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Unlocking the Value of Ranger-Based Monitoring for Biodiversity Conservation and Protected Area Management

Timothy Kuiper[1,2] | Anthony Dancer[3] | Colin M. Beale[4] | Arash Ghoddousi[5] | Harriet Ibbett[6] | Laure Joanny[7] | Aidan Keane[8] | Blessing Kavhu[9] | Daniel Makaza[10] | E. J. Milner-Gulland[2] | Jennifer F. Moore[11] | Lily Xu[12,13]

[1]School of Natural Resource Science and Management, Nelson Mandela University, George Campus, George, South Africa | [2]Interdisciplinary Centre for Conservation Science, Department of Biology, University of Oxford, Oxford, UK | [3]Zoological Society of London, London, UK | [4]Department of Biology, University of York, York, UK | [5]Wildlife Ecology and Conservation Group, Wageningen University, Wageningen, the Netherlands | [6]School of Natural Sciences, College of Environmental Science and Engineering, Bangor University, Bangor, UK | [7]Fauna and Flora International, Cambridge, UK | [8]School of Geosciences, University of Edinburgh, Edinburgh, UK | [9]Senckenberg Gesellschaft für Naturforschung, Frankfurt, Germany | [10]Zimbabwe Parks and Wildlife Management Authority, Harare, Zimbabwe | [11]Moore Ecological Analysis and Management, LLC, St. Petersburg, Florida, USA | [12]Leverhulme Centre for Nature Recovery, University of Oxford, Oxford, UK | [13]Department of Economics, University of Oxford, Oxford, UK

Correspondence: Timothy Kuiper (timothykuiper@gmail.com)

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ABSTRACT

Globally, hundreds of thousands of rangers patrol protected areas every day. The data they collect have immense potential for monitoring biodiversity and threats to it. Technologies like SMART (Spatial Monitoring and Reporting Tool), which facilitate the management of ranger-collected data, have enhanced this potential. However, based on our experience across diverse use cases and geographies, we have found that ranger-based monitoring is often implemented without a clear plan for how the data will inform management and without critical evaluation of whether the data are reliable enough to meet specific monitoring goals. Here we distill six key lessons and present a decision framework to guide funders, governments, protected area managers, and NGOs toward more effective use of ranger-based monitoring for protected area management and suggest when alternative monitoring approaches may add value. Essential considerations include the welfare and motivation of rangers, biases in patrol coverage and detectability, the capacity to analyze data, and the buy-in of those tasked with using the data to inform management decisions. When implemented well, ranger-based monitoring can help improve conservation outcomes through evaluating management interventions, more efficient deployment of limited law enforcement budgets to optimize the deterrence of illegal activities, and basic ecological monitoring.

1 | Data Collection by Rangers: Challenges and Opportunities

Although basic monitoring of biodiversity is essential for understanding the drivers of biodiversity loss, evaluating the effectiveness of different solutions to tackle this loss, and tracking progress toward positive biodiversity targets, recent analyses have revealed large gaps in the coverage (whether geographic or of different species groups) and reliability of global biodiversity monitoring (Johnson et al. 2024; Leung and Gonzalez

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2024). Part of the problem is that government and nongovernment conservation agencies often see monitoring of biodiversity and threats as a separate exercise for scientists, rather than seeing it as integral to the practice of conservation through guiding and evaluating management strategies (Nichols and Williams 2006). Another challenge is the often limited institutional willingness, human capacity, and resources to design and implement effective long-term monitoring programs (Field et al. 2007).

The collection of data by rangers is one promising way to fill these gaps. Every day in protected areas and additional conservation areas (ACAs) around the world, hundreds of thousands of rangers conduct patrols (Afriyie et al. 2021; Appleton et al. 2022; Farhadinia et al. 2023; Salafsky et al. 2024). While deterring illegal activity is often the primary aim of ranger patrols, the collection of monitoring data on plants, animals, and threats to biodiversity is an increasingly important secondary goal (Cronin et al. 2021; Stolton et al. 2023; see Table 1 for a diversity of examples). These data have significant potential to inform protected area management and wider biodiversity policy (Critchlow et al. 2016; Dobson et al. 2020; Ghoddousi et al. 2022; Kuiper et al. 2020; Moore, Udell, et al. 2021; Moore, Uzabaho, et al. 2021). However, most ranger-collected data fall short of this potential, partly due to shortcomings in implementation but also because of insufficient feedback into decision-making by protected area managers.

We use the term "ranger" to refer to "a field-based operative whose regular work involves surveillance, protection, and maintenance of species and ecosystems" (Belecky, Singh, and Moreto 2019). Rangers play an essential role as planetary stewards who take responsibility for safeguarding nature as well as cultural heritage in protected and conserved areas and wider landscapes and seascapes (International Ranger Federation 2021; Stolton et al. 2023). Rangers may be employed by governments, nongovernmental organizations, or private or community organizations (Appleton et al. 2022). Their work is diverse and can include activities like tourist guiding, community engagement, environmental education, relief work, maintenance of infrastructure, work in climate adaptation, and many other activities (see Stolton et al. 2023 for a comprehensive review).

We use "ranger-based monitoring" to refer to the collection of various forms of field data by rangers while on patrol and the term "ranger-collected data" to refer to the data itself. This most commonly involves "law enforcement monitoring" of illegal activities, such as livestock grazing, land clearing, logging, fuelwood collection, and illegal harvest or hunting of protected species (Moreto et al. 2014). In some instances, it also includes recording ranger activity in response to these threats (e.g., patrol routes and enforcement actions, such as arrests or snare removals). Rangers may also collect ecological data on species they encounter, on their ecosystems, and increasingly on other factors relevant to conservation management, such as the status of important natural features, human-wildlife conflict, animal health, or legal activities such as trophy hunting (Kuiper et al. 2021). We contrast ranger-based monitoring with independent surveys—monitoring carried out with a specific aim (e.g., to estimate the abundance of a particular species within the PA)—which are conducted separately from rangers' day-to-day activities. Typically, these are undertaken by scientists rather than rangers.

Ranger-collected data have been used in a diversity of ways, from tracking elephant poaching and tiger prey to mapping the distribution of rare plant species and the expansion of the mongoose range (Table 1). While site-level management at a single protected area is the most common use, ranger-based monitoring may also inform national and regional biodiversity indicators and policy (e.g., the program for Monitoring the Illegal Killing of Elephants (MIKE); CITES Secretariat 2019) and has the potential to contribute to monitoring progress toward global protected area effectiveness targets (Geldmann et al. 2021). As Table 1 illustrates, most case studies involved monitoring illegal activity, which reflects the general pattern that there are indeed only very few studies that report using ranger-collected data to address ecological (as opposed to threat) questions.

A key perceived benefit of ranger-based monitoring is that data can be collected while rangers are on their regular patrol routines and therefore is more cost-effective than conducting independent surveys. Furthermore, rangers are often present within PAs year-round, providing a continuous and sometimes immediate source of information, which can fill gaps between dedicated surveys. Also, rangers often live in the communities near their work and have excellent local ecological and social knowledge of these areas, so ranger-led monitoring may be more accurate than traditional monitoring conducted by external scientists and more likely to translate into locally supported and relevant conservation action (Danielsen et al. 2022). Monitoring can also motivate rangers by adding a new dimension to their work (Kuiper et al. 2021). In recent years, these monitoring opportunities have been further bolstered by the advent of technologies for collecting, analyzing, and reporting on ranger-collected data, from handheld GPS and rugged smartphone devices to software platforms, such as SMART (Spatial Monitoring and Reporting Tool), which is used in over 1200 sites in over 120 countries (Kavhu and Mpakairi 2021; SMART Partnership 2022).

2 | Identifying Lessons for Enhanced Ranger-Based Monitoring

Despite these benefits, ranger-based monitoring is seldom implemented in a way that reliably meets its intended goals. Based on our collective experience researching and implementing ranger-based monitoring, key barriers include: (1) a failure to develop clear monitoring goals and critically evaluate whether ranger-based monitoring is the right way to meet these goals (Kuiper, Ngweya, et al. 2023); (2) a failure to properly consider data reliability challenges (Harmsen et al. 2021); (3) a failure to consider the human dimensions of ranger-based monitoring (Wyatt, Singh, and Read 2023); and (4) a failure to integrate ranger-based monitoring with management decision-making (Dancer 2019; Wyatt, Singh, and Read 2023). Collecting data without a clear plan for how that data will feed into site management is perhaps the most common weakness of ranger-based monitoring, as is also true for monitoring more generally (Nichols and Williams 2006; Yoccoz, Nichols, and Boulinier 2001). Informed by these barriers, this article is intended to guide more appropriate and effective use of ranger-based monitoring by:

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TABLE 1 | Use cases of ranger-based monitoring for monitoring biodiversity and threats to inform protected area management.

Type of data collected	Where	Who used the data	How data were used	Reference
Illegal snaring and gorilla behavior	Protected areas in Rwanda, Uganda & Democratic Republic of Congo	Local managers and scientists at the International Gorilla Conservation Programme (IGCP)	To inform gorilla conservation	Gray and Kalpers (2005)
Elephant carcasses	90 sites across Africa and Asia (Monitoring the Illegal Killing of Elephants program: MIKE)	Global governments developing illegal wildlife trade policy	To track elephant poaching and inform global illegal wildlife trade policy	Kuiper, Altwegg, et al. (2023)
Egyptian mongoose observations	Iberian peninsula, Spain	Scientists, municipal authorities	To predict the expansion of mongoose range to predict human-wildlife conflict	Díaz-Ruiz et al. (2024)
Records of detected illegal activity while on patrol	Single protected area in Iran	Protected area authorities (protected area managers or other law enforcement agents)	To understand and address ungulate poaching via efficient patrol allocation	Ghoddousi et al. (2022)
	Single protected area in Rwanda		To understand trends in poaching activity and the effectiveness of management	Moore et al. (2018)
	Eight protected areas in India		To monitor and address threats to tigers to allow rapid law enforcement response	Stokes (2010)
Marine patrol records of illegal fishing	Single marine protected area in Cambodia (Koh Rong Archipelago Marine Fisheries Management Area)	Protected area managers	To understand illegal fishing and help inform protected area management including law enforcement strategies	Roig-Boixeda et al. (2018)
Patrol records of tigers, their prey, and threats to prey	Four protected areas in Russia	Wildlife authorities and scientists	To inform tiger conservation planning	Hötte et al. (2016)
Saiga antelope observations by vehicle patrol	Two protected areas in Russia	Local scientists and protected area managers	Measure effectiveness of *Saiga* conservation strategies	O'Neill (2008)
Compliance data from vessel patrols	Single marine protected area in Australia (Great Barrier Reef Marine Park)	Commonwealth and Queensland Field Management Program	To monitor and police illegal fishing	Weekers, Mazerolle, and Zahnow (2020)
Plant species presence and abundance	Northeast Spain	Scientists	Feed into a scientific monitoring program for rare and threatened plants	García et al. (2019)
Individual lions	Single protected area in Uganda	Scientists and protected area managers	Estimate lion abundance	Braczkowski et al. (2024)

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1. *Highlighting six key lessons* to help users better unlock the value of ranger-collected data for protected area management.
2. *Providing a decision framework* to help guide users through questions on whether and how to implement ranger-based monitoring to optimize its effectiveness in supporting management decisions in specific contexts.

The lessons and decision framework were developed from two parallel and overlapping processes:

1. *Our collective experience*: The vision for this article was developed via a symposium on ranger-based monitoring at the International Congress for Conservation Biology in December 2021. For this, we gathered as a network of researchers and practitioners from several countries, each working on different use cases of ranger-based monitoring, to present our individual work as a catalyst for a focused symposium discussion on leverage points to improve ranger-based monitoring for protected area management. The group included three of us who were undertaking our PhD dissertations on some aspect of ranger-based monitoring at the time. We then held several follow-up meetings and consulted with additional researchers and practitioners in the field to help translate our collective knowledge and experience into the lessons and decision framework that we present in this article.
2. *A scoping literature review*: In parallel, we started gathering a collection of academic and gray literature on ranger-based monitoring that we had encountered as part of our work (including our own published work). Our intention, however, was not to provide a comprehensive review of the literature but rather to produce a policy-facing piece that represents both our practical experience and the state of knowledge on the topic. To ensure we did not miss any key papers, we also conducted a rapid search of the Web of Science and Google Scholar databases using the search terms *"ranger" AND "monitoring" OR "law enforcement" AND "monitoring."*

3 | Six Lessons for More Effective Use of Ranger-Based Monitoring

Lesson 1: Set clear monitoring goals. Have a clear plan for how ranger-collected data will feed into decision-making.
Lesson 2: Avoid wishful thinking. Critically assess whether ranger-based monitoring can reliably meet your monitoring needs.
Lesson 3: Raw data have limitations. Beware of drawing conclusions from raw ranger-collected data.
Lesson 4: Consider human dimensions. Carefully consider the human and institutional dimensions of ranger-based monitoring (such as ranger welfare and manager buy-in).
Lesson 5: Adapt to your team's capacity. Adjust your monitoring goals according to the resources and capacity available to deliver effective ranger-based monitoring.
Lesson 6: Don't be distracted by technology. Use technologies like SMART as tools to achieve your broader monitoring and adaptive management goals, not as solutions in themselves.

3.1 | Lesson 1: Have a Clear Plan for How Ranger-Collected Data Will Feed Into Decision-Making

A recent stocktake of area-based conservation identified robust monitoring and evaluation as essential to future sustainability by addressing persistent gaps in protected management effectiveness (Gurney et al. 2023). Nichols and Williams (2006) argue that monitoring should not be viewed as a stand-alone activity but rather as one part of a larger process of conservation science or management. It is critically important, before implementing a ranger-based monitoring program to define, as specifically and clearly as possible, what the program aims to monitor and why. Will the data, for example, be used to measure and improve patrol coverage? To maximize detections and removal of snares targeting large mammals? To track the distribution of an endangered species? And/or to evaluate the effectiveness of a new payment for environmental services scheme?

We recommend that users integrate ranger-based monitoring within an adaptive management cycle to make the link between monitoring data and management decisions explicit (Gillson et al. 2019; Keith et al. 2011). Adaptive management involves clearly defining the management goals, identifying available strategies to meet these goals, implementing the preferred strategies with uncertain outcomes, learning from monitoring data about the effectiveness of these strategies, and then updating management strategies accordingly (Walters and Holling 1990; Figure 1). A recent comprehensive review of SMART implementation across 49 protected and conserved areas in 14 countries identified a lack of clear planning and active involvement of management as the weakest elements of the SMART adaptive management cycle (Wyatt, Singh, and Read 2023).

Clarifying how ranger-collected data will translate into specific management actions within an adaptive management cycle is difficult but essential. One useful strategy is to use *state-dependent triggers* for management and decision-making, whereby a monitored change in the "state" variable of interest (e.g., an increase in the number of illegal hunting snares detected) triggers a specific management action such as greater benefit sharing from the protected area with local people (see Cook et al. 2016 and McDonald-Madden et al. 2010 for more examples).

3.2 | Lesson 2: Critically Assess Whether Ranger-Based Monitoring Can Reliably Meet Your Monitoring Needs (Avoid Wishful Thinking)

A common mistake is to view ranger-based monitoring as a silver bullet that meets most monitoring needs without the need to invest in tailored monitoring programs. The reality, however, is that low ranger numbers, limited patrol coverage, and infrequent or imperfect detection of illegal activities or species of interest mean that ranger-collected data may not be reliable or statistically powerful enough to meet the specific monitoring need (Jones et al. 2017). For example, ranger-collected data on elephant carcasses in a Zimbabwean protected area had generally low statistical power to detect small to medium changes in illegal hunting rates from year to year (Kuiper 2020). Low patrol effort and the infrequent encountering of carcasses meant it

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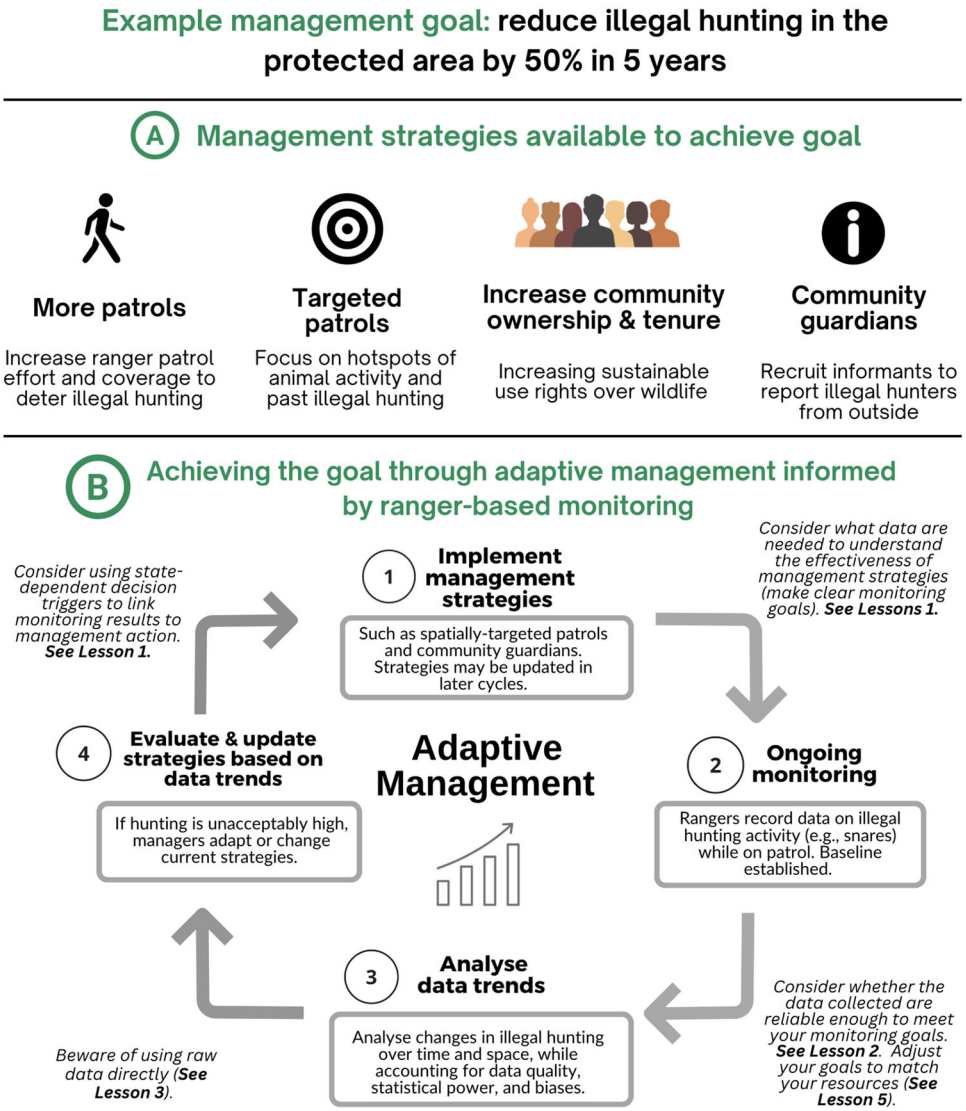

FIGURE 1 | A simplified example of integrating ranger-based monitoring into an adaptive management cycle to reduce illegal hunting for wild meat in a protected area.

was difficult to be confident that illegal hunting was increasing or decreasing based on ranger-collected data alone. Similarly, across eight tiger reserves in India, ranger-collected data provided a rapid source of information on illegal activity to which law enforcement could respond, but the data were not reliable enough to monitor longer-term trends in the abundance of tigers and their prey (Stokes 2010).

When issues of reliability are properly understood and can be accounted for, however, ranger-based monitoring can be a powerful tool. It is particularly well suited to guiding the spatial deployment of patrols to optimize the detection and deterrence of illegal activities on limited patrol budgets. Critchlow et al. (2016) demonstrated how detections of illegal hunting in a Ugandan protected area could double when patrols were deployed into hotspot areas, based on careful analyses of ranger-collected data on past incidents that accounted for biased patrol efforts. Similarly, Xu et al. (2020) used machine learning to identify high-risk poaching areas based on ranger-based monitoring data and designed optimal patrol strategies that were shown to efficiently increase snare detection and removal in field tests in Uganda and Cambodia.

Simpler monitoring needs, such as establishing the presence or absence of a particular threat or species, building a species inventory, or quickly identifying new threats or short-term upticks in illegal activity, are more achievable with limited patrol coverage (Moreto et al. 2014). Confidently estimating the abundance of a particular species or capturing relatively small changes in rates of illegal activity over time may fall into the "wishful thinking" category—requiring unrealistically high patrol effort and coverage. In these cases, an independent monitoring method, such as camera trapping, aerial surveys, or line transects, may be more appropriate. Of course, protected area budgets rarely allow costly independent surveys, but it is critical to be realistic about the limitations of ranger-collected data and adjust monitoring goals accordingly.

When limitations around reliability are properly accounted for, however, ranger-collected data may be well-suited to addressing

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ecological questions, such as estimating species distribution within a protected area or assessing local extinction and colonization rates (Moore et al. 2018). Yet the focus of ranger patrols on law enforcement has meant that the data they collect are underutilized for addressing ecological questions, and we encourage greater consideration of opportunities in this area. Furthermore, ranger-based monitoring and independent surveys can complement one another. Rangers are present year-round, often monitored daily, and can cover much wider areas than focused ecological surveys. Rangers may thus record cryptic species that surveys miss or provide "between survey" estimates of change points in species presence or abundance, particularly if dedicated surveys are infrequent.

3.3 | Lesson 3: Beware of Drawing Conclusions From Raw Ranger-Collected Data

Because gathering representative monitoring data is not their priority, rangers do not generally patrol evenly across space and time, with certain areas and time periods patrolled more heavily than others. Consequently, changes in detections of illegal activity over time may simply reflect operational changes that aim to increase the probability of encountering illegal activity or the response of poachers to patrolling (Keane et al. 2011; Harmsen et al. 2021), whilst "poaching hotspots" may reflect areas more frequently patrolled by rangers (Kuiper et al. 2020). Before drawing conclusions from raw ranger-collected data, therefore, it is essential to understand and account for these biases.

Using SMART data from 21 sites across Africa and Asia, Dancer (2019) found that spatial coverage of protected areas by ranger patrols was very low across nearly all sites. Recent global reviews across thousands of protected areas indicate that ranger numbers are often well below recommended levels for each context, which may mean that reliably detecting species or threat trends may be unrealistic at many sites (Appleton et al. 2022; Farhadinia et al. 2023). Insufficient resources, imperfect detection, inconsistent data logging both within and across patrol teams, and preferential recording of certain species or threats may further bias data (Dobson et al. 2019; Ibbett et al. 2020).

Dobson et al. (2020) provide a useful strategy to mitigate bias in messy data. The first step is to understand the observation process, assess how bias is introduced to data, and, where feasible, minimize this bias (e.g., by promoting more exploratory or randomized patrol coverage outside known hotspots of illegal activity). However, such changes may come at a short-term cost to enforcement effectiveness. Where patrol effort and coverage cannot be changed, those implementing ranger-based monitoring may consider whether statistical models can adequately account for uneven observer effort and imperfect detection. Critchlow et al. (2015) and Moore et al. (2018), for example, used statistical methods to estimate robust spatial patterns of illegal activity from ranger-collected data by explicitly incorporating the effect of a reduced probability of detection in areas (protected area grid cells) where patrols were less frequent. In a similar vein, Dobson et al. (2019) developed a simple metric of deterrence, which accounts for confounding temporal effects and autocorrelation in traditional patrol data metrics. Application of this new metric found evidence consistent with the deterrence of illegal activities by ranger patrols (Dancer et al. 2022).

These methods rely heavily on (1) consistent and reliable records of patrol effort and coverage and (2) technical capacity to conduct the analyses. Users should carefully assess whether this is feasible in their context.

3.4 | Lesson 4: Carefully Consider the Human Dimensions of Ranger-Based Monitoring (Such as Ranger Welfare and Manager Buy-In)

Ranger-based monitoring is often implemented without careful consideration of the welfare and complex motivations and priorities of the people collecting (rangers) and using (e.g., protected area managers) the data. Well-meaning organizations may donate smartphones to collect data, provide computers and software to analyze data, and deliver training to build skills. But without the buy-in of rangers and protected area managers, these efforts are unlikely to succeed and may even contribute to decreased motivation of rangers.

For example, whilst handheld devices can enable rangers to capture more data, they may also be used by supervisors to assess rangers' performance and compliance with patrol directives and to encourage rangers to conduct longer patrols and target less frequently patrolled areas. Rangers can respond negatively to such surveillance (Joanny 2020; Simali and Sandbrook 2021). Moreover, this negativity may be compounded where working conditions are poor, basic equipment is lacking, and ranger welfare benefits like access to health care and insurance are limited (Belecky, Singh, and Moreto 2019). Conversely, we have also found that rangers may enjoy monitoring as a new dimension to their work, feel pride in monitoring results as a demonstration of a job well done, and appreciate the incentives tied to performance monitoring, alongside the opportunity for friendly competition with other teams (Dancer 2019; Kuiper et al. 2021).

Furthermore, protected area managers may not take ownership of ranger-based monitoring and analysis if it does not align with their priorities. Interviews with managers in Zimbabwe, for example, showed that they did not see how adaptive management based on ranger-collected data would improve their work and felt that the costs of data management and analysis outweighed the benefits (Kuiper, Ngwenya, et al. 2023). Ranger-collected data on the state of illegal activities may also influence national budget allocations or feed into performance reviews for protected area managers and affect their career progression (Joanny 2020). There is a risk that government wildlife departments may resist data collection and reporting for fear that their management may come under scrutiny. The institutional culture of the implementing organization, such as the dynamics of hierarchy and authority and incentives accompanying data collection, may also affect how managers and rangers perceive ranger-based monitoring and associated technologies like SMART (Kavhu and Mpakairi 2021).

In summary, before designing and implementing a new ranger-based monitoring program, users should carefully and sensitively seek and consider the opinions and values of the rangers and managers that are the engine behind day-to-day ranger-

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based monitoring and adaptive management. Furthermore, users should ensure that the program integrates well with the broader organizational and institutional setting within which it is implemented.

3.5 | Lesson 5: Adjust Your Monitoring Goals According to the Resources and Capacity Available to Deliver Effective Ranger-Based Monitoring

Effective ranger-based monitoring requires resources and capacity that may not be available locally (Moore, Udell, et al. 2021). Ensuring adequate patrol coverage requires enough boots on the ground, infrastructure (ranger bases, roads, electricity), and significant equipment (vehicles and patrol essentials). Sustainably collecting, managing, and analyzing data often demands extensive technology (handheld devices, computers, large monitors, and software), sophisticated in-house technical capacity, and extensive and regular training. Securing sensitive ranger-collected data (on the locations of high-value species and patrol schedules, for example) requires additional resources and capacity to encrypt hard drives and servers. The key lesson here is to be aware of what can and cannot be implemented within current resources and capacity and adjust expectations accordingly.

As emphasized under Lesson 2, ranger-based monitoring may not be the best tool to meet all monitoring needs, especially if ranger numbers and patrol coverage are constrained by limited resources. Even on the most basic budgets, however, certain types of ranger-based monitoring can be effective (such as ongoing surveillance of the presence or absence of a particular threat that does not require sophisticated analysis). The costs and benefits of ranger-based monitoring may change, so over time, users can develop a more focused monitoring program to meet specific goals as budgets allow while being careful to work through the other lessons that we suggest here. Users should also be careful to assess and ensure the availability of capacity and resources over the long term, beyond the initial establishment of an effective ranger-based monitoring program.

Finally, Value of Information (VoI) methods may be used to assess whether monitoring generates enough additional information to improve management outcomes and justify these long-term resource and capacity costs (Canessa et al. 2015). Those considering the implementation of ranger-based monitoring for a specific purpose can use VoI to assess whether the uncertainty in the outcome of management decisions is high enough to justify the collection of more data to reduce this uncertainty. Users can choose to apply the array of VoI methods available (which can be quite technical) or simply use the concepts behind these methods (Bolam et al. 2019).

3.6 | Lesson 6: Use Technologies Like SMART as Tools to Achieve Your Monitoring and Adaptive Management Goals, Not as Solutions in Themselves

The spread of data collection, management, and analysis technologies like SMART and EarthRanger (Earth Ranger 2023) to new sites globally is an encouraging trend that can bolster the effectiveness of ranger-based monitoring for protected area management. There is a risk, however, that users see the technology itself as the solution, rather than as a tool to achieve wider monitoring and management goals. As Lessons 1–5 above highlight, effective ranger-based monitoring involves a great deal more than implementing new technologies for collecting and managing data. As the literature on technology adoption across diverse sectors attests, focusing too much on the technology itself rather than the problems it addresses can lead to failure (Oliveira and Martins 2011).

Users should neither start with getting the technology to work smoothly nor stop when this has been achieved. Users should instead start by carefully assessing their management goals and monitoring needs and then assess whether and how ranger-based monitoring can help meet these needs (Lessons 1 and 2). Only then should users consider how technologies can help facilitate this process, including how careful data collection and analysis can help measure and account for biases in the data (Lesson 3). One way to ensure SMART is better integrated with adaptive management is to use it as a tool for monitoring protected area management effectiveness in combination with tools like the Management Effectiveness Tracking Tool (METT) (Coad et al. 2015). Users should also consider how the motivations and priorities of those tasked with using the technologies may affect success (Lesson 4). In a Zimbabwean protected area, for example, there was initial resistance to SMART by rangers because they felt it was designed to police their activities while also requiring extra effort in the field (Kavhu and Mpakairi 2021).

In summary, SMART, EarthRanger, and other technologies are valuable tools for collecting and managing ranger-collected data, but in isolation, they are not a silver bullet, and they need to be integrated with strategies for analyzing and effectively responding to these data. The lesson here is that users should see these technologies not as ends in themselves but as means to the greater end of focused and reliable data collection, management, and analysis to inform decision-making.

4 | A Framework for Deciding How to Implement Ranger-Based Monitoring

Building on these six lessons, we present a framework to help guide decisions about how to implement ranger-based monitoring to optimize its effectiveness and to support adaptive management (Figure 2). We present this framework in the form of a series of questions to ask both before and while implementing ranger-based monitoring. While some questions are pertinent to monitoring in general (see McDonald-Madden et al. 2010 for a useful and complementary decision framework), others are specific to ranger-based monitoring. Adopting ranger-based monitoring is not a one-time decision, and users are encouraged to use this framework iteratively as management goals and monitoring needs change.

5 | Conclusions

Overall, our analysis suggests that users can best unlock the value of ranger-based monitoring when there is a clear monitoring need that ranger-collected data can reliably address, there are

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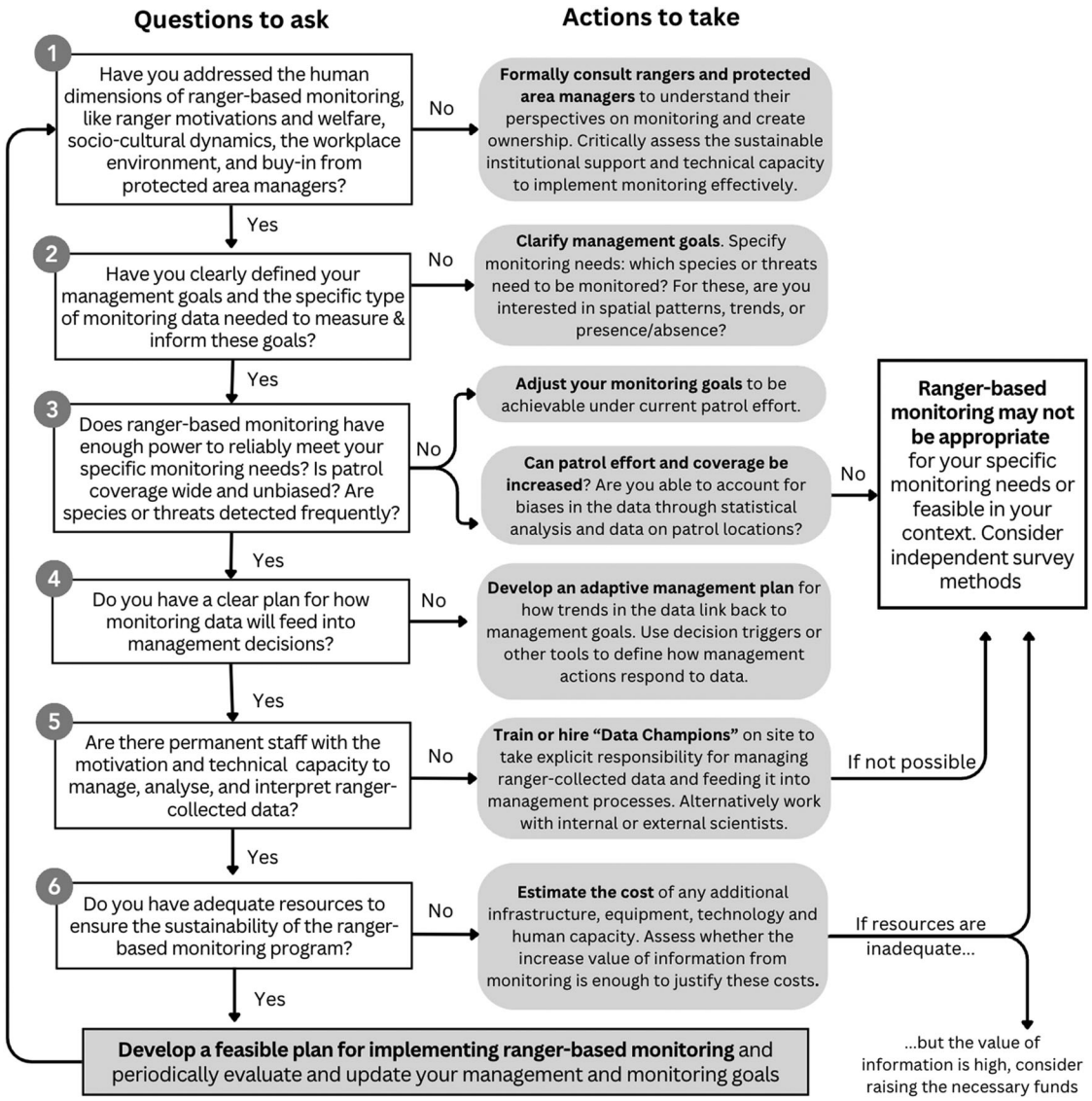

FIGURE 2 | A decision framework to help guide decisions about whether and how to invest in ranger-based monitoring. This is targeted primarily at higher-level decision-makers in government, private or nongovernment organizations who make strategic and budgetary decisions around monitoring and management of protected areas. The six overarching questions that should be asked by users before implementing ranger-based monitoring are numbered.

capacity and resources to analyze and interpret data, there is a clear plan for how data will inform management decisions, and there has been careful consideration of the costs and trade-offs involved. Improving the quality of ranger-collected data (e.g., through training and empowering rangers, reducing collection biases as part of adaptive management strategies, and through the judicious use of technology) is paramount to unlocking the usefulness of these data. A key leverage point is supporting permanent staff with the capacity to plan ranger-based monitoring to meet management goals (Lesson 1), as well as take responsibility for managing and analyzing the data to feed into decisions (see the "Data champions" role in Figure 2 question 5). Indeed, a recent comprehensive review of lessons learned from SMART and adaptive management across 49 sites in Africa and Asia identified the need to develop competencies at all levels of adaptive management, from planning and collection to analysis and evaluation (Wyatt, Singh, and Read 2023).

While we emphasize the challenges associated with implementing an effective ranger-based monitoring program, the lessons show how these challenges can be overcome. The potential conservation and management value that can be unlocked from ranger-collected data is enormous. We foresee such data playing an increasing role in filling the large gaps in our knowledge and certainty of trends in biodiversity globally (Johnson et al. 2024). This potential is further enhanced when one considers how intimately rangers understand the biodiversity in the areas they work in and how widely and frequently they patrol these areas. We encourage a culture of harnessing these insights to help foster an inclusive environment in which rangers feel that their insights are valued for what they are.

More broadly, we urge the government and other conservation agencies to acknowledge more clearly and invest more generously in biodiversity monitoring programs, understanding their critical

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importance for achieving effective conservation, despite the costs involved (Gillson et al. 2019).

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The authors have nothing to report.

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