○	○
Picture Fish	○	○	○	○
FishVerify	○	○	○	○
UMAPIT	○	○	○	○

Are there any other biodiversity monitoring apps that you are aware (not listed above)?
Please list these below, separating each entry with a semicolon (;).

Please ***rate*** the following **challenges/barriers** on a scale of 0-5, in terms of **how much they impact on your ability to adopt novel monitoring tools/technologies.**
Where 0 indicates a weak barrier to adoption (does not impact your decision to adopt novel tools or technologies, and 5 indicates a strong barrier (i.e. is a major reason why you haven't adopted novel tools or technologies).

	0 - doesn't have an impact	**1**	**2**	**3**	**4**	**5** -has a strong impact
Financial - I find modern tools and technologies are often too expensive	○	○	○	○	○	○
Lack of awareness - I don't know what tools/tech is available	○	○	○	○	○	○
Technological complexity - I don't find novel tools and technologies very user-friendly	○	○	○	○	○	○
Taxonomic resolution isn't sufficient for my needs	○	○	○	○	○	○
Geographic coverage or spatial resolution isn't suitable for my needs	○	○	○	○	○	○
They don't offer the **metrics** I need (e.g. measure of abundance, diversity etc.)	○	○	○	○	○	○
They currently cannot handle the **volume of data** I need to process (e.g. images, recordings etc.)	○	○	○	○	○	○
I don't feel confident to adopt new tools/technologies	○	○	○	○	○	○

Are there any other **reasons why you might *not* adopt** novel tools or technologies for your species/habitat monitoring?
Please use the box below to give further details.

Which of the following would ***increase your use of novel biodiversity monitoring tools and technology?***
Please select all that apply.

- ☐ Geographic specificity - having high resolution data for a specific area
- ☐ Taxonomic focus - specialised to certain taxa
- ☐ Improved level of accuracy - e.g identification to species
- ☐ Tools/tech being open source (free to use)
- ☐ Ease of analysis of data
- ☐ Having tools to support the processing of data
- ☐ Being provided with the underlying code
- ☐ Being involved in the co-design process
- ☐ Being invited to a demonstration by a relevant expert
- ☐ Having contact with the developer at certain times during development
- ☐ Other - please specify
- ☐ None of the above

Thank you for your responses so far, this final section includes some questions that will help anonymise your data for analysis.

Firstly, in terms of biodiversity monitoring, which of the following best describes you?
Please select the most appropriate response.

- ○ Data collector
- ○ Data holder (e.g. platform or database)
- ○ Data user
- ○ Data analyser
- ○ Data provider
- ○ Other - please specify

Which **sector** do you primarily work in?
Please select the most appropriate response.

- ○ Citizen - part a citizen science project, but not working in a biodiversity-related sector
- ○ Land manager - Please specify (e.g. urban, rural, agricultural, nature reserve etc.)
- ○ Research - Academic
- ○ Non-profit or NGO
- ○ Research - Industry
- ○ Government
- ○ Policy
- ○ Other - please specify

Finally, over the course of the MAMBO project, we will be organising a series of stakeholder engagement activities and events. **Would you be interested in being invited to any of the following?**
Please select any that you are interested in. By selecting any of the following options, you are expressing an interest in being invited or kept up-to-date on MAMBO events, there is no obligation to participate/attend any.

- ☐ Participating in **co-design** of **species** monitoring tools/tech
- ☐ Participating in **co-design** of **habitat** monitoring tools/tech
- ☐ Being invited to **attend a demonstration** by key experts
- ☐ Being invited to **attend other stakeholder engagement activities**
- ☐ Being invited to attend **online webinars** on MAMBO's work
- ☐ Being **alerted to any outputs** by the MAMBO team (e.g. research papers, tool or technologies etc.)
- ☐ Not interested in follow-up

If you are interested in any of the above activities, or would be open to follow-up communication about your survey responses, please provide the most appropriate email to contact you on.
This is entirely voluntary, and will allow us to tailor communications to you and include you in stakeholder events.
Your contact information will be stored in a secure password-protected spreadsheet, and will not be published or shared externally.