Identifying Conservation Technology Needs, Barriers, and Opportunities

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Research Article

Keywords: ecosystems, biodiversity, off-the-shelf devices, Cross-discipline collaborations

Posted Date: June 3rd, 2021

DOI: https://doi.org/10.21203/rs.3.rs-567968/v1

Abstract

Amid accelerating threats to species and ecosystems, technology advancements to monitor, protect and conserve biodiversity have taken on increased importance. While most innovations stem from adaptation of off-the-shelf devices, these tools can fail to meet the specialized needs of conservation and research or lack the support to scale beyond a single site. Despite calls from the conservation community of its importance, a shift to bottom-up innovation driven by conservation professionals remains limited. We surveyed practitioners, academic researchers, and technologists to identify limitations of currently-available technologies, barriers to the development of new tools, and emerging technology needs. High cost was the main barrier to technology use across occupations, while development of new technologies faced barriers of cost and partner communication. Automated processing of data streams was the largest emerging need, and respondents focused mainly on applications for individual-level monitoring and automated image processing. Cross-discipline collaborations and expanded funding networks that encourage cyclical development and continued technical support are needed to address current limitations and meet the growing need for conservation technologies.

Introduction

The infusion of new technologies into conservation efforts make it easier and faster to monitor species and ecosystems[1]. Technology tools can provide novel data sources, expanded spatial and temporal coverage, real-time data access, and rapid processing and analysis for intervention[1–4]. For example, the inclusion of real-time access and processing of data streams from remote monitoring devices such as acoustic recorders has amplified their utility for management interventions, such as detection and response to illegal logging[5]. The rapid growth and availability of technologies has been driven largely by adapting consumer-oriented technologies to fit conservation use cases[6], including hobby drones for monitoring and response to threats[7,8] and the applying blockchain protocols to fisheries supply chain management[9]. While these options are widely available, they can lack features essential to use in conservation settings like durability and power efficiency (i.e. long term deployment without power access), or may have a high technical knowledge barrier to entry[6]. Such constraints are thought to limit the uptake of new tools, but we lack information on the degree to which they restrict the use of technologies in conservation settings or how to prioritize improvements for future development.

In response to the limitations of off-the-shelf technologies, efforts have grown to actively create novel technologies geared for conservation[10,11]. Conservation-driven efforts for purpose-built research and monitoring tools include hardware with a lower price point than consumer versions[12,13], integration of existing technologies for real-time alerts[14], and collaborations with technologists and companies to produce open-source products for research and management (such as Microsoft's MegaDetector - https://github.com/microsoft/CameraTraps/blob/master/megadetector.md, Google Earth Engine, and Vulcan's EarthRanger). The bottom-up approach of small scale innovation puts increasing importance on cross-discipline collaborations between end users with first-hand knowledge of local needs and obstacles

(i.e. practitioners or researchers), and technologists who have the skills to develop and adapt custom technologies[10]. For technology-based solutions to have substantial conservation impacts, collaborations must be able to effectively identify feature needs, share data, and build a development pipeline that allows iterative development and support[6,10].

To drive development of conservation technologies and effectively leverage the support of technologists, we must understand the factors contributing to or inhibiting engagement in the conservation technology space[6]. To address this gap, we surveyed active conservation practitioners, researchers and conservation-oriented technologists on three key areas regarding conservation technology development: 1) What are the technical barriers to use of technology among end-users, and are development priorities focused on alleviating these?; 2) How are conservation technology collaborations structured, and what are the perceived barriers to successful collaborations?; 3) What future technologies are the conservation community looking for?

Results

Of the 101 completed survey responses, we categorized respondents into three groups: 53 were conservation practitioners, 42 were academic researchers, and 7 were technologists. Familiarity and experience with conservation technologies varied widely among respondents. 71% of respondents reported being extremely or very familiar with technologies, while 26% reported being moderately familiar. Most respondents had experience using existing technologies for conservation applications (96%), while fewer had tested unproven tools (48%), adapted or modified technologies for their use case (54%), and developed new tools (34%). Among user groups, more conservation practitioners were engaged in the development of new conservation technologies (71%) compared to academic researchers (45%).

In our first question, the technical barriers to use of technologies identified by conservation practitioners and academic researchers were similar, highlighting durability, cost, power efficiency, data management, and real-time transmission (Fig. 1a). However, only cost was identified as likely to prevent the use of a technology in the field (Fig. 1b). Overall, practitioners reported a higher frequency of issues and encountered more problems that prevented use of technology tools in their work compared to academic researchers. Development priorities highly ranked among practitioners and researchers were similar to the major issues identified, being durability, cost, and power efficiency, and we found no differences in rankings between these groups (Fig. 1c). In the limited responses from technologists, we found feature priorities were focused on cost (7/7 respondents included cost in the top 3) and ease of use (4/7). In contrast, durability (2/7 in top 3) and power efficiency (1/7) were not highly ranked among technologists (SM Fig. 1).

In our second question, we recorded 84 unique collaborations ranging from 2 to 15 partners (median of 5 partners). Of the collaborations, 93% involved practitioners, 68% involved academic researchers, and 58% involved technologists. Only 29% of collaborations used websites or forum resources (e.g. wildlabs.net), but 75% of these occurred in a collaboration without a tech expert. Technologists were disproportionately

involved in the design stage, while practitioners and researchers were mainly involved in the testing and use phase (SM Fig. 4). Among barriers to collaborations with conservation technology, high cost (53%) was reported most frequently, followed by delayed timelines (41%) and lack of technical support (25%) (SM Fig. 5). In relation to collaboration experiences, lack of partner communication and high cost were the most likely to result in poor collaborations (SM Table 7,8).

In our third question, we identified several strong themes for desired future technologies. Most of the technologies identified were improvements or extensions to existing tools (e.g. mesh network tracking tags, field-ready genetic analysis kits), while some had extremely specific use cases, such as a device to non-invasively collect and protect hair samples for DNA analysis. Automation was mentioned in nearly one third of responses (32/101), with most use cases for automation in reference to animal image processing (53%) and individual-level monitoring (22%) (Fig. 2b). Additionally, researchers were largely focused on automation advancements, while practitioners listed a more diverse set of feature needs (Fig. 2a). For all responses on desired technologies, individual-level monitoring (51%) and animal image processing (28%) were the most-mentioned use cases.

Discussion

The shift in conservation technology from adaptation of off-the-shelf devices to bottom-up innovation requires a strong collaborative environment and solid understanding of the current and future needs of conservation practitioners and researchers[10]. Our assessment of technical barriers identified frequent issues with multiple feature types, but cost disproportionately prevented the use of technologies in conservation and research settings. While previous studies have touted advanced technologies as a cost-effective pathway to expand the reach and resolution of environmental monitoring[1,7], our results suggest that the high upfront cost of new technologies puts currently-available tools out of reach for many groups; high costs can manifest across device purchase, training and implementation time, maintenance, data storage, and processing. In addition, low cost is often misaligned with other features that respondents identified, such as durable environment-proofing and robust technical support. For example, the popular AudioMoth low-cost acoustic monitoring platform is sold without a protective case for 60 USD, but users can purchase one for 35 USD. While this extra durability increases the cost by over 50%, the design demonstrates a flexible approach to keep prices low for users who do not require robust environmental protection or can build their own solution.

Our assessment of collaboration structures found that just over half involved a technologist, which may explain the highly reported issues with delayed timelines and lack of technical support. While lack of communication between partners was only reported in 17% of responses, it was the most significant contributor to poor collaborations. This appears to stem from identified issues that end users were under-represented in the development and adaptation stages of the development cycle, and technologists were under-represented in the testing and use phases. Additionally, our limited data from technologists suggest a different set of feature priorities for conservation technologies, highlighting the importance of involving end-users from the beginning to ensure that tool specifications meet conservation needs. In the absence

of direct technology support, websites and forums appeared to be an important source of information. Conservation technology sites that collate solutions (e.g. Wildtech.mongabay.com) and platforms that facilitate networking and information sharing (e.g. Wildlabs.org) could be a viable solution to alleviate some of the technical knowledge roadblocks to development and use of technologies in practice.

Our assessment of emerging needs in the conservation technology space identified a developing desire for software-based automation tools. Many respondents referenced the need to handle the increasing size of data streams, suggesting that automation is an emerging need among the broader conservation community. Surprisingly, many of the ideas for automation technology already exist in some form, for example automated identification and counting of individual animals in camera trap images[15]. This suggests that scaling new devices and software beyond the original project may prove difficult when most end users lack the technical know-how and infrastructure to adapt it to their specific use case. One example of this scenario is AI-based classification and detection models for camera trap images, where the drift in species assemblages and environments between sites can severely degrade classification performance[16], and where users require the skills or collaborators to implement models and code from open source repositories (see Mega Detector).

To reduce existing barriers and meet the emerging needs of conservation professionals through bottom-up innovation, our results point to the importance of a cyclical development process that brings end-users to the table early and keeps developers involved beyond the initial release, and an expanded funding network that encourages cyclical development and reducing cost barriers to scale beyond pilot sites. To achieve the full potential of conservation technologies through small-scale innovation, we must continue to foster collaborations across disciplines, provide accessible documentation for trouble shooting and future tech developments, and maintain an acute awareness of the needs and limitations of end users.

Methods

Survey

We identified our survey population using established groups with a conservation or conservation-technology focus (SM). The survey was distributed via email and listserv postings to these groups. Due to privacy requirements, it was not always possible to collect individual email addresses for distribution. The survey consisted of 24 questions, involving a combination of multiple-choice, Likert-scale, and open-response questions (SM). The survey was designed around two ways of interacting with conservation technology: 1) the use of technology tools for conservation and research, and 2) the development (i.e. design, adaptation, and testing) of new tools. In conjunction, we defined four distinct roles that respondents could take on: Use of existing and established tools for work, testing of new or unproven tools, adaptation or iterative development of existing tools, and design of new tools. We used skip logic to only show respondents questions relevant to their experience and roles with conservation technology.

We administered the survey online through Qualtrics from 10th July 2020 to 30th October 2020. To access the survey, respondents were required to consent to participate in our study and were assured that their responses would remain completely anonymous. The survey distribution list reached 648 people. Follow-up emails were sent to each group once, approximately one month after the initial email. We received 101 complete responses, for a response rate of 15.6%. Although this rate is relatively low[17], it is consistent with other online surveys that used email to contact respondents[18,19]. The survey was carried out according to the United States Federal Policy for the Protection of Human Subjects, and all protocols and methods were approved by Colorado State University’s Institutional Review Board before implementation (Protocol No. 20-10050H). Informed consent was obtained from all participants.

Statistical Analysis

Due to data imbalances from some occupation groups, occupation was collapsed into conservation practitioners, academic researchers, and technologists. Descriptive statistics were reported as percentages. For all models, responses from technologists were withheld and evaluated separately due to low response rates from this occupation group. We conducted all statistical analyses using R version 4.0.3 and the ordinal package[20,21].

To investigate our first question on technical barriers, we used two question. First, to identify the prevalence of issues, we asked respondents to list the frequency at which they encountered different technical limitations. We used an ordinal logistic regression model to evaluate the frequency of occurrence, defined as Never to Always, in relation to technical limitation and occupation. Limitations were defined as high or prohibitive cost, lack of durability, poor power efficiency, data access limitations, data management problems, lack of interoperability with other devices or software, and lack of or poor real-time data transmission. Durability was defined to respondents as features that prevented damage to tools (e.g. waterproofing, theft-proofing, etc.). Second, to determine the extent to which technical limitations impacted use of technologies, we asked respondents to indicate whether each limitation had prevented them from using a device or tool in the past. We used a logistic regression model to evaluate the prevention of use in relation to the technical limitation and occupation. To investigate our second question on conservation technology collaborations, we first quantified collaboration structures by calculating the percentage of collaborator types involved in each of the four roles (design, adapt, test, use) in the development process for each collaboration. Collaborator types were collapsed into four categories: practitioners and non-academic researchers, academic researchers, technologists, and website and forum resources. To evaluate barriers, we first summarized the overall frequency of barrier types reported, and evaluated the relationship between barriers and collaboration success using ordinal logistic regression models. We used Likhert-scale collaboration ratings (n = 54) as the response variable, and covariates for collaboration group size, type of technology, respondent occupation, and collaboration limitations. We fit multiple candidate models and used AIC to select the most informative model[22]. To investigate our third question on emerging needs, we assessed unmet needs using answers derived from a theme analysis of the open-ended survey question “Assuming unlimited funding and resources, what technological solution would you want to see developed?”. SB used NVivo 12 Pro[23] to inductively (i.e.,

without predetermined categories) code responses into themes (SM Table 9, 10). After the initial coding, all authors reexamined, refined, and integrated codes, when necessary, based on our research objectives[24,25]

Declarations

Data availability

The authors declare that the data supporting the findings of this study are available within the paper and its Supplementary Information files.

Code availability

The code that supports the ordinal and logistic regression findings presented here is available within the paper and its Supplementary Information files.

Author Contributions

N.R.H., S.P.B., and G.W. conceived the study, designed the survey, and wrote the manuscript. N.R.H. and S.P.B. analyzed the data. All authors read and approved the final version of the manuscript.

Acknowledgements

We thank our survey respondents for their participation, and the graduate students at Colorado State University who helped to pilot early versions of the survey.

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Figures

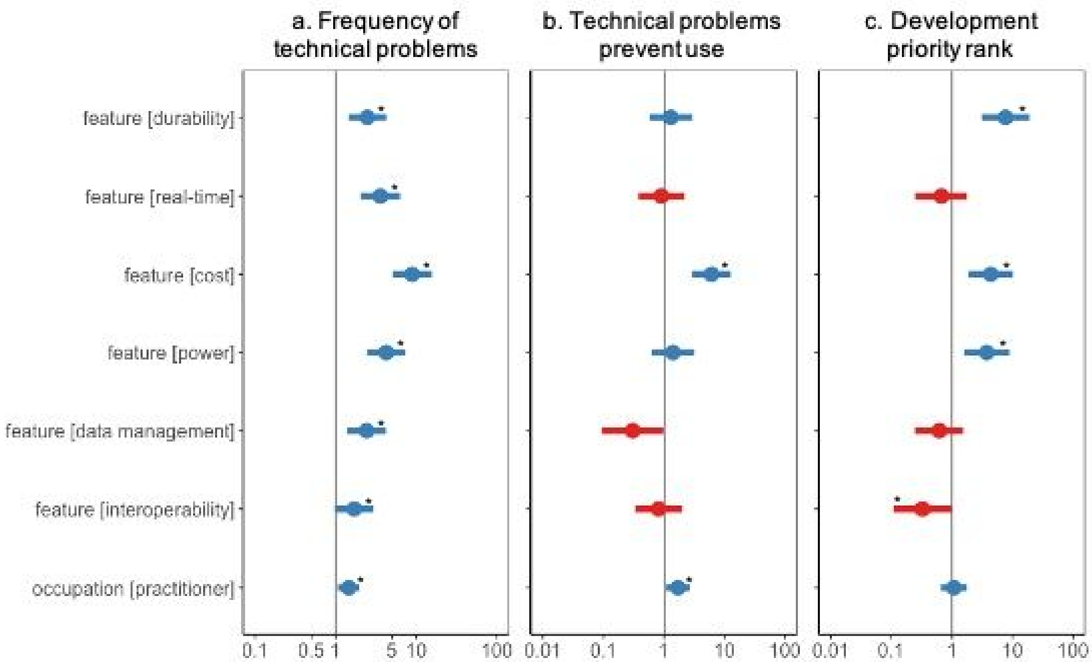

Figure 1

The importance of technology features as barriers to use and development priorities. Coefficient estimates and 95% confidence intervals (odds ratios) are shown for predicted relationships between feature types and a) the frequency of feature-related issues experienced during use, b) the frequency that feature-related issues prevented use of a tool or device, and c) the feature priority in development of new tools and devices. For A and B, blue circles indicate where respondents experienced more problems. For C, blue circles indicate where respondents ranked features with higher priority. Asterixis denote where coefficient estimates and confidence intervals did not overlap 1 and indicate a significant influence.

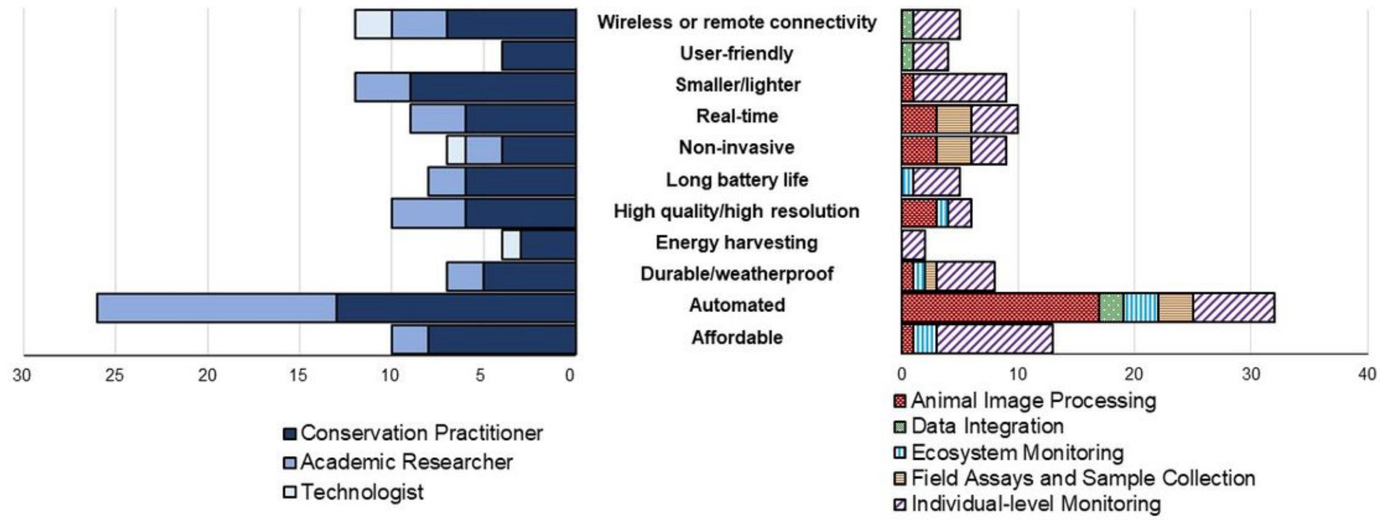

Figure 2

Categories of improvements to existing technology identified by occupation group and application type. The x-axis denotes the counts of respondents. Answers were derived from a theme analysis of the open-ended survey question “Assuming unlimited funding and resources, what technological solution would you want to see developed?”. Theme analysis codebooks can be found in SM Table 9 and 10.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- CTNAHahnSupplementaryMaterials20210512.pdf
- CTNArawDatanumeric20210113.csv
- CTNASMCode.rmd