PARKS

The International Journal of Protected Areas and Conservation



Issue 32.2 November 2026

IUCN WCPA WORLD COMMISSION ON PROTECTED AREAS

IUCN PROTECTED AREA DEFINITION, MANAGEMENT CATEGORIES AND GOVERNANCE TYPES

IUCN defines a protected area as:
A clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values.

The definition is expanded by six management categories (one with a sub-division), summarized below.

Ia Strict nature reserve: Strictly protected for biodiversity and also possibly geological/ geomorphological features, where human visitation, use and impacts are controlled and limited to ensure protection of the conservation values.

Ib Wilderness area: Usually large unmodified or slightly modified areas, retaining their natural character and influence, without permanent or significant human habitation, protected and managed to preserve their natural condition.

II National park: Large natural or near-natural areas protecting large-scale ecological processes with characteristic species and ecosystems, which also have environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities.

III Natural monument or feature: Areas set aside to protect a specific natural monument, which can be a landform, sea mount, marine cavern, geological feature such as a cave, or a living feature such as an ancient grove.

IV Habitat/species management area: Areas to protect particular species or habitats, where management reflects this priority. Many will need regular, active interventions to meet the needs of particular species or habitats, but this is not a requirement of the category.

V Protected landscape or seascape: Where the interaction of people and nature over time has produced a distinct character with significant ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values.

VI Protected areas with sustainable use of natural resources: Areas which conserve ecosystems, together with associated cultural values and traditional natural resource management systems. Generally large, mainly in a natural condition, with a proportion under sustainable natural resource management and where low-level non- industrial natural resource use compatible with nature conservation is seen as one of the main aims.

The category should be based around the primary management objective(s), which should apply to at least three-quarters of the protected area – the 75 per cent rule.

The management categories are applied with a typology of governance types – a description of who holds authority and responsibility for the protected area.

IUCN defines four governance types.

Governance by government: Federal or national ministry/agency in charge; sub-national ministry/agency in charge; government-delegated management (e.g. to NGO)

Shared governance: Collaborative management (various degrees of influence); joint management (pluralist management board); transboundary management (various levels across international borders)

Private governance: By individual owner; by non-profit organisations (NGOs, universities, cooperatives); by for- profit organsations (individuals or corporate)

Governance by Indigenous Peoples and local communities: Indigenous Peoples' conserved areas and territories; community conserved areas – declared and run by local communities.

For more information on the IUCN definition, categories and governance type see the 2008 *Guidelines for applying protected area management categories* **which can be downloaded at: www.iucn.org/pa_categories**

IUCN WCPA'S BEST PRACTICE PROTECTED AREA GUIDELINES SERIES

IUCN-WCPA's Best Practice Protected Area Guidelines are the world's authoritative resource for protected area managers. Involving collaboration among specialist practitioners dedicated to supporting better implementation in the field, they distil learning and advice drawn from across IUCN. Applied in the field, they are building institutional and individual capacity to manage protected area systems effectively, equitably and sustainably, and to cope with the myriad of challenges faced in practice. They also assist national governments, protected area agencies, nongovernmental organisations, communities and private sector partners to meet their commitments and goals, and especially the Convention on Biological Diversity's Programme of Work on Protected Areas.

A full set of guidelines is available at: www.iucn.org/pa_guidelines
Complementary resources are available at: www.cbd.int/protected/tools/
Contribute to developing capacity for a Protected Planet at: www.protectedplanet.net/

PARKS is published electronically twice a year by IUCN's World Commission on Protected Areas.
For more information see: www.parksjournal.com

PARKS is published to strengthen international collaboration in protected and conserved areas development and management by:

- exchanging information on practical management issues, especially learning from case studies of applied ideas;
- serving as a global forum for discussing new and emerging issues that relate to protected and conserved areas;
- promoting understanding of the values and benefits derived from protected and conserved areas to communities, visitors, business and others;
- ensuring that protected areas fulfil their primary role in nature conservation while addressing critical issues such as ecologically sustainable development, social justice and climate change adaptation and mitigation;
- changing and improving protected and conserved areas support and behaviour through use of information provided in the journal; and
- promoting IUCN's work on protected and conserved areas.

MANAGING EDITOR

Dr. Margaret F. Kinnaird, Kenya; Conservation biologist; IUCN World Commission on Protected Areas

ADVISORY BOARD MEMBERS

Dr Tom Brooks, Switzerland: Chief Scientist IUCN

Dr Madhu Rao, Singapore: Chair, IUCN World Commission on Protected Areas

Nigel Dudley, UK: Partner, Equilibrium Research and IUCN World Commission on Protected Areas and Commission on Environmental, Economic and Social Policy

Dr Kent Redford, USA: principal at Archipelago Consulting

Sue Stolton, UK: Partner, Equilibrium Research and IUCN World Commission on Protected Areas and Commission on Environmental, Economic and Social Policy

Professor Marc Hockings, Australia: Emeritus Professor, University of Queensland; IUCN World Commission on Protected Areas; Fellow, UNEP-World Conservation Monitoring Centre

EDITORIAL BOARD MEMBERS

Dr. Paulina G. Karim, Taiwan: National Dong Hwa University

Ms. Lucia Ruiz Bustos, USA: Director of Conservation Areas, WWF-US

Dr. Yue Cao, China: Associate Professor / Special Research Fellow / PhD Supervisor,

Department of Landscape Architecture, School of Architecture / Institute for National Parks, Tsinghua University

Dr. Dipankar Ghose, India: Senior Director - Biodiversity Conservation, WWF-India

Dr. Daniel Gorczynski, USA: Florida Atlantic University

Dr. Sreekar Rachakonda, Australia: Postdoctoral Fellow, School of the Environment, The University of Queensland

Dr. David Wilkie, USA: Senior Conservation Fellow, Wildlife Conservation Society

Dr. Emiel de Lange, Cambodia: Social Research & Conservation Partnerships Advisor, Wildlife Conservation Society.

Thanks to: Miller Design UK for design and layout, Caroline Snow for proofreading. And to all the reviewers who so diligently helped in the production of this issue.

Spanish and French translations of abstracts in this issue were translated with www.DeepL.com/ Translator.

The views expressed in this publication do not necessarily reflect those of the IUCN or WCPA.



The designation of geographical entities in this journal, and the presentation of the material, do not imply the expression of any opinion whatsoever on the part of IUCN concerning the legal status of any country, territory, or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

The views expressed in this publication do not necessarily reflect those of IUCN.

IUCN does not take any responsibility for errors or omissions occurring in the translations in this document whose original version is in English.

Published by:	IUCN, Gland, Switzerland
Copyright:	© 2026 IUCN, International Union for Conservation of Nature and Natural Resources
	Reproduction of this publication for educational or other non-commercial purposes is authorized without prior written permission from the copyright holder provided the source is fully acknowledged.
	Reproduction of this publication for resale or other commercial purposes is prohibited without prior written permission of the copyright holder.
Citation:	IUCN WCPA (2026). PARKS. *The International Journal of Protected Areas and Conservation*, Volume 32.2 Gland, Switzerland: IUCN.
ISSN:	ISSN 2411-2119 (Online)
DOI:	https://doi.org/10.2305/RPUP5642
Cover photo:	Maputo National Park, Mozambique © Yves Olatoundji
Contents photo:	© Margaret Kinnaird
Layout by:	Miller Design, UK
Available from:	IUCN (International Union for Conservation of Nature) IUCN Centre for Conservation Action Rue Mauverney 28 1196 Gland Switzerland Tel +41 22 999 0000 Fax +41 22 999 0002 parksjournal.com iucn.org/theme/protected-areas/publications/parks-journal



PARKS: THE INTERNATIONAL JOURNAL OF PROTECTED AREAS AND CONSERVATION

Edited by Yue Cao, Jonas Geldmann, Margaret Kinnaird, David Wilkie

editor@parksjournal.com

CONTENTS *hyperlinked for easier navigation*

Editorial: Towards IMPAC6 and WPCAC **6**
Sara Magdalena Pineda Torres and Yves Olatoundji

From participation to impact: reviewing the transformative potential of citizen science in Brazilian protected areas **10**
Gabrielle Abreu Nunes, Natalia Pirani Guilhard Lopes and Teresa Cristina Magro-Lindenkamp

Fragmented data, fragmented oceans: How reporting discrepancies undermine Canada's marine conservation commitments **24**
Leila Vaziri Zanjani, Christine Grossutti and Monica Mulrennan

Collaborative governance drives Banteng habitat reclamation in Thailand's world heritage buffer zone **35**
Nantachai Pongpattananurak, Nuttapong Kongraphan, Natthanicha Chookaew and Sangsan Phumsathan

Animation-based CEPA for collaborative management in Hoang Lien National Park, Vietnam **46**
Ho Ngoc Son and Nguyen Dang Cuong

Status, pressures and management priorities in Upemba National Park, DR Congo **57**
Manuel Weber

Effectiveness of conservation measures for birds in 100 European Union Special Protection Areas **68**
Concha Olmeda, Viera Šefferová Stanova, Kerstin Sundseth, Lucia Millán Agudo, Marita Arvela, Barbara Calaciura, Alvaro García Herrero, Otars Opermanis, Pawel Pawlaczyk, Claire Pirat, Mihai Proca, Jasminka Radovic, Angela Ruiz, David Stroud and Marc Thauront

Jerusalem wilderness and dead sea: conservation significance of two newly designated protected areas in Palestine **81**
Sara Khair, Nina Lütkehermöller, Conrad Schittko, Johann Gedeon, Banan Al-Sheikh, Saed Shomaly and Mazin B. Qumsiyeh

Book Reviews **93**

Meanings that matter: A review of Jon Kohl's interpretive theme writer's field guide
Kelley Anderson

Drawing the map that Florida (and the world) followed: A Review of Regional Landscape Conservation Planning: Wildlife, Connectivity, and the Florida Model 95
Eric Dinerstein



EDITORIAL: TOWARDS IMPAC6 AND WPCAC

Sara Magdalena Pineda Torres & Yves Olatoundji

Co-chairs of the IUCN WCPA's Early Career Professional group

Sara Pineda is a biologist and National Geographic Explorer working at the intersection of biodiversity conservation and social equity, with expertise in participatory and gender-inclusive approaches. She currently serves as the WCPA Representative on the IUCN Youth Advisory Committee.
biol.sarapineda@gmail.com

Yves Olatoundji is a nature photographer and conservationist. His works focus on wildlife and area-based conservation. He is currently serving as Co-Chair for the IUCN WCPA Early Career Professional group.
wcpa.yves.olatoundji@gmail.com

Saharan dust travels across the Atlantic and settles over the Amazon, carrying minerals that will nourish its soil. Tiny wasps slip inside figs through a narrow opening into a chamber lined with hundreds of flowers ready for pollination. Beneath the forest floor, mycorrhizal networks connect neighbouring trees, quietly carrying nutrients from one root to another. Across scales, life and its processes are threaded through such relations. A world shaped by movement, exchange and interdependence.

These dynamics do not end at the boundaries we draw between human societies and nature, boundaries that exist more as habits of thought than as lines in the world. We, too, are also embedded in complex dynamics of socio-environmental transformation**.** Because our very existence and futures are interwoven with these systems, humanity has built architectures of cooperation to match them. It is within this broader web that the International Union for Conservation of Nature (IUCN), shaped by its Members, Council, Secretariat, committees and seven Commissions, also operates. Among these, the World Commission on Protected Areas (WCPA) is now preparing for two key events: the sixth International Marine Protected Areas Congress (IMPAC6) and the World Protected and Conserved Areas Congress (WPCAC). Soon, thousands of people will converge from across continents and disciplines: organisers setting things in motion, speakers taking the floor, researchers exchanging ideas, practitioners comparing experiences, conversations spilling into new ones. Different backgrounds, languages, and ways of knowing will meet in the same space, pulled together by a common purpose: strengthening efforts to conserve nature through protected and conserved areas (PCAs).

IMPAC6 and WPCAC in 2027: Coordinated action shaping conservation

Throughout the history of nature conservation, global commitments and agreements have proven capable of unleashing fresh waves of bold actions among stakeholders worldwide. These decisions are often the result of productive discussions at international gatherings, setting change in motion across governance, investments and technologies. This momentum extends to the upcoming IMPAC6 and the WPCAC happening next year in Senegal and Panama, respectively. The year 2027 will therefore mark a major turning point, this time for world marine and terrestrial PCAs. It will ultimately shape our common fate *vis-à-vis* the achievement of Target 3 of the Kunming–Montreal Global Biodiversity Framework (KM-GBF), which calls on the global community to effectively protect 30 per cent of land and oceans by 2030.

The IMPAC6 and WPCAC represent unique opportunities for the global area-based conservation community to come together. With IMPAC6 convening only every four years and WPCAC every 10 years, ensuring their success is crucial. That success will be measured by how we refine our priorities, reimagine better collaboration across actors and countries, innovate, and design a strong yet flexible action plan capable of carrying us beyond the KM-GBF Target 3. In addition, we will need a strong focus on societal issues, including those related to socio-economic and socio-political dynamics amidst the current context of shifting global powers and national priorities.

Against this backdrop, IMPAC6 will provide a global forum for the marine conservation community to share knowledge, experience and practice around

https://doi.org/10.2305/DIXZ4615

marine protected areas (MPAs). Its sixth gathering will convene more than 3,000 participants from over 50 countries across five days with more than 100 sessions and workshops. Discussions will centre on four strategic priorities: inclusive, fair and appropriate governance; production, enhancement and sharing of useful knowledge to strengthen MPAs' effectiveness and resilience; promotion of representative MPA networks connected all the way to the open sea; and, sustainable financing linked to a fair and regenerative blue economy.

Conversely, WPCAC will bring together governments, the private sector, civil society, Indigenous Peoples and local communities to advance effective, equitable and enduring area-based conservation. Over seven days, with more than 600 sessions and 6,000 expected participants, the Congress will focus on three major themes: building resilient societies and economies with nature at their core; scaling up effective, equitable and sustainable conservation; and strengthening the rights, capacity and resources of those who steward nature. All of this will culminate in a High-Level Outcome Statement, the Panama Action Plan, recommendations and commitments – building on WPCAC's longstanding contribution to global biodiversity policy and practice. This trajectory is rooted in previous congresses, which have helped shape major milestones such as the Convention on Biological Diversity's Programme of Work on Protected Areas in 2004; more than 60 commitments to expand PCA systems in 2014; the IUCN Green List of PCAs; and PANORAMA: Solutions for a Healthy Planet.

The WCPA is playing a major role to ensure better preparedness and successful outcomes for the global conservation community, bridging strategic coordination with the development of high-impact content. To this end, the Commission is currently working to produce technical knowledge products across a wide variety of topics relevant for both congresses. These include two special guest edited issues of PARKS for IMPAC6 and WPCAC; a stocktaking publication on the state of play on PCAs since the Promise of Sydney; and a series of white papers that explore emerging and debated issues in PCAs, helping stimulate critical thinking and discussion ranging from contested approaches such as fortress conservation and rewilding to emerging issues like artificial intelligence. In addition, WCPA as a key player in the organisation of these congresses is ensuring that actors, particularly early-career professionals (ECPs) and Indigenous Peoples, are engaged, involved and motivated at every stage.

Our contributions and hopes as Early-Career Professionals

For those of us beginning our careers in conservation, these congresses provide the chance to enter the conversation at the moment when our career is still being formed, and when the future of PCAs is, in its own way, still being forged. We are joining the conservation community at a time when many of the questions we face are changing faster than the answers we have inherited. These congresses offer us the opportunity to step into these evolving conversations: to learn from those who have shaped the field, bring our own questions and experiences to the table, and take part in defining the direction of PCAs over the next decades. There are disciplines to cross, assumptions to question, expertise to acquire, and collaborations to begin – an opportunity to solidify our presence in a field shaped by decades of knowledge and experience.

Within this shifting landscape, ECPs are eager to contribute meaningfully. At IMPAC6 and WPCAC, ECPs are prepared to actively engage in the decisions that will determine how area-based conservation actions are delivered in future by: 1) participating in crucial discussions which will inform the future direction of area-based conservation to ensure the global community achieves KM-GBMF Target 3 and beyond; 2) fostering a global and collaborative space that supports youth in strengthening their knowledge, leadership and expertise related to PCAs, beyond the traditional conservation approaches; 3) bringing together innovative ideas and perspectives from various sectors and cultures around the pressing and emerging issues facing PCAs; 4) advocating for a more inclusive area-based conservation, not just as a narrative but also and mostly through meaningful actions.

This is where the value of generations meeting one another becomes apparent by carrying knowledge forward: to test it against new circumstances, revise it where necessary, and let it acquire new meanings in the hands of diverse people whose stories, backgrounds and ways of seeing may be different from those already present at the table. Institutions and the conservation field as a whole, like ecosystems, are stronger when they can accommodate diversity. Bringing together diverse actors and perspectives can strengthen both the social and ecological success of PCAs. In that sense, diversity becomes a source of resilience and a condition for adaptation.

The need for diversity and inclusivity in area-based conservation is no longer optional. More than just a box to tick, it should be at the centre of discussions aiming to deeply understand the social dynamics that influence



Maputo National Park, Mozambique © Yves Olatoundji

successful PCA conservation. If we want to see positive, consented and lasting changes, we ought to make them necessary components of any area-based conservation strategy or design. The congresses offer an opportunity to do so, provided we initiate and hold such discussions with the right stakeholders. This means asking difficult questions: Who decides what must be protected and why? Who has the final say in decisions concerning PCAs? Are the management documents and subsequent communication files written in a language that is accessible to the communities or landowners? What are the underlying power dynamics? These are some of the questions to address as we approach these congresses, if we hope to ensure the success of PCA conservation over the next decade. Moving beyond traditional stakeholder engagement to foster genuine stewardship is now an absolute necessity. Because recent years have revealed that substantive and impactful conservation outcomes in PCAs have stalled due to weak and poorly targeted stakeholders' engagement (Fidler et al., 2022; Maccioni et al., 2024; Worboys et al., 2015).

The two congresses should not only focus on onsite engagement. We expect them to set the stage for the global PCA community and all relevant actors to rethink conservation approaches that are no longer effective. For instance, we need to collectively move beyond merely testing new financing mechanisms and instead leverage these gatherings to strategise their implementation at scale while identifying and addressing structural barriers. This, we hope, will help create measurable, tailored solutions ready for implementation. Equally important is unifying management tools: centralising tech-driven data for real-world decision-making, while grounding this technical alignment in cultural and linguistic accessibility so that frameworks truly resonate with the local communities stewarding these spaces.

The challenges of the present are not without precedent: those before us also lived through profound social change, but the conditions through which these challenges are experienced are shifting. Technology accelerates the pace of change, systems have become more tightly entangled, and the consequences of decisions made in one place can arrive with surprising speed somewhere else. Every generation inherits a world it did not make, along with the institutions, habits and assumptions that came with it. A world already in motion. Yet each generation also participates in remaking it. What we receive can be questioned, adapted and carried forward in different ways. For ECPs, these congresses are an opportunity to influence an evolving conversation, learn from those who have shaped conservation, and contribute new perspectives to the future of PCAs. IMPAC6 and WPCAC offer the opportunity to rethink area-based conservation in a

way that is inclusive, evidence-based, and culturally grounded, in order to advance, strengthen and shape the future of marine and terrestrial PCAs.

The scale of the task undertaken by the IUCN, the WCPA and the many entities involved in delivering both events is remarkable. It is an opportunity to bring people together from opposite corners of the world, with different experiences, knowledge systems and worldviews. These spaces as global architectures of cooperation also return us to a connection that is profoundly human: to listen, to engage in dialogue, and to find common ground – without assuming that every way of inhabiting and understanding the world can be translated into a single logic. Through these exchanges, current narratives and practices can be questioned and adapted, helping to shape sound policies, build partnerships, mobilise resources, and promote the effective governance needed to turn conversations, commitments and agreements into meaningful actions. Just as particles travel across oceans, insects co-evolve with plants, and fungi create complex webs to exchange nutrients with other species, conservation advances through the circulation of knowledge, experiences and relationships across cultures and generations.

References

Fidler, R. Y., Ahmadia, G. N., Amkieltiela, Awaludinnoer, Cox, C., Estradivari, Glew, L., Handayani, C., Mahajan, S. L., Harborne, A. R. (2022). Participation, not penalties: Community involvement and equitable governance contribute to more effective multiuse protected areas. *Science Advances*, *8*(18). https://doi.org/10.1126/sciadv.abl8929

Maccioni, S., d'Angella, F., De Carlo, M., & Sfogliarini, B. (2024). Stakeholder engagement and triggers for sustainable development in complex fragile ecosystems: Evidence from Alpine Trentino Region. *Sustainability*, 16(22), 9879. https://doi.org/10.3390/su16229879

G. L. Worboys, M. Lockwood, A. Kothari, S. Feary and I. Pulsford (eds). (2015). *Protected Area Governance and Managemen*t. ANU Press, Canberra. http://doi.org/10.22459/PAGM.04.2015



FROM PARTICIPATION TO IMPACT: REVIEWING THE TRANSFORMATIVE POTENTIAL OF CITIZEN SCIENCE IN BRAZILIAN PROTECTED AREAS

Gabrielle Abreu Nunes[12] *, Natalia Pirani Ghilardi-Lopes[3] and Teresa Cristina Magro-Lindenkamp[1]

*Corresponding author: gabinunes.bio@gmail.com

[1] University of Sao Paulo, Forest Department, ESALQ, Piracicaba, Brazil

[2] World Wide Fund for Nature, WWF-Brazil, São Paulo, Brazil.

[3] Federal University of ABC, Center for Natural and Human Sciences, São Paulo, Brazil.

ABSTRACT

Citizen science holds considerable potential as a strategic approach for public engagement in protected areas, yet its implementation varies substantially across conservation contexts. This paper analyses the integration of citizen science in Brazilian protected areas, focusing on its main characteristics and the variations in its use across different conservation types. Based on a systematic review of 59 publications from 2011 to 2023, the study identifies 24 good practices grouped into four analytical dimensions: volunteering, research, governance and operational. The review highlights 20 recurring challenges and compiles 35 recommendations to address methodological, institutional and participatory barriers. The findings reveal variation between conservation types: national parks tend to favour scientific and educational approaches with limited community engagement, while extractive reserves and sustainable development reserves demonstrate stronger community integration and territorial participation. This study presents a comparative mapping by protected area type, relating the characteristics of citizen science to conservation objectives. The full realisation of the transformative potential of citizen science will depend on its deeper integration into decision-making processes and governance structures, consolidating it as a strategic tool for more democratic and effective conservation.

Key words: participatory monitoring, environmental governance, biodiversity conservation, volunteer engagement, sustainable resource management

INTRODUCTION

Citizen science has gained increasing relevance in environmental conservation and natural resource management, as it values local knowledge and the observational skills of individuals and communities closely connected to their ecosystems (Conrad & Hilchey, 2011; McKinley et al., 2017). In a megadiverse country such as Brazil, with its extensive and varied network of protected areas, citizen science emerges as a promising strategy to strengthen monitoring and management of natural territories. When integrated into biodiversity research, citizen science can help transform conservation strategies by promoting more inclusive and participatory approaches that embrace diverse governance models and socio-environmental demands (Laxmi et al., 2025; Mamede et al., 2017; Nunes et al., 2023; Riesch & Potter, 2014; Vidal et al., 2025).

Although the term 'citizen science' is relatively recent in Brazilian environmental policy discourse, similar practices such as participatory monitoring have been adopted for some time (Nunes et al., 2023). The growing potential of citizen science in Brazil is reflected in the rise of initiatives registered as 'citizen science' in the Brazilian Biodiversity Information System (SiBBr), currently around 59 projects. Furthermore, more than 50 initiatives are conducted by research institutions and government bodies through the Brazilian Citizen Science Network (RBCC). The Chico Mendes Institute for Biodiversity Conservation (ICMBio) reports over 35,000 volunteers registered for environmental actions across the country (ICMBio, 2026).

Brazil's protected areas cover around 32.5 per cent of its territory (FUNAI, 2024; ICMBio, 2024), representing a unique opportunity to enhance biodiversity conservation through local and Indigenous knowledge. Despite robust

https://doi.org/10.2305/PQWW5344



Participants during an environmental education activity at Cachoeira da Marta Municipal Park, São Paulo, Brazil © Gabrielle Abreu Nunes

public policies, the country faces structural challenges such as weak enforcement, limited sustainable financing and underuse of traditional knowledge (Joly et al., 2019). Citizen science can contribute to overcoming these challenges by promoting public engagement, environmental education and equitable resource management (Dickinson et al., 2012).

As defined by RBCC (2025), citizen science should be understood as collaborative partnerships between scientists and interested citizens that integrate diverse forms of knowledge. This model strengthens public involvement in scientific processes, promotes scientific and technological literacy and facilitates co-development of public policies on complex socio-environmental issues.

While international studies highlight the benefits of citizen science for conservation, few integrative analyses have examined its role in Brazilian protected areas. Nunes (2021) and Nunes et al. (2023) conducted a systematic review of citizen science publications in protected areas globally between 2009 and 2019, but found no cases representing Brazil. Pegler and Ranieri (2024) provided valuable insights by identifying six studies with good practices for project design and implementation in Brazilian protected areas. However, their scope was limited to studies up to 2020, with a focus on operational guidelines rather than the social, scientific and institutional impacts of citizen science or differences across categories of conservation.

This article aims to address this gap by conducting a systematic review of citizen science publications relating to Brazilian protected areas. The study seeks to (a) identify the scope of these initiatives; (b) map good practices and challenges concerning governance, operational, scientific and volunteer engagement; (c) assess variations in citizen science application across different categories of protected areas; and (d) identify recommendations in the reviewed studies to overcome challenges and strengthen the effectiveness and sustainability of future initiatives.

METHODS

Systematic review criteria

The first stage of this study consisted of a systematic literature review to identify and analyse studies on public participation in scientific research in Brazilian protected areas. To ensure methodological rigour and transparency in the selection process, PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) were followed (Figure 1).

The search equation combined three main blocks of terms, structured using Boolean operators, to maximise scope while maintaining specificity:

- (“protected areas” OR “park” OR “forest*”): this first block of keywords was designed to capture studies carried out in different types of protected and conserved natural areas. The use of the

asterisk (*) allowed inclusion of variations of these terms (e.g. “parks”, “forests”).
AND

- (“citizen science” OR “participatory monitoring”): this block aimed to cover both the consolidated term “citizen science” and related expressions representing similar practices, particularly in applied or community contexts. For example, “participatory monitoring” is widely used in projects involving traditional and Indigenous populations.
AND
- (“Brazil” OR “Brazilian”): the third block ensured the geographical focus, retrieving only studies directly related to the Brazilian context, whether through author affiliation, case study location, or study focus.

The search was conducted in the Web of Science (Clarivate Analytics) and Scopus databases, including publications indexed up to 2023. Exclusion criteria were: (1) studies not written in English, Portuguese or Spanish; (2) duplicates between platforms; (3) lack of full access via the University of São Paulo or CAPES portal; and (4) irrelevance to the study objectives based on the title, abstract and, when necessary, full text.

Despite the methodological rigour applied following PRISMA guidelines, some limitations inherent to the review process should be considered. Because the search equation prioritised terms such as “citizen science” and “participatory monitoring”, it may not have captured studies using alternative or informal terminology, such as “community monitoring”, “participatory research” or “participatory environmental education”, particularly in initiatives led by civil society organisations or

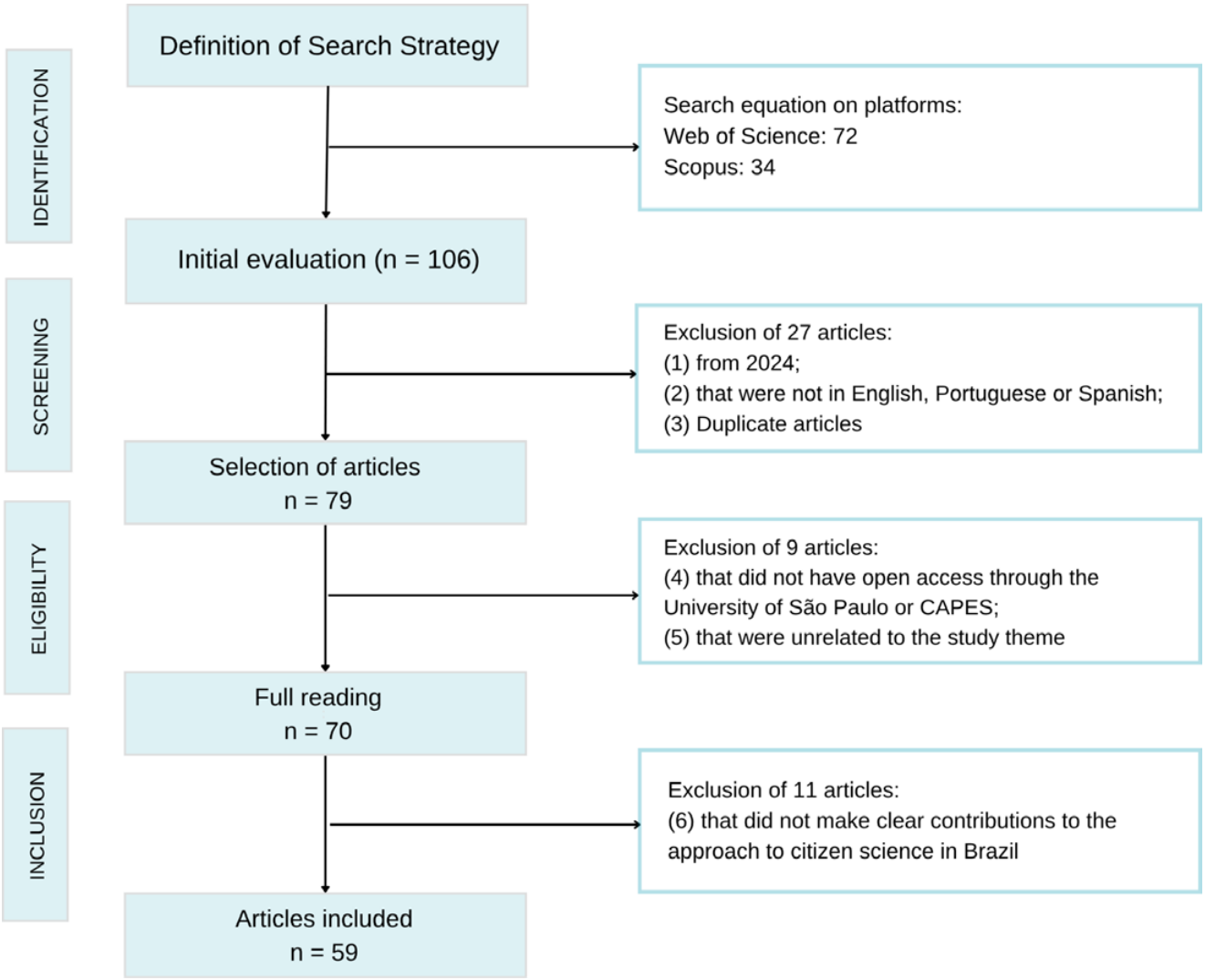


Figure 1. Systematic review steps followed in this article according to the PRISMA method.
Source: Authors

grassroots groups. This limitation may have reduced the representation of projects outside the academic sphere.

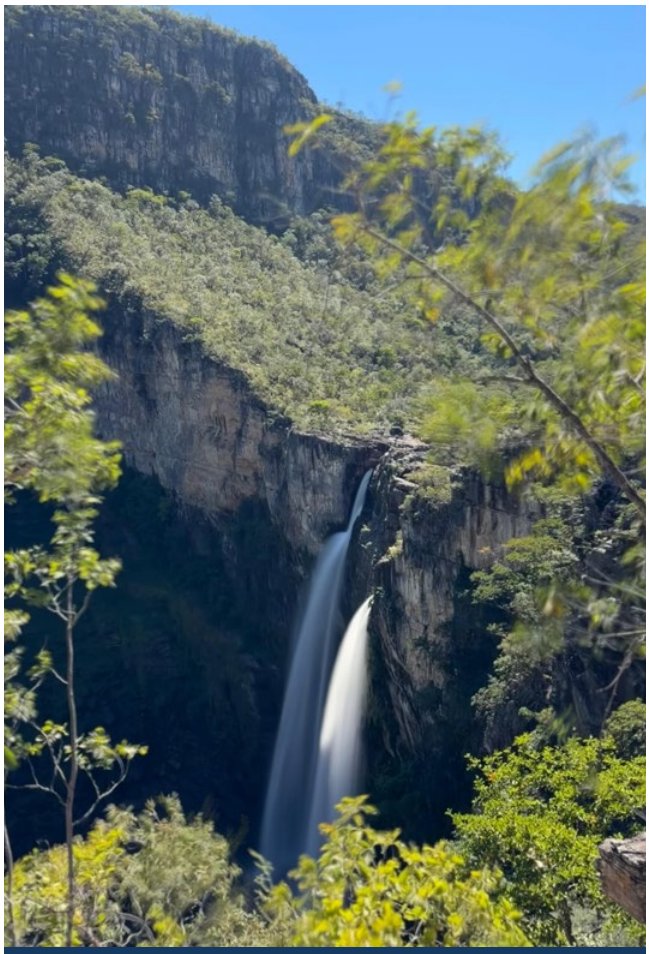
Furthermore, restricting the search to Web of Science and Scopus may have excluded relevant material from grey literature, such as technical reports, NGO documents, dissertations and theses, which often present applied results. Finally, the language criterion (English, Portuguese and Spanish) was chosen to ensure critical understanding of the material by the research team, but may have omitted publications in other languages. Nevertheless, this study offers a unique and systematic overview of the state of citizen science in Brazilian protected areas, advancing research and improving more participatory and locally adapted approaches.

DATA ANALYSIS

For the purpose of this analysis, protected areas were classified according to Brazil's National System of Nature Conservation Units (SNUC; Law No. 9.985/2000, Brasil, 2000), which organises conservation units into two main groups: Strict Protection and Sustainable Use. Strict Protection units, such as ecological stations and biological reserves, prioritise the indirect use of natural resources and restrict public access, permitting primarily scientific research and environmental education. Sustainable Use units, including environmental protection areas, national forests and extractive reserves, allow human activities compatible with conservation, often involving resident communities. In this study, the term 'protected area' refers to conservation units recognised under SNUC, excluding other territorial categories such as Indigenous lands.

Specific indicators were extracted from the selected studies to address the research objectives. For objective (a), the analysis identified the main characteristics and focus areas of citizen science initiatives, including their stated objectives, the themes addressed (e.g. biodiversity, climate change, natural resource management), alignment with the Sustainable Development Goals (SDGs) as classified by the search platforms, and their geographical distribution across Brazil, with attention to different types of protected areas.

To ensure consistency in thematic classification, studies were grouped according to their primary focus as described in titles, abstracts and keywords. Broad biodiversity studies were distinguished from ecology and environmental sciences based on their analytical scope. Studies classified as ecology explicitly addressed ecological processes such as species interactions, population dynamics or ecosystem functioning, whereas environmental sciences referred to broader and often



Waterfall and native vegetation in Chapada dos Veadeiros National Park, Goiás, Brazil © Gabrielle Abreu Nunes

interdisciplinary topics, including deforestation, ecosystem services and environmental quality.

SDG alignment was derived from metadata provided by the Web of Science and Scopus databases. These classifications reflect thematic indexing by the platforms and do not necessarily indicate that the SDGs were explicitly mentioned or analysed within each publication.

For objective (b), the analysis focused on identifying good practices, challenges and gaps using four core dimensions of citizen science in protected area contexts (Nunes et al., 2023).

The term 'volunteering' is used in this study as an analytical category to refer to participant engagement in citizen science initiatives, following previous classification frameworks. However, it is recognised that this term may not fully capture the diversity and complexity of participation in citizen science, which can include co-production of knowledge, recognition of local and Indigenous knowledge systems, and different forms of social and political engagement. In some cases, participation may also involve incentives, compensation or institutional arrangements.

i. Volunteering: covering participant profiles, recruitment strategies, training, types of activities, and perceived benefits;
ii. Research: addressing efficiency in the use of human and infrastructural resources, and complementarity with conventional scientific research (e.g. data collection, monitoring, analysis);
iii. Governance: including social participation practices, collaborative mechanisms, decision-making processes, and transparency;
iv. Operational: involving administrative and logistical elements such as funding, resource management, infrastructure, and institutional sustainability.

A qualitative content analysis was conducted to assign each study to one or more of these dimensions. This classification was based on project characteristics, outcomes and processes reported in each article. When multiple dimensions were present, all relevant categories were recorded.

For objective (c), which aimed to assess variations in the use of citizen science across different categories of protected areas, data were organised into a comparative matrix to identify which dimensions are more frequent or better integrated within each conservation unit type.

Finally, for objective (d), recommendations were compiled according to their relevance for overcoming identified challenges and strengthening project effectiveness and sustainability. These recommendations included methodological improvements, strengthened participatory governance, integration with public policies and increased long-term social engagement.

Co-occurrence analysis

A co-occurrence analysis of keywords was conducted based on article abstracts using VOSviewer software (version 1.6.20). This enabled visualisation of the relationships and clusters among the most frequently used terms, highlighting the main focus areas of citizen science within the context of Brazilian protected areas. Additionally, the temporal evolution of publications was examined, revealing possible shifts in research interest over time.

Heatmap analysis

To assess how citizen science subcategories vary across different types of Brazilian protected areas, a comparative analysis was carried out using a heatmap. This visual tool illustrates the degree of presence and integration of the four analytical dimensions examined (volunteering, research, governance and operational) across the two categories of protected areas (Table 1). For each category, an intensity score was assigned according to how frequently and deeply each citizen

Table 1. Types of Protected Areas categories in the National System of Conservation Units. *Source: Authors, based on Brazilian law no. 9.985/2000; CNUC, 2020.*

Strict Protection		
Type of UC	**IUCN Category**	**Focus/Short Objective**
Ecological Station (EE)	Ia	Strict nature protection and scientific research
Biological Reserve (Rebio)	Ia	Integral biodiversity protection with minimal human interference
National Park (Parna)	II	Conservation of ecosystems, environmental education, and controlled visitation
Natural Monument (Monat)	III	Protection of outstanding natural features with ecological or cultural value
Wildlife Refuge (RVS)	III	Maintenance of habitats critical for species conservation
Sustainable Use		
Type of UC	**IUCN Category**	**Focus/Short Objective**
Environmental Protection Area (APA)	V	Sustainable resource use, balancing conservation with local livelihoods
Area of Relevant Ecological Interest (ARIE)	IV	Protection of smaller areas with high ecological importance
National Forest (Flona)	VI	Sustainable forestry, research, and resource management
Extractivist Reserve (Resex)	VI	Sustainable use of renewable natural resources by traditional communities
Fauna Reserve (Reserva de Fauna, REF)	VI	Maintenance of viable wildlife populations with regulated resource use
Sustainable Development Reserve (RDS)	VI	Conservation of biodiversity integrated with sustainable livelihood strategies
Private Natural Heritage Reserve (RPPN)	IV	Voluntary private conservation, managed by the landowner

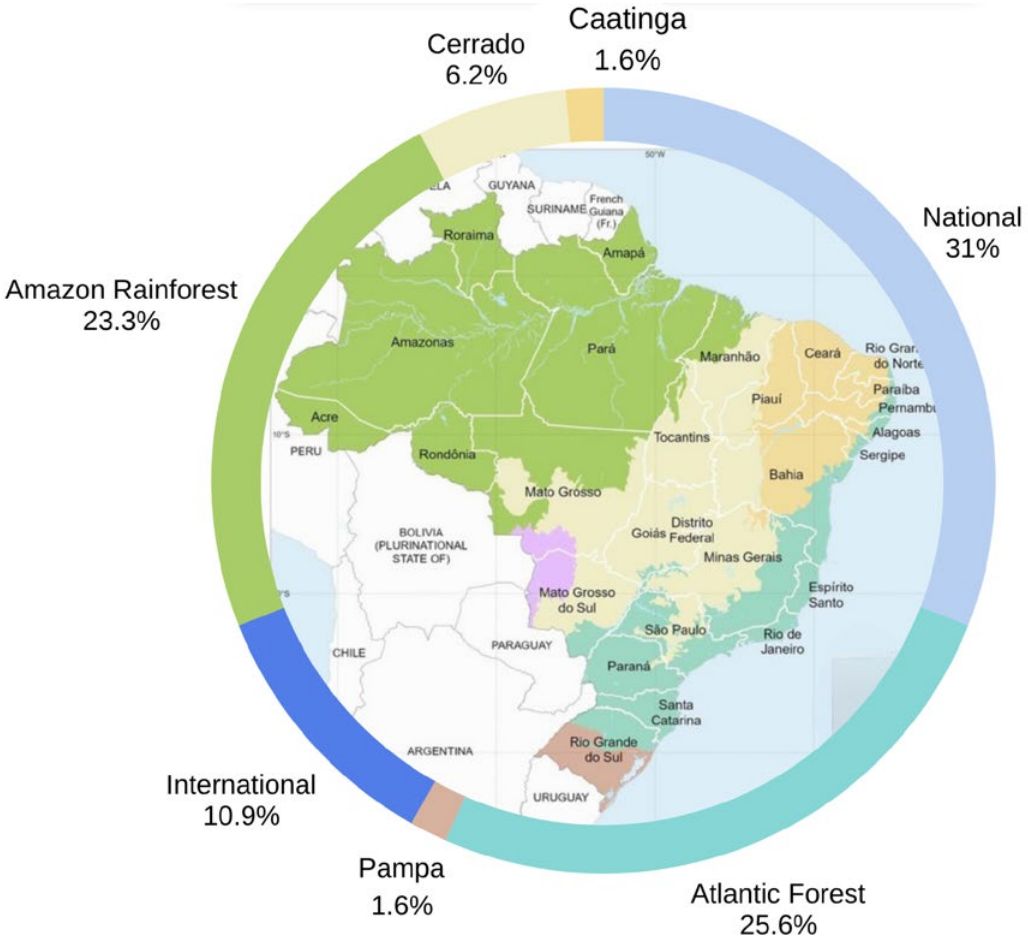


Figure 2. Geographic coverage reported in the Brazilian citizen science papers in protected areas by biome. National indicates it occurs in more than one biome. *Source: Authors adapted map from Dockendorf et al., 2022.*

science dimension was addressed in the 59 articles analysed: 0 – no mention or negligible alignment; 1 – occasional mention with low integration; 2 – moderate presence with some practical application; 3 – strong integration and frequent mention. The scores were organised into a matrix, with rows representing the citizen science dimensions and columns representing the different categories of protected areas with values converted into a colour code: white (0), light yellow (1), dark yellow (2) and dark green (3).

RESULTS

Web of Science and Scopus databases identified 79 articles, of which 59 met the inclusion criteria and provided clear contributions to at least one of the four dimensions examined: governance, operational, research and volunteering, in the context of citizen science in Brazil.

Among the themes addressed, biodiversity conservation was predominant, with 29 publications highlighting a strong focus on preserving biological diversity through citizen science initiatives. The main clusters of publications related to general biodiversity studies (9 articles), research on aquatic animals (9), and birdwatching initiatives (8). Other studies focused on mammals, plants and insects, albeit less frequently. Ecology was another significant area, with 22 articles reflecting growing interest in how citizen participation contributes to understanding ecological processes. The environmental sciences, represented by 11 publications, emphasised the relevance of citizen science in broader environmental research, including deforestation, ecosystem services and environmental quality.

The geographical scope of the studies ranged from local and regional scales to national coverage (Figure 2), with 20 articles explicitly referring to national analyses and 7 with an international scope. The most cited biomes were the Amazon (15 articles) and the Atlantic Forest (9), followed by coastal regions (6), Cerrado (4), Caatinga (1) and Pampa (1).

The regional distribution of studies was linked to the presence of human populations in protected areas and the availability of funding for research and conservation. Many of these areas, such as extractive reserves in the Amazon, are priority territories for biodiversity studies due to their ecological importance and the existence of

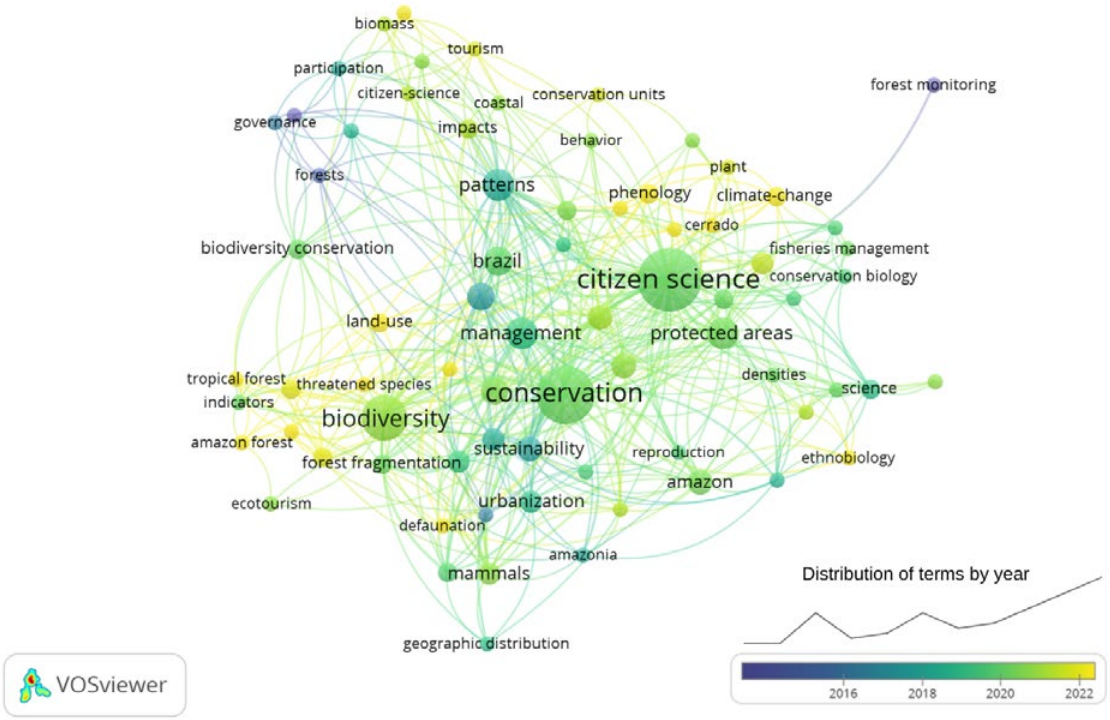


Figure 3. Correlation of keywords in Brazilian citizen science articles over time, their trends and distribution of papers published over the years in VOSviewer software 1.6.20. *Source: Authors*

communities directly dependent on natural resources for their livelihoods. Funding directed to these regions facilitates long-term research, allowing deeper understanding and improved ecosystem management.

The most represented SDG was Goal 15 – Life on Land, with 59 publications addressing the protection, restoration and sustainable use of terrestrial ecosystems, including deforestation, habitat conservation, biodiversity and land-use management. SDG 13 – Climate Action was also significant, with 37 articles discussing climate change mitigation and adaptation, including emissions reduction and policy measures. SDG 14 – Life Below Water appeared in 18 studies, focusing on marine conservation, pollution control and sustainable fishing. Other SDGs identified included SDG 1 – No Poverty (9 articles), SDG 3 – Good Health and Well-being, and SDG 11 – Sustainable Cities and Communities, each with 3 articles, addressing health access, disease prevention, urban planning and community resilience. SDG 6 – Clean Water and Sanitation was mentioned in only 1 article, highlighting the critical need for safe drinking water and sanitation in vulnerable areas. It is important to note that a single article may align with multiple SDGs, reflecting the cross-cutting nature of the challenges addressed by citizen science.

A co-occurrence map of keywords generated using VOSviewer (version 1.6.20; Figure 3) shows the central role of citizen science, which is frequently linked with terms such as conservation, biodiversity, protected areas, management and sustainability, underscoring its broad application in Brazilian environmental research. Emerging terms like “climate change” and “phenology” appear in yellow, suggesting that these areas are gaining prominence, and that citizen science is increasingly employed to gather data and engage the public on critical environmental issues. Recent trends, highlighted by terms such as “land use” and “defaunation”, emphasise how anthropogenic factors, including agriculture and deforestation, are altering ecosystems.

The annual distribution of publications showed a marked increase over time, particularly following the COVID-19 pandemic (Figure 3). Four articles were published between 2011 and 2014, followed by steady growth between 2015 and 2020, averaging around five publications per year, then a notable acceleration from 2021, with 8 publications in 2021, 11 in 2022 and 14 in 2023.

Categorisation of good practices in citizen science publications in Brazil

This study identified 24 good practices resulting from the impacts of citizen science, distributed across four main categories: volunteering, which concentrated the majority of mapped practices, followed by research, governance and, lastly, operational. The categorisation results confirm aspects of the international review by Nunes et

Table 2. "Volunteers" classification of Brazilian citizen science papers compared to the international categorisation by Nunes et al., 2023, and the total number of articles that were cited for each subcategory. Source: Authors

Volunteers	Papers
	Total
Promotes local empowerment	33
Increases community interest in the topic	47
Promotes personal satisfaction; community appreciation	22
Encourages education; increases community knowledge	51
Promotes economic benefits	18
New subcategories	
Promote social interactions	6
Cultural preservation	5
Ecological awareness	4
Promotes environmental sustainability	4
Environmental justice	2
Improves physical and mental well-being	1

Research	Papers
	Total
Promotes time optimisation	38
Complements traditional research	50
Increases reliability	44
Encourages future research	52
New subcategory	
Increase biodiversity conservation	11

Governance	Papers
	Total
Encourages communication and learning	53
Affects public policies	8
New subcategories	
Enhances decision-making	4
Promotes better land-use planning	3

Operational	Papers
	Total
Promotes financial optimisation	39
Promotes transparency	28
Improves community and management relations	46
Optimises time and resources	44

al. (2023) and introduce nine new subcategories that reflect the evolving nature of citizen science in relation to Brazil's social and territorial diversity (Table 2).

Citizen science initiatives demonstrated significant impacts on volunteer participants. The subcategory "Encourages education; increases community knowledge" was the most frequent, with 51 articles describing how these projects foster learning and enhance community knowledge. Similarly, "Increases community interest" was found in 47 studies, highlighting the capacity of citizen science to spark environmental curiosity and strengthen social engagement. The subcategory "Promotes local empowerment", cited in 33 articles, showed how direct community involvement can enhance autonomy and capacity for action.

Beyond categories identified in the international review, this study identified six new subcategories emphasising the evolving character of citizen science in Brazil and its strong connection to traditional and local communities. The subcategory "Promotes social interactions" highlights social benefits and stronger community bonds (Alexandrino et al., 2022; Martins et al., 2020; Purchase et al., 2024; Schmiedel et al., 2016). "Cultural preservation", noted in five articles (Begossi et al., 2019; De Melo et al., 2021; Morcatty et al., 2020; Ponce-Martins et al., 2022; Rumenos & Spazziani, 2020), stresses the importance of safeguarding cultural heritage and traditional knowledge as integral to natural history and local identity.

Another emerging subcategory is "Promotes environmental sustainability", cited in four articles, which discuss how community-led monitoring contributes to sustainable resource use (De Melo et al., 2021; Delfino et al., 2023; González & Kröger, 2022; Marioni et al., 2013). "Ecological awareness", also present in four studies (De Angelo et al., 2011; Freitas & Macedo, 2023; Loss et al., 2023; Mangelli et al., 2020), highlights the educational role of citizen science in raising environmental consciousness. The findings of this study align in part with Pegler and Ranieri (2024), who also conducted a systematic review of good practices in citizen science in Brazilian protected areas. However, their focus was on project design and implementation. They proposed seven main categories – financial aspects, governance, project design, methodological aspects, engagement, result dissemination and evaluation – which overlap in part with the analytical dimensions used

in this study (volunteering, research, governance and operational), though with different approaches and aims.

Although less frequent, “Improves physical and mental well-being” was cited in one article (De Melo et al., 2021), suggesting possible health benefits of participation. This perspective is reinforced by recent findings from Nunes et al. (2024) and Nunes et al. (2025), who emphasise the synergistic effects between citizen science activities and direct engagement with natural environments in promoting psychological well-being and reducing stress. These studies suggest that such initiatives contribute not only to data collection and environmental monitoring but also serve as practical strategies for fostering individual health and community resilience.

Within the "Research" article category, citizen science contributed to scientific production, with "Encourages future research" identified as the top subcategory in 52 articles. This categorization emphasizes the role of citizen science in catalyzing further investigation. “Complements traditional research”, identified in 50 articles, demonstrates synergy between volunteer-generated data and traditional methods. “Increases reliability”, cited in 44 articles, points to enhanced accuracy and robustness of information obtained. “Promotes time optimisation”, noted in 38 articles, reflects efficiency gains that allow scientists to focus on strategic tasks. A new subcategory, “Increases biodiversity conservation”, appeared in 11 publications, highlighting the expanded impact of citizen participation on biodiversity protection.



Gabrielle Nunes during fieldwork at Chapada dos Veadeiros National Park, Goiás, Brazil © Gabrielle Abreu Nunes

Operational benefits were also evident: “Improves community–management relations” was cited in 46 articles, while “Optimises time and resources” appeared in 44, both indicating efficiency gains in project delivery. In governance, “Promotes communication and learning” was widely cited (45 articles), demonstrating that citizen science can act as a tool for dialogue among stakeholders. In contrast, “Affects public policy” appeared in 8 articles, suggesting that, while there is potential, direct impact on policymaking, it remains under-documented.

Two new subcategories with transformative potential emerged: “Enhanced decision-making”, mentioned in four articles, points to more informed and inclusive conservation management (Freitas & Macedo, 2023); and “Promotes better land-use planning”, identified in three articles, highlights the role of citizen science in supporting land-use strategies through fostering community cooperation and encouraging more sustainable practices (Delfino et al., 2023; Loss et al., 2023).

Heatmap analysis of citizen science across protected area types

The heatmap analysis reveals significant variation in volunteer engagement depending on the conservation objectives and accessibility of each unit type (Figure 4). Strict Protection units such as ecological stations (EE) and biological reserves (Rebio) show low integration with volunteer-related subcategories, due to restrictions on public use and the focus on preserving minimally disturbed ecosystems. National parks (Parna), natural monuments (Monat) and wildlife refuges (RVS) display moderate to high alignment with subcategories such as cultural preservation and ecological awareness, owing to environmental education activities and controlled volunteer initiatives. However, even in these contexts, direct engagement with marginalised communities remains limited, reflected in low alignment with the subcategory “environmental justice”. Where outreach or education activities do exist, they tend to focus on environmental awareness and tourism management rather than addressing structural social inequalities.

Sustainable Use units such as environmental protection areas (APA), national forests (Flona), extractive reserves (Resex) and sustainable development reserves (RDS) show a different pattern. The presence of resident or closely connected local communities facilitates continuous biodiversity monitoring, contributing to stronger alignment with socio-environmental objectives.

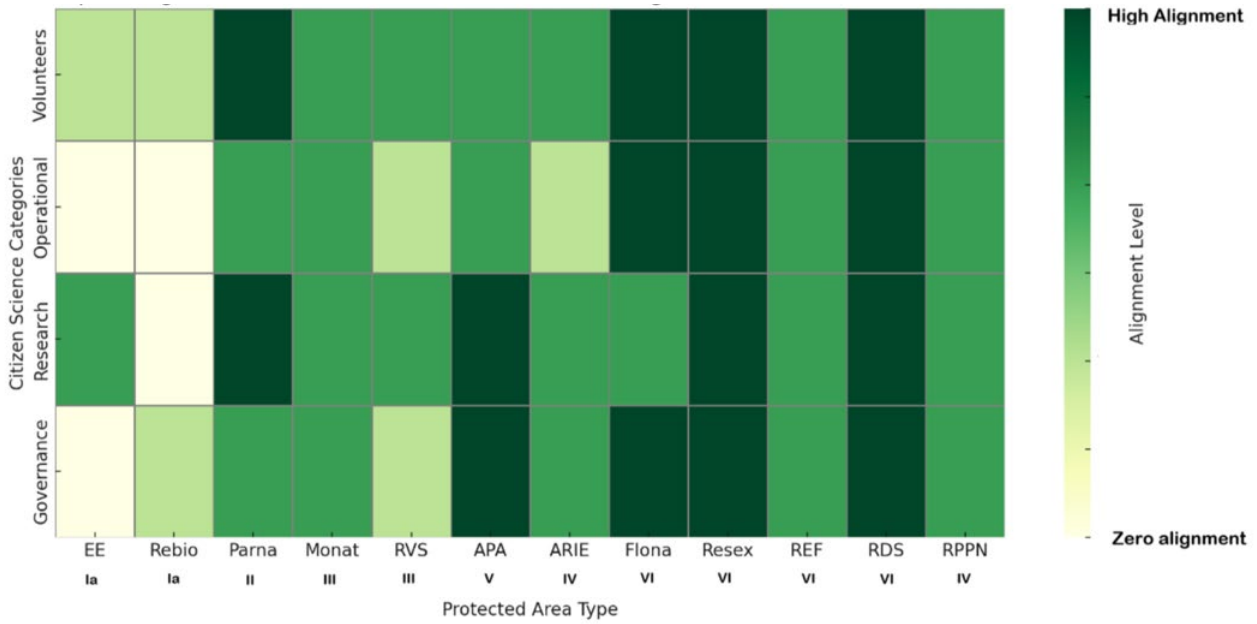


Figure 4. Heatmap in table format highlighting the alignment of citizen science characteristics within the "Volunteers, Research, Operational and Governance" scope compared to the categories of Brazilian protected areas. *Source: Authors.*

These areas show higher scores in subcategories such as local empowerment, economic benefits and participatory decision-making, although the effectiveness of these initiatives depends on the existence of clear management plans and their implementation.

In terms of research, national parks show the strongest alignment, reflecting their historical focus on scientific investigation. In contrast, operational aspects exhibit low or no integration in the most restrictive Strict Protection units, where limited access constrains opportunities for resource optimisation, community engagement and transparency. Governance remains moderate in these units, as the emphasis on ecological integrity restricts broader participatory mechanisms. While these units perform well in research-oriented citizen science, expanding opportunities for community participation could strengthen both operational and governance dimensions.

Sustainable Use units show moderate to high alignment in research subcategories, particularly where traditional knowledge and local practices are integrated. The flexibility of access and the familiarity of resident populations with their territories support more continuous and embedded initiatives. These units also show stronger alignment in operational and governance dimensions, including participatory financial management, shared decision-making and integrated land-use planning. Among these, extractive reserves and sustainable development reserves stand out as contexts where sustained community engagement enables a more consistent integration of social and ecological objectives.

These findings indicate that the effectiveness and scope of citizen science are closely shaped by the institutional and social context of each protected area category. In settings where participation is embedded within management structures, citizen science can extend beyond data collection to support decision-making processes and adaptive management. Conversely, in more restrictive contexts, its role remains more limited and primarily research-oriented, highlighting opportunities for more inclusive approaches where appropriate.

Challenges and recommendations for future projects

Volunteer engagement emerged as a primary challenge. Fourteen studies noted that participants often lack the necessary expertise, underscoring the need for enhanced training and capacity-building. Communication difficulties (4 studies) and trust issues (3 studies) further impede effective collaboration and data collection. To mitigate these challenges, recommendations include increasing volunteer participation (10 studies), tailoring engagement strategies to community profiles (8 studies), providing non-economic incentives (4 studies) and implementing comprehensive education programmes (9 studies).

Methodological challenges in research were prominent. Sixteen studies highlighted deficiencies in the design and implementation of citizen science methodologies, while 13 studies pointed to issues with data reliability and 11 studies raised concerns about overall project viability. Recommendations to address these issues include improving communication between researchers and volunteers (12 studies), leveraging technological tools (9



Participants engaging in a nature-based educational activity at Cachoeira da Marta Municipal Park, São Paulo, Brazil
© Gabrielle Abreu Nunes

studies), refining research methods (21 studies) and ensuring consistent project monitoring (13 studies).

Operational challenges involve limited management openness to community input (3 studies), underutilisation of data for decision-making (2 studies) and funding shortages (4 studies). Suggested solutions are increasing management transparency (4 studies), adopting best practices (8 studies), identifying diverse funding sources (5 studies) and optimising resource allocation (5 studies).

Governance challenges, such as ineffective stakeholder communication (7 studies), data ownership issues (2 studies) and conflicts of interest (4 studies), further complicate project success. Recommendations for governance include exploring alternative institutional arrangements (7 studies), enhancing stakeholder communication (10 studies), and aligning projects with public policies from the outset (8 studies).

DISCUSSION

The results highlight that citizen science in Brazilian protected areas is not applied uniformly, but rather shaped by institutional arrangements, levels of access and the presence of local communities. This variation suggests that the effectiveness of citizen science depends less on the methodology itself and more on how it is embedded within governance structures and management practices. In particular, the stronger performance observed in Sustainable Use units indicates that long-term engagement and locally grounded participation are critical for achieving broader conservation outcomes beyond data collection.

These findings reinforce the idea that citizen science can contribute not only to knowledge production but also to governance processes. In contexts where communities are directly involved in resource use and management, citizen science appears to facilitate more continuous monitoring, stronger local ownership and greater alignment with socio-environmental objectives. Conversely, in more restrictive contexts, its role remains limited to supporting scientific research, with fewer opportunities to influence decision-making or promote inclusive governance.

An example of an integrated and participatory approach is the Monitora Participatory Biodiversity Monitoring Programme in the Amazon (Tófoli et al., 2019). By combining traditional knowledge with scientific methods, the programme has strengthened data collection and decision-making processes. Shared research priorities have contributed to sustained community engagement and long-term commitment to conservation, resulting in more context-specific and effective biodiversity management strategies. This example illustrates how citizen science can move beyond contributory models towards more collaborative and co-produced forms of knowledge.

The identification of 24 good practices, particularly those related to education, community engagement and research complementarity, further supports the role of citizen science as a bridge between scientific and social dimensions of conservation. However, the limited presence of practices associated with policy influence and decision-making highlights an important gap. This suggests that, despite its potential, citizen science remains underutilised as a governance tool in many protected area contexts.

From a management perspective, these results indicate that aligning citizen science initiatives with the specific objectives, governance models and socio-territorial contexts of protected areas is essential to enhance their effectiveness. Initiatives that are designed with local realities in mind, and that actively involve communities in both data generation and decision-making processes, are more likely to produce lasting outcomes. This also implies that standardised approaches may be less effective than context-sensitive strategies.

More broadly, these findings offer valuable insights for conservation strategies both within and beyond Brazil. The Brazilian case reflects a combination of high

biodiversity, social inequality and complex institutional arrangements that are common across many countries in the Global South. In this context, citizen science emerges as a flexible approach that can be adapted to different governance settings, helping to address ecological and social challenges. Mapping where citizen science is well integrated, and where limitations persist, can support the development of more inclusive and effective conservation strategies.

The challenges identified across volunteering, research, operational and governance dimensions point to the need for more integrated approaches. Strengthening citizen science requires coordinated efforts that combine capacity-building, methodological refinement, institutional openness and long-term engagement strategies. When these elements are addressed together, citizen science has the potential to evolve from a data collection tool into a mechanism that supports adaptive management, social inclusion and more equitable conservation outcomes.

CONCLUSION

This article evaluated the potential of citizen science as a strategic tool for protected area management in Brazil. Based on a systematic review of 59 studies, the findings show that citizen science is expanding, but remains unevenly distributed across biomes and protected area categories. While it is strongly associated with biodiversity research, its integration into governance and decision-making processes is still limited.

The study identified 24 good practices across volunteering, research, governance and operational dimensions, highlighting the central role of public engagement and the growing relevance of social and territorial aspects such as cultural preservation and environmental justice. Significant variation was observed between Strict Protection and Sustainable Use units, with the latter showing greater potential for integrating citizen science into management and governance processes.

By providing a comparative analysis across protected area types, this study offers practical insights for managers, practitioners and policymakers seeking to strengthen participatory and context-sensitive conservation strategies. Given Brazil's ecological diversity and socio-institutional complexity, the findings also contribute to broader debates on conservation in the Global South. The analytical framework and lessons identified here are transferable to other contexts facing similar challenges, supporting the development of more inclusive, adaptive and effective approaches to protected area management.



Freshwater ecosystem and surrounding native vegetation in Chapada dos Veadeiros National Park, Goiás, Brazil
© Gabrielle Abreu Nunes

ABOUT THE AUTHORS

Gabrielle Abreu Nunes has a PhD in Applied Ecology (USP) and is Conservation Specialist at WWF Brasil. She works at the interface of environmental governance, public engagement and strategic communication, leading scientific projects and advancing research on how nature connection supports human well-being and policy innovation.

Natalia Pirani Ghilardi-Lopes is an Associate Professor at the Federal University of ABC (UFABC) and co-founder of the Brazilian Citizen Science Network (RBCC). She holds a PhD in Biological Sciences from USP and specialises in marine ecology and environmental education, with a focus on public engagement and the democratisation of scientific knowledge.

Teresa Cristina Magro-Lindenkamp is an Associate Professor at the University of São Paulo's ESALQ. A forestry engineer with a PhD in Environmental Engineering, she specialises in the management of protected areas and recreation ecology, researching the links between natural ecosystems, sustainable tourism and human well-being.

REFERENCES

Alexandrino, E. R., Camboim, T. A., Chaves, F. G., Bovo, A. A. A., da Silva, M. A. G., da Silva, D. A. M., Moss, M., Souza, T. P., de Oliveira Santos, C., de Mattos Brito, C. B., et al. (2022). Which birds are Brazilians seeing on urban and non-urban feeders? An analysis based on a collective online birding. *Ornithology Research*, *30*(2), 104–117.

Begossi, A., et al. (2019). Fishers and groupers (*Epinephelus marginatus* and *E. morio*) on the coast of Brazil: integrating information for conservation. *Journal of Ethnobiology and Ethnomedicine, 15*, 1–26.

Brasil (2000). Lei nº 9.985, de 18 de julho de 2000. Regulamenta o art. 225, §1º, incisos I, II, III e VII da Constituição Federal, institui o Sistema Nacional de Unidades de Conservação da Natureza e dá outras providências. *Diário Oficial da República Federativa do Brasil*, Brasília, DF, 18 jul. 2000.

Conrad, C. C., & Hilchey, K. G. (2011). A review of citizen science and community-based environmental monitoring: issues and opportunities. *Environmental Monitoring and Assessment, 176*, 273–291. https://doi.org/10.1007/s10661-010-1582-5

Delfino, H. C., et al. (2023). Multisource data reveals relevant trends in a Chilean Flamingo (*Phoenicopterus chilensis*) population at an important coastal wetland of southern Brazil: implications for conservation and planning. *Journal of Coastal Conservation, 27*, 33.

De Melo, E. P. C. et al. (2021). Exotic species are perceived more than native ones in a megadiverse country such as Brazil. *Anais da Academia Brasileira de Ciências, 93*, e20191462.

Dickinson, J. L., et al. (2012). The current state of citizen science as a tool for ecological research and public engagement. *Frontiers in Ecology and the Environment, 10*, 291–297.

Dockendorff, C., Fuss, S., Agra, R., Guye, V., Herrera, D., & Kraxner, F. (2022). Committed to restoring tropical forests: An overview of Brazil's and Indonesia's restoration targets and policies. *Environmental Research Letters*, *17*(9), 093002.

Freitas, E. M. O., & Macedo, H. S. (2023). Perspectivas e limitações do monitoramento participativo de cetáceos: utilização de plataforma de oportunidades pelo setor turístico na APA do Anhatomirim. *Desenvolvimento Regional e Meio Ambiente, 13*, 56–90.

FUNAI (2024). *Brasil indígena*. Retrieved from http://mapas2.funai.gov.br/portal_mapas/pdf/brasil_indigena.pdf

González, N. C., & Kröger, M. (2022). The adoption of earth-observation technologies for deforestation monitoring by Indigenous people: evidence from the Amazon. *Globalizations, 20*, 415–431.

ICMBio - O Instituto Chico Mendes de Conservação da Biodiversidade (2026). Volunteer Program Dashboard [Painel do Programa de Voluntariado]. Retrieved from https://app.powerbi.com/

ICMBio – Instituto Chico Mendes de Conservação da Biodiversidade (2020). *Manual de aplicação do Sistema de Análise e Monitoramento de Gestão*. Brasília: ICMBio.

ICMBio - O Instituto Chico Mendes de Conservação da Biodiversidade (2026). Dashboard of Brazilian natural conservation units [Painel unidades de conservação Brasileiras]. Retrieved from https://app.powerbi.com/view?r=eyJrIjoiMDNmZTA5Y2ItNmFkMy00Njk2LWI4YjYtZDJlNzFkOGM5NWQ4IiwidCI6IjJiMjY2ZmE5LTNmOTMtNGJiMS05ODMwLTYzNDY3NTJmMDNlNCIsImMiOjF9

Joly, C. A., et al. (2019). Brazilian assessment on biodiversity and ecosystem services: summary for policy makers. *Biota Neotropica, 19*(4).

Laxmi, K. R., Reddy, M. N., Reddy, P. A., Sandeepa, P., & Hemanth, L. (2025). Bio-eye: an advanced wildlife detection framework. *International Journal of Engineering Research and Science & Technology, 21*(1), 28–39.

Loss, S. R., et al. (2023). Citizen science to address the global issue of bird–window collisions. *Frontiers in Ecology and the Environment, 21*, 418–427.

Mamede, S., Benites, M., & Alho, C. J. R. (2017). Ciência cidadã e sua contribuição na proteção e conservação da biodiversidade na Reserva da Biosfera do Pantanal. *Revista Brasileira de Educação Ambiental (RevBEA), 12*(4), 153–164.

Mangelli, T. S., et al. (2020). Voluntary scuba diving as a method for monitoring invasive exotic marine species. *Ethnobiology and Conservation, 10*.

Martins, G. de M., et al. (2020). Territorial behaviour and breeding in the Southern Antpipit *Corythopis delalandi* (Aves: Rhynchocyclidae) in southeastern Brazil. *Journal of Natural History, 54*, 1827–1844.

Marioni, B., Botero-Arias, R., & Fonseca Junior, S. (2013). Local Community Involvement as a Basis for Sustainable Crocodilian Management in Protected Areas of Central Amazonia: Problem or Solution? *Tropical Conservation Science*, *6*(4), 555–569.

McKinley, D. C., et al. (2017). Citizen science can improve conservation science, policy, and practice. *Conservation Biology, 31*, 282–283.

Morcatty, T. Q., et al. (2020). Adapting a traditional hunting technique to improve capture rates for the endangered yellow-footed tortoise (*Chelonoidis denticulatus*) during ecological surveys in Amazonia. *Journal of Ethnobiology, 40*, 252–267.

Nunes, G. A., & Lindenkamp, T. C. M. (2021). Citizen science and sustainability: potentials of public participation in tourism in conservation units. *Revista Eletrônica Uso Público em Unidades de Conservação*, *9*(14), 79-99.

Nunes, G. A., Pegler, G. F., & Ranieri, V. E. L. (2023). Public engagement in scientific research in protected areas: from research to management *Revista Brasileira de Ecoturismo, 16*, 4. https://doi.org/10.34024/rbecotur.2023.v16.14314

Nunes, G., Duarte, D. M., & Magro, T. C. (2024, junho). *Citizen science as a tool to promote mental well-being and connection with nature in a Brazilian park*. Conference, FORESTS & SOCIETY TOWARDS 2050 IUFRO 2024, Stockholm, Sweden. https://www.researchgate.net/publication/390838715_Citizen_Science_as_a_tool_to_promote_mental_well-being_and_connection_with_nature_in_a_Brazilian_Park

Nunes, G., Soldado, E. B. R., Buijs, A., & Magro, T. C. L. (2025). *Impacts of citizen science on well-being among older adults: Insights from a small-scale study* [Paper presentation]. 4th World Conference on Forests and Parks for Public Health, Luxembourg. https://www.researchgate.net/publication/396311819_Impacts_of_citizen_science_on_well-being_among_older_adults_Insights_from_a_small-scale_study

Nunes, G. A., Soldado, E. B. R., Magro, T. C. L. (2025). Can observing nature improve human well-being? Opportunities for Ecotourism. *Revista Brasileira de Ecoturismo, 18*, 83–98. https://doi.org/10.34024/rbecotur.2025.v18.19293

Nunes, G. A. & Ranieri, V. E. L. (2025). Citizen science as a promising approach for cave monitoring in protected areas. *Ambiente & Sociedade, 28*, e00184. https://doi.org/10.1590/1809-4422asoc01841vu28L4OA

Pegler, G. F., & Ranieri, V. E. L. (2024). Citizen Science in protected areas: best practices for project formulation and implementation. *Ambiente & Sociedade*, *27*, e00152. https://doi.org/10.1590/1809-4422asoc01521vu27L4OA

Ponce-Martins, M., et al. (2022). Assessing the contribution of local experts in monitoring Neotropical vertebrates with camera traps, linear transects and track and sign surveys in the Amazon. *Perspectives in Ecology and Conservation, 20*, 303–313.

Purchase, C., et al. (2024). Reintroduction of the extinct-in-the-wild Spix's Macaw (*Cyanopsitta spixii*) in the Caatinga Forest Domain of Brazil. *Diversity, 16*, 80.

RBCC - Rede Brasileira de Ciência Cidadã. (2025). *Documento orientador do sistema de Governança da RBCC* (3rd ed.). RBCC

Riesch, H., & Potter, C. (2014). Citizen science as seen by scientists: methodological, epistemological and ethical dimensions. *Public Understanding of Science, 23*(1), 107–120.

Rumenos, N. N., & Spazziani, M. D. L. (2020). Citizen science and environmental education: training courses and encouragement in a national park. *Remea – Revista Eletrônica do Mestrado em Educação Ambiental*, 127–144.

Schmiedel, U., et al. (2016). Contributions of paraecologists and parataxonomists to research, conservation, and social development. *Conservation Biology, 30*, 506–519. https://doi.org/10.1111/cobi.12661

Tófoli, C. F., et al. (2019). *Monitoramento participativo da biodiversidade: aprendizados em evolução* (Vol. 2). São Paulo: Instituto de Pesquisas Ecológicas/MEMNON.

Vidal, D. G., Lopes, H. S., & Maia, R. L. (2025). Exploring the multifaceted relationship between human health and urban nature in times of crises. *Frontiers in Ecology and Evolution, 13*, 1562049. https://doi.org/10.3389/fevo.2025.1562049

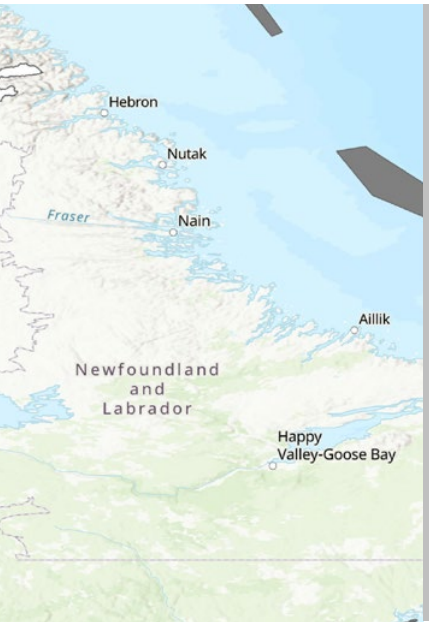
RÉSUMÉ

La science citoyenne recèle un potentiel considérable en tant qu'approche stratégique pour l'engagement du public dans les aires protégées, mais sa mise en œuvre varie considérablement selon les contextes de conservation. Cet article analyse l'intégration de la science citoyenne dans les aires protégées brésiliennes, en mettant l'accent sur ses principales caractéristiques et les variations dans son utilisation selon les différents types de conservation. S'appuyant sur une revue systématique de 59 publications parues entre 2011 et 2023, l'étude identifie 24 bonnes pratiques regroupées en quatre dimensions analytiques: le bénévolat, la recherche, la gouvernance et les aspects opérationnels. Cette revue met en évidence 20 défis récurrents et compile 35 recommandations visant à surmonter les obstacles méthodologiques, institutionnels et participatifs. Les résultats révèlent des disparités entre les différents types de zones de conservation : les parcs nationaux ont tendance à privilégier des approches scientifiques et éducatives avec une implication communautaire limitée, tandis que les réserves extractives et les réserves de développement durable font preuve d'une intégration communautaire et d'une participation territoriale plus fortes. Cette étude présente une cartographie comparative par type de zone protégée, mettant en relation les caractéristiques de la science citoyenne avec les objectifs de conservation. La pleine réalisation du potentiel transformateur de la science citoyenne dépendra de son intégration plus profonde dans les processus décisionnels et les structures de gouvernance, ce qui permettra de la consolider en tant qu'outil stratégique pour une conservation plus démocratique et plus efficace.

RESUMEN

La ciencia ciudadana encierra un potencial considerable como enfoque estratégico para la participación ciudadana en las áreas protegidas; sin embargo, su aplicación varía sustancialmente según los distintos contextos de conservación. Este artículo analiza la integración de la ciencia ciudadana en las áreas protegidas brasileñas, centrándose en sus principales características y en las variaciones en su uso según los distintos tipos de conservación. A partir de una revisión sistemática de 59 publicaciones entre 2011 y 2023, el estudio identifica 24 buenas prácticas agrupadas en cuatro dimensiones analíticas: voluntariado, investigación, gobernanza y aspectos operativos. La revisión destaca 20 retos recurrentes y recopila 35 recomendaciones para abordar las barreras metodológicas, institucionales y participativas. Los resultados revelan diferencias entre los distintos tipos de conservación: los parques nacionales tienden a favorecer enfoques científicos y educativos con una participación comunitaria limitada, mientras que las reservas extractivas y las reservas de desarrollo sostenible muestran una mayor integración comunitaria y participación territorial. Este estudio presenta un mapeo comparativo por tipo de área protegida, relacionando las características de la ciencia ciudadana con los objetivos de conservación. La plena realización del potencial transformador de la ciencia ciudadana dependerá de su mayor integración en los procesos de toma de decisiones y en las estructuras de gobernanza, consolidándola como una herramienta estratégica para una conservación más democrática y eficaz.

Traducción realizada con la versión gratuita del traductor DeepL.com



FRAGMENTED DATA, FRAGMENTED OCEANS: HOW REPORTING DISCREPANCIES UNDERMINE CANADA'S MARINE CONSERVATION COMMITMENTS

Leila Vaziri Zanjani, Christine Grossutti and Monica Mulrennan

* Corresponding author: lil.vaziri@gmail.com

ABSTRACT

Canada's ability to fulfil international marine conservation commitments, notably Aichi Target 11, depends on transparent, consistent and inclusive monitoring of marine protected areas (MPAs). This study identifies persistent discrepancies between the Canadian Protected and Conserved Areas Database (CPCAD), World Database on Protected Areas (WDPA) and Oceans Act MPAs despite recent efforts to establish a national baseline for coastal protected and conserved areas. Using spatial overlay analysis and a Decision Support Tool (DST) framework, we show how fragmented governance and inconsistent reporting hinder assessment of coverage targets, particularly at the land–sea interface. Findings highlight underrepresentation of Indigenous-led protected and conserved areas and the need for harmonised terrestrial-marine reporting, clearer procedures for overlapping designations, and Indigenous-led pathways to recognise Indigenous Protected and Conserved Areas (IPCAs) in national and international databases.

Key words: marine protected areas, conserved areas, land-sea interface, fragmentation, reporting

INTRODUCTION

Jurisdictional fragmentation at the land–sea interface remains a critical but often overlooked barrier to effective conservation governance (Pittman & Armitage, 2016). Terrestrial and marine environments are typically governed by separate authorities, a division reinforced by global frameworks. Instruments such as the United Nations Convention on the Law of the Sea (UNCLOS) and the World Database on Protected Areas (WDPA) institutionalise boundaries that treat land and ocean as distinct, perpetuating colonial cartographic traditions rather than recognising ecologically interconnected and culturally continuous coastal spaces (Jay et al., 2016; Todd, 2016). Governance arrangements, often developed without the meaningful participation of Indigenous Peoples, tend to reflect worldviews that fragment land-seascapes and overlook customary systems of stewardship (Ban et al., 2018; Mulrennan & Scott, 2000; Smith, 2021). This exclusion has contributed to inconsistencies in how marine and terrestrial protected areas are designated, reported and governed. These mismatches undermine biodiversity representation, Indigenous rights recognition, and coherent national conservation efforts (Artelle et al., 2019).

The designation and recognition of Marine Protected Areas (MPAs) are central to Canada's efforts to meet national and international biodiversity targets. However, effective governance is often undermined by jurisdictional fragmentation and inconsistent data reporting across agencies and databases. A significant milestone in global conservation policy was marked by the adoption of the Aichi Targets, during the 10th Conference of the Parties (COP10) to the Convention on Biological Diversity (CBD). These targets introduced the first comprehensive global framework for biodiversity conservation, with reporting mechanisms and indicators. Aichi Target 11 committed signatory countries, including Canada, to conserving at least 10 per cent of its coastal and marine areas through effective, equitable and representative management by 2020. The Aichi framework marked a global conservation milestone by explicitly acknowledging Indigenous Peoples' rights to their lands, territories and traditional knowledge within the CBD. The Aichi Targets have since been succeeded by

https://doi.org/10.2305/FTOJ3311

the Kunming-Montreal Global Biodiversity Framework (GBF), adopted at COP15 in 2022.

To advance Aichi Target 11, Canada launched the Pathway to Canada Target 1 initiative in 2015 and established the Indigenous Circle of Experts in 2016. Its 2018 *We Rise Together* report introduced Indigenous Protected and Conserved Areas (IPCAs) and called for shared governance of protected and conserved areas and formal recognition of Indigenous rights and responsibilities in their territories (Indigenous Circle of Experts, 2018).

Co-led by Environment and Climate Change Canada (ECCC) and the Assembly of First Nations (AFN), the Pathway to Canada Target 1 initiative focused on terrestrial and inland waters. In 2021, it released Pan-Canadian Standards for Protected Areas (PAs) and Other Effective Area-based Conservation Measures (OECMS), with a Decision Support Tool (DST) for Indigenous Nations, governments, NGOs and other decision-makers to evaluate areas against the criteria.

Because Fisheries and Oceans Canada leads the coastal and marine dimensions of Canada Target 1, MPAs are qualified and reported through separate processes. As of 2024, 12 MPAs were formally included in the Canadian Protected and Conserved Areas Database (CPCAD) (ECCC, 2024), compared with more than 9,000 terrestrial Protected Areas since the Pan-Canadian Standards were operationalised. This disparity reflects challenges in how governing authority is identified and operationalised across the Pan-Canadian Standards, the Oceans Act and CPCAD.

The Pan-Canadian Standards require proposed areas to have clearly defined, mutually agreed boundaries and tenure supporting long-term, legally secure protection. Marine legal authority generally rests with federal and provincial governments through frameworks including the Oceans Act, UNCLOS, and Canada Shipping Act (Table 1). Canada and Quebec also use instruments such as the Fisheries Act (1985, c. F-14), Natural Heritage Conservation Act, and intergovernmental administrative agreements to designate and manage MPAs. These constraints complicate CPCAD recognition of marine spaces, particularly those governed or co-governed by Indigenous Nations.

Indigenous rights and title to marine and freshwater areas are constitutionally protected under Section 35 of the Constitution Act, 1982, affirming Indigenous Peoples' rights to govern, access and steward traditional territories, including aquatic environments. Yet Indigenous-led marine conservation remains largely invisible in official reporting. As of 2024, the only marine IPCA listed in CPCAD is the Gwaxdlala/Nalaxdlala (Lull/Hoeya) Marine Refuge, classified as an OECM and formally designated under federal ownership. This reflects recognition frameworks that prioritise state-defined legal mechanisms over Indigenous governance, limiting the visibility and legitimacy of Indigenous-led marine protection in national and international reporting. MPAs are central to Canada's Target 3 commitments under the Kunming-Montreal GBF (Fu et al., 2024; Lemieux et al., 2023; Wilson et al., 2024), but Target 3 requires effective conservation and management, making governance quality, management responsibilities, ecological connectivity, and Indigenous authority essential to credible assessments. Despite increased MPA coverage, challenges in data integration, jurisdictional overlap and fragmentation, and recognition of Indigenous governance persist (Fu et al., 2024; Lemieux et al., 2023; Wilson et al., 2024).

Lemieux et al. (2023) established the first national CPCAD baseline of protected and conserved coastal areas, identifying gaps in representation, data transparency, and spatial coherence. Building on this work, we compare CPCAD, WDPA, and federally designated Oceans Act MPAs to assess convergence

Table 1. Governing authority and legal instruments of Canada's marine territories

Zone	Governing authority	Key instruments
Offshore (12–200 nm)	Federal (Crown)	Oceans Act, UNCLOS
Territorial Sea (0–12 nm)	Federal (Crown)	Oceans Act, Canada Shipping Act
Tidal Waters (e.g. bays, estuaries)	Federal (surface), Provinces (shoreline)	Fisheries Act, Land Acts (legislative frameworks at the federal or provincial level that govern the administration, allocation, tenure, and use of land, often including Crown land, Indigenous lands, and private property such as Federal Real Property and Federal Immovables Act (FRPFIA), Canada National Parks Act and Canada National Marine Conservation Areas Act)
Indigenous Territories	Indigenous + negotiated Crown roles	Treaties and Comprehensive Land Claims, IPCAs, Canadian Constitution (Section 35), United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP)

and divergence across datasets. Using multi-source spatial overlay and governance gap analysis, we evaluate MPA reporting consistency and the implications of overlapping designations and jurisdictional boundaries. We focus on IPCA representation or omission, especially at the land–sea interface where legal, ecological and cultural boundaries intersect.

Our objectives are to: quantify and map governance overlaps and omissions; assess jurisdictional fragmentation and recognition gaps; and advance a framework for harmonised, inclusive marine accounting, with recommendations to improve data integration and recognition of marine and coastal conservation areas in Canada.

METHODS

We used ArcGIS Pro to analyse three national-level MPA datasets: CPCAD (2024 edition), WDPA (UNEP, 2025), and Oceans Act MPAs from Fisheries and Oceans Canada (DFO, 2024; Government of Canada 2025) open data services. After filtering CPCAD and WDPA for marine areas, we used the Union tool to preserve overlapping and non-overlapping input features and associated attributes (ESRI, 2024), then classified polygons by source combination (e.g. CPCAD only, CPCAD + WDPA, All Three). We calculated area in square kilometres and created an 'Overlap Type' attribute for each polygon. Symbolic heat maps and fragmentation scores visualised governance complexity. IPCA data and information were acquired from the IPCA Knowledge Basket and Indigenous data portals, where permitted.

The lead and second authors are directly engaged in supporting the inclusion of protected and conserved areas into the CPCAD by applying the Pan-Canadian criteria for terrestrial and inland waters. The third author has been directly involved in supporting the establishment of IPCAs in Canada, contributing to the foundational proposal for the Wiinipaakw (James Bay) IPCA as a National Marine Conservation Area in the offshore waters of the Eeyou Marine Region (Mulrennan et al., 2019). The first and third authors are members of the Conservation through Reconciliation Partnership and honorary members of the ICCA Consortium. This positionality provides insight into the institutional mechanisms, spatial standards, and procedural constraints shaping recognition and reporting, while grounding our critical examination of DST limitations in engaging Indigenous governance and biocultural conservation approaches.

DATA PROCESSING

All spatial datasets were reprojected to EPSG:3979 for consistent spatial resolution. We used ArcGIS Pro Union and Intersect tools to compare overlapping features across CPCAD, WDPA, and Oceans Act MPA layers. Each resulting polygon was examined to identify whether it was recognised by one, two or all three databases.

We measured fragmentation with a three-point scoring scheme: polygons recognised in one database received a Fragmentation Score of 1 (low integration), those in two databases scored 2, and those in all three scored 3 (high integration), reflecting multi-source agreement and integration.

This approach has several limitations. First, overlapping geometries required manual inspection to retain attributes accurately across differing dataset schemas. Second, near-identical extents with inconsistent attributes (e.g. name or designation type) created ambiguity in overlap categories. Third, mutually exclusive CPCAD and WDPA biome tags (terrestrial vs. marine) sometimes disrupted land–sea spatial continuity, complicating classification of estuarine and coastal protected and conserved areas. We summarised area (km²) by overlap type, visualised governance complexity with a fragmentation heat map, mapped unique or omitted MPAs separately, and analysed CPCAD recognition gaps for IPCAs using overlay and attribute comparisons.

RESULTS

We found 78.7 per cent of MPAs in all three databases (Figure 1). The WDPA includes several sites missing from the CPCAD and Oceans Act datasets, while the CPCAD includes areas with no representation in the WDPA. Oceans Act MPAs are legally established and are consistently reflected in the CPCAD. Several IPCAs are absent from all three federal datasets. As of December 2024, CPCAD reports that 15.5 per cent of national marine environments are under some form of official recognition. We found that information is not clearly communicated between national agencies and international organisations as the total area under conservation is reported by the WDPA as 9.18 per cent (Table 2).

Spatial overlap analysis indicates that jurisdictional fragmentation is pronounced in coastal regions of British Columbia (BC) and Atlantic Canada. The union of CPCAD, WDPA and Oceans Act MPA layers reveals complex overlaps in these regions. Areas with high *Fragmentation Score* values (2 or 3) are concentrated in BC's fjords and the bays of Nova Scotia. These zones

Table 2. Comparison between CPCAD and WDPA conservation coverage data as of August 2025

	Total area of MPAS and OECMS (km²)	Total percentage of baseline area
CPCAD	893,437	15.5
WDPA	526,161	9.18

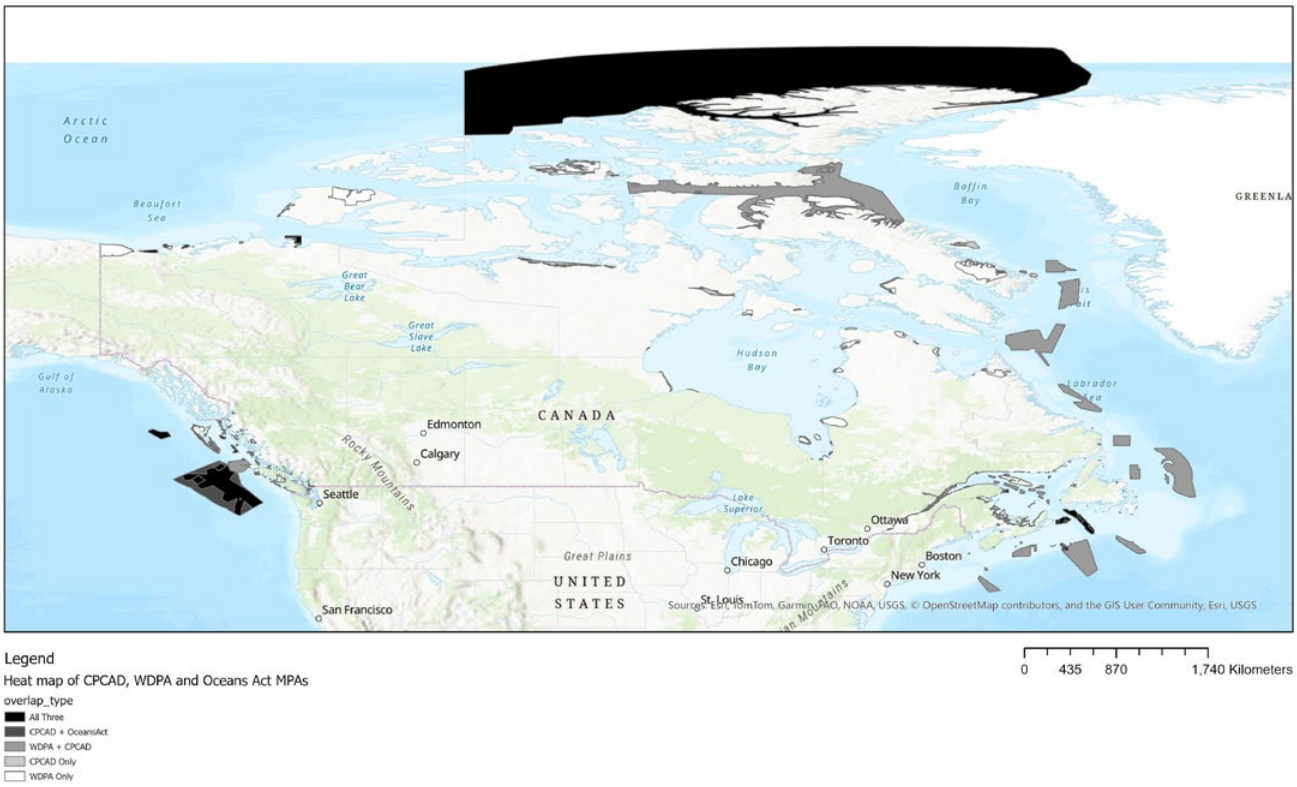


Figure 1. Overlap type map of MPAs recorded in CPCAD, WDPA and Oceans Act

illustrate complex governance landscapes, where multiple layers of protection and management intersect. Overlaps include federal fisheries closures, provincial or territorial parks, IPCAs and MPAs reported under international frameworks. Each of these designations may be governed by distinct authorities, reported through different frameworks, and guided by varying objectives and criteria for protection. The result is a mosaic of jurisdictions that can lead to opportunities for collaborative management and challenges related to coordination, accountability, and clarity of purpose. Inconsistencies in reporting can compound these challenges. For example, some MPA polygons reported to the WDPA for BC's coast are absent from the CPCAD, while certain Oceans Act MPAs in Atlantic Canada appear in the CPCAD but have no corresponding entries in the WDPA.

The spatial distribution of the *Fragmentation Score* values vary across Canada's marine and coastal zones (Figure 2). Darker colours indicate higher scores (greater integration across CPCAD, WDPA and Oceans Act datasets). Three-way overlap (score = 3) is concentrated in parts of the high Arctic – particularly around Lancaster Sound – and in sections of coastal BC and the Cabot Strait where federal and provincial jurisdictions have historically coordinated protection. Large stretches of Atlantic Canada, particularly the Gulf of St. Lawrence and parts of Nova Scotia, display lower scores (1–2), reflecting gaps in WDPA or CPCAD reporting. Several coastal and estuarine areas that are known to have local or Indigenous protections are absent from the composite layer, indicating that these sites are missing from one or more datasets.

Nearly 27 per cent of MPAs appear solely in the WDPA. This discrepancy reflects technical classification issues and institutional fragmentation across federal conservation mandates. In Canada, responsibility for marine and coastal environments lies with the DFO, while terrestrial and inland water areas are tracked through a process managed by ECCC. CPCAD's reporting structure categorises sites by a single biome – either *terrestrial* or *marine* – resulting in many coastal or interface-spanning protected areas appearing as discontinuous. The WDPA reporting structure allows

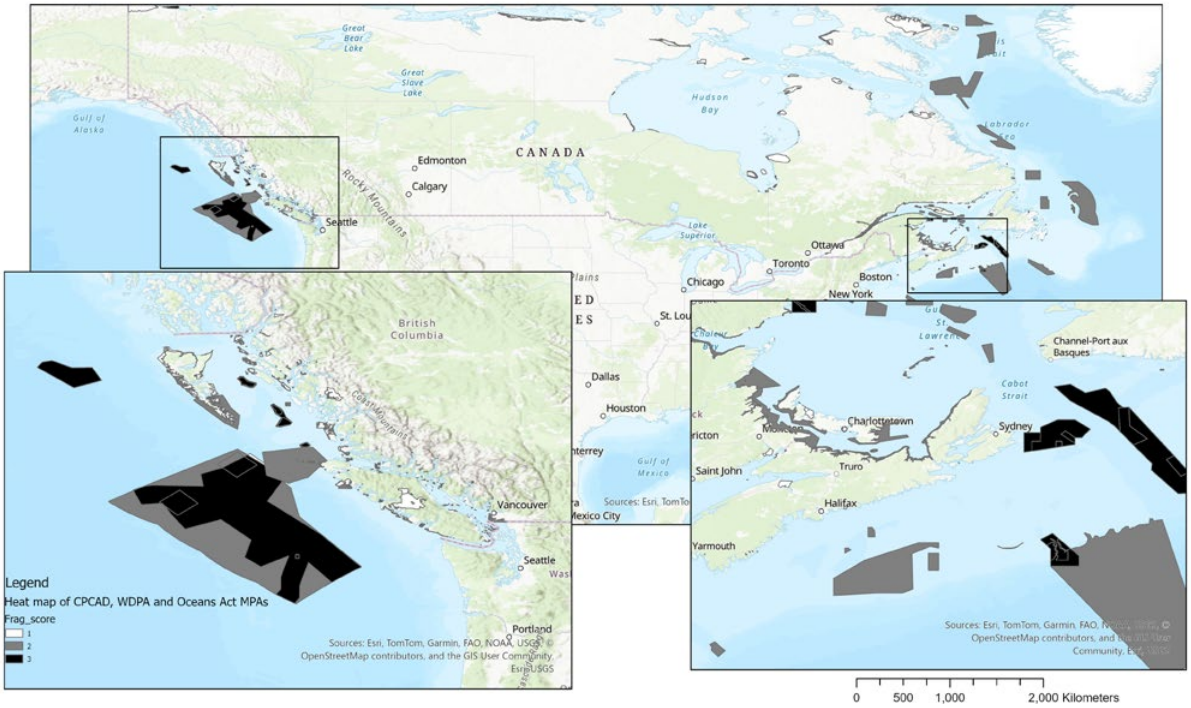


Figure 2. Fragmentation scoring between the WDPA, CPCAD and Ocean Act layers

for one contiguous area to be reported with both terrestrial and marine components. The 17per cent share of WDPA-only marine designations illustrates this misalignment and highlights how institutional silos and biome-based classification reinforce spatial and jurisdictional fragmentation at the land–sea interface. 3.9 per cent of MPAs appear only in the CPCAD database and all fall under national (ECCC and Parks Canada) or provincial governance.

Marine representation along the land–sea interface is patchy, with some estuaries and fjords fragmented into terrestrial and marine components due to classification rules such as biome type, which limits visibility of truly integrated coastal conservation (Figure 2). Jurisdictional fragmentation is highest at ecotones, including estuaries, inlets and fjords where federal, provincial and Indigenous jurisdictions converge.

To further investigate discrepancies between the designation of protected areas, we compared the Decision Support Tool (DST) of the terrestrial-oriented Pan-Canadian Standards for Protected and Conserved Areas with the DFO Oceans Act MPA designation process (Table 3). The CPCAD's rigid requirement to classify protected areas as either 'terrestrial' or 'marine' – and to submit appropriately categorised shapefiles – is ill-suited to conservation initiatives that span the land–sea interface, leading to systematic underrepresentation of coastal and transitional ecosystems. The DFO process (pre-planning → feasibility and policy → regulatory development → management) is structured to include ecological, socio-cultural, and traditional knowledge inputs during coastal and marine planning. However, in practice, the "lack of policy direction around IPCAs and DFO's role in supporting their establishment" constrains the operational capacity for new area designations (Heidt & Jones, 2023; Hubert & Gray, 2020; Warrior et al., 2022). For example, in Atlantic Canada, Mi'kmaq perspectives were consulted during the DFO Oceans Act MPA process, yet Warrior et al. (2022) found that these perspectives were not systematically incorporated into governance structures.

DISCUSSION

The Assembly of First Nations (AFN) report on marine conservation in Canada (Heidt & Jones, 2023) sets out 21 short- and long-term policy recommendations to strengthen the operationalisation of IPCAs by DFO. The report calls for enhanced data coordination and transparency across jurisdictions and between Indigenous and Crown governments, and closer collaboration with ECCC and Parks Canada to facilitate the formal inclusion of IPCAs in national reporting frameworks. Our analysis supports these recommendations by showing that technical and legal silos, including CPCAD's biome restrictions and the separation of terrestrial and marine reporting pathways, can exclude or obscure Indigenous-led marine conservation even where areas are ecologically and culturally significant. The resulting gaps are not just accounting problems; they can weaken coordination, accountability,

Table 3. Comparison of Oceans Act new MPA establishment with the ECCC's reporting process

Feature	Pan-Canadian Standards for PAs and OECMS for Terrestrial and Inland Waters	DFO Oceans Act MPA process
Scope / biome	Designed primarily for **terrestrial and inland-water protected areas**; requires specification of biome (marine vs. terrestrial) and GIS shapefile submission.	Focused exclusively on **marine environments**; includes coast, territorial sea, and EEZ.
Spatial data requirement	Requires **GIS boundaries** and **marine/terrestrial category**; cross-interface areas may be split or omitted if not properly defined.	Area of Interest (AOI) defined via scoping stage; boundaries refined in step-by-step process with consultation and science input.
Governance typology	Uses WDPA-based governance categories (e.g. national, sub-national, Indigenous, NGOs) standardised through 2022 Data Schema.	Advisory committees include interested parties, input phases, but governance types not codified as rigid categories.
Regulatory pathway	Uses administrative data submission; designation depends on concordance with Pan-Canadian criteria and data provider.	Formal regulatory pathway: pre-planning → feasibility/policy → regulation → management, published in *Canada Gazette*.
Engagement of Indigenous/traditional knowledge	Optional or dependent on submission; inclusion may require Indigenous bodies to adapt to tool's technical standards.	Indigenous/traditional knowledge is required in feasibility assessments and consultations (e.g. in AOI, advisory committees).
Integration across land–sea interface	Biome dichotomy may exclude cross-interface features unless specifically submitted; no coastal integrative logic.	Spatial process considers ecological, biophysical, social, cultural, risk data across coastal/marine zones in AOI phase.
Transparency and reporting	Data aggregated in CPCAD for national and international reporting; inclusion depends on data provider.	DFO follows a structured, phased process with public comment, gazettal notice, management planning; data is public via DFO portals.

and management clarity, affecting achievement of conservation objectives. The AFN's call for co-developed legal recognition pathways is central to improved reporting and effective, rights-based marine conservation.

Our analysis reveals systemic challenges in MPA recognition and data integration. The CPCAD prioritises legal designation and enforcement over Indigenous governance and biocultural values (Mansuy et al., 2023; Mullen, 2022). The current tracking framework does not account for place-based protection led by Indigenous nations. We propose that federal datasets include self-declared IPCAs, provincial marine areas, and harmonise reporting with WDPA standards. Further, the CPCAD's data schema should be restructured to include Indigenous indicators and flexible governance models.

The classification of the only marine IPCA as an OECM under federal governance reinforces a prevailing limitation in Canadian conservation accounting: Indigenous governance is frequently recorded through the lens of federal designation rather than an autonomous governance authority. The Kluskap IPCA, led by the Mi'kmaq Nation in Unama'ki (Cape Breton Island), is an example of an Indigenous-led conservation initiative that is currently unrecognised in Canada's official conservation datasets. Although formal negotiations began in early 2023 between the Province of Nova Scotia and Mi'kmaq representatives to co-govern the Kluskap Wilderness Area – the first agreement of its kind in the province's history – this IPCA has not yet been included in national or international spatial inventories (Government of Nova Scotia, 2023). Encompassing both terrestrial and marine ecosystems and rooted in Mi'kmaw cultural principles such as *Netukulimk* and *Etuaptmumk* (Two-Eyed Seeing), the site remains absent from CPCAD due to requirements for state-endorsed designation, GIS shapefile submission, and a governance typology that continues to privilege colonial categories (Nova Scotia Environmental Network, 2021; Gunasinghe, 2022). This omission is concerning given Nova Scotia's pledge to protect 20 per cent of its land and water by 2030, a target that will be difficult to meet without the formal recognition of Indigenous-led conservation efforts (Nova Scotia Environmental Network, 2023). Other IPCAs declared under Indigenous law and absent from all databases include the Hada (Bond Sound) & Kakweikan (Thompson Sound) by the K̲wik̲wa̲sut'inux̲w̲ Ha̲xwa'mis First Nation (KHFN), (K̲wik̲wa̲sut'inux̲w̲ Ha̲xwa'mis First Nation, 2021).

A similar dynamic is visible in the Nunatsiavut Government's Imappivut ('Our Oceans') initiative, which seeks to develop a marine management plan for the Labrador Inuit Settlement Area marine zone, including

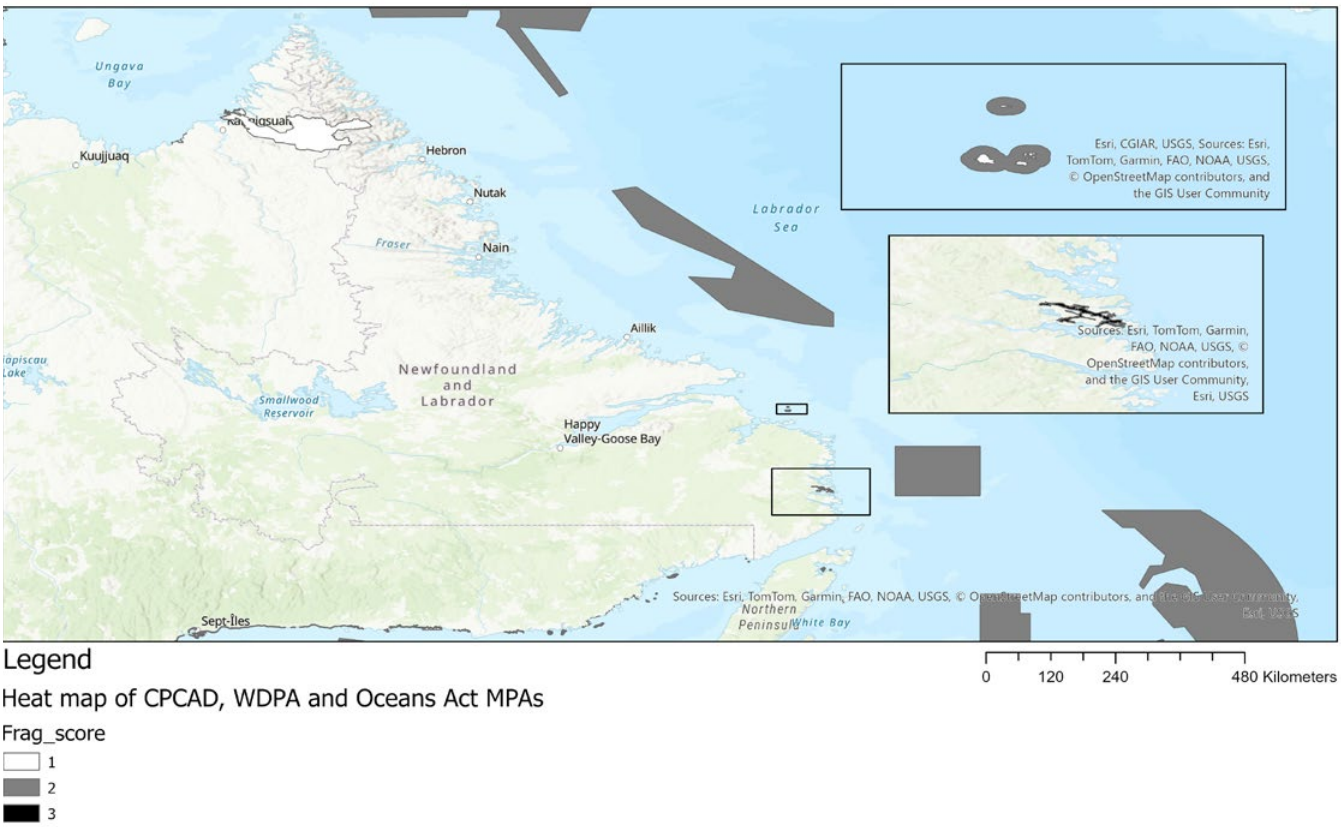


Figure 3. Gilbert Bay Marine Protected Area (rectangle A) and Gannet Islands Ecological Reserve (rectangle B) are the only two protected areas on the coastline of Newfoundland and Labrador. The former appears in all databases and the latter in CPCAD and WDPA respectively. The offshore areas are OECMs under DFO governance designated through the Fisheries Act

consideration of future Indigenous-led protected areas (Nunatsiavut Government, n.d.). Under the Labrador Inuit Land Claims Agreement (LILCA), however, clause 6.2.2 excludes National Parks and other federally designated protected areas from the Agreement's co-management provisions (Government of Canada, Crown-Indigenous Relations and Northern Affairs Canada, 2005). If an Imappivut-designated conservation zone were to be established through the Oceans Act MPA process, governance authority would rest primarily with the DFO, with Inuit participation limited to advisory or consultative roles as defined by federal policy. Any National Marine Conservation Area designation would be led by Parks Canada, again operating outside LILCA's co-management framework. Conversely, areas protected through Fisheries Act measures, such as Marine Refuges, or through provincial coastal mechanisms could fall more squarely within LILCA's governance scope, enabling greater Inuit authority in management decisions. Given that the coastline of Newfoundland and Labrador has only two protected areas (Figure 3), the Imappivut initiative offers a unique opportunity for advancing Inuit governance over their traditional marine territories.

The CPCAD has adopted the same governance types as the WDPA-defined categories, including 'National Government', 'Sub-national Government', 'Government-delegated Management' and 'Indigenous Peoples'. In practice, however, many Indigenous communities do not submit their IPCAs to the CPCAD. This may be due to the requirement to clearly define geographic boundaries using GIS shapefiles, limited resources to comply with CPCAD's technical protocols, lack of incentives or benefits to reporting, and reluctance to fit Indigenous conservation practices into a federal framework that can overlook relational land–sea continuities or customary stewardship systems. It is also shaped by historical distrust and disengagement from environmental decision-making processes (Boyd & Lorefice, 2018).

A deeper problem lies in how governance fragmentation is normalised within the CPCAD classification system. For example, CPCAD requires that each protected or conserved area (PCA) be designated as either a 'marine' or 'terrestrial' biome. This split fails to accommodate biocultural spaces spanning the land–sea interface. When a PCA spans both marine and terrestrial environments, it can be submitted to the CPCAD with only a single biome indicated in its GIS metadata. This

means the other component is either omitted from the federal dataset or classified solely as either marine or terrestrial, contributing to underreporting of spatial extent and complexity. By contrast, the WDPA metadata structure allows a protected area to include one or both biomes.

Pan-Canadian criteria as applied to the DST process often privilege legal mechanisms such as fee-simple ownership by land-trusts, not-for-profit organisations, and government delegated governance and state forms of tenure. While the DST nominally includes Indigenous Peoples among its governance types, the recognition of this category is contingent on alignment with government-defined standards. In effect, customary law and Indigenous stewardship regimes – particularly those outside modern land claims agreements – are subordinated to Crown or provincial governance systems. This reinforces spatial and jurisdictional fragmentation and inhibits progress towards inclusive, rights-based conservation reporting under Target 3 of the Kunming-Montreal GBF.

DFO protected area designation vs ECCC's pan-Canadian Standards decision support tool

The CPCAD enforces a standardised governance typology based on WDPA categories, which tends to reify colonial administrative models and places Indigenous governance on par only if communities submit to state-defined definitions. The DFO approach includes advisory committees and feasibility assessments where Indigenous and local knowledge can be incorporated, but this is not guaranteed nor uniformly applied, and outcomes depend on local political will, staff capacity, and pre-existing relationships (Durand, 2020; Hubert & Gray, 2020). Together, these differences perpetuate fragmentation: areas managed through marine-specific processes, such as those under the Fisheries Act or designated as Marine Refuges, are often excluded from terrestrial databases, and vice versa, reinforcing artificial divisions at the land–sea interface. This structural misalignment compromises holistic conservation accounting and undermines Canada's ability to meet Target 3 commitments, unless tools like the data requirements of the CPCAD are adapted to support cross-ecosystem inclusion and recognition of Indigenous governance systems (Boyd & Lorefice, 2018).

To clarify how these differing processes and governance pathways influence Canada's progress towards the GBF Target 3, Table 4 summarises the principal mechanisms available for the designation of MPAs in Canada. The table distinguishes between Oceans Act MPAs, Fisheries Act measures (including Marine Refuges), National Marine Conservation Areas (NMCAs), and other federal or provincial designations, indicating their legal basis, lead authority, and whether they are currently counted towards Target 3.

In addition to the Oceans Act, DFO employs other legal and policy tools such as the Fisheries Act and the designation of Marine Refuges (OECMs) to protect marine habitats. These mechanisms can be implemented more rapidly than Oceans Act MPAs and can address specific ecological features, but their establishment and reporting do not consistently centre Indigenous governance or knowledge systems (Hubert & Gray, 2020). For instance, while Central Coast First Nations in Pacific Canada developed marine use plans combining Indigenous and scientific knowledge, Reid et al. (2022) report that these plans were only partially reflected in formal federal protections. The absence of a national framework for bringing Indigenous and Western knowledge systems into equitable relation in MPA or OECM designation means that some areas under strong Indigenous stewardship remain invisible in the CPCAD and the WDPA, even when they are functionally protected (Jessen et al., 2011).

Table 4. Principal mechanisms available for the designation of MPAs in Canada

Mechanism	Legal status	Used by DFO?	Counts towards Target 3?
Oceans Act MPAs	Legally designated	Yes	Yes
Fisheries Act – Fishing Area Closures	Legally designated (regulatory)	Yes	Sometimes (if meets OECM criteria)
Marine Refuges (Other Effective Area-Based Conservation Measures – OECMs)	Policy-based; not legislated but recognised	Yes	Yes (if meets DFO's science criteria)
Canada National Marine Conservation Areas Act (NMCAs)	Legally designated	No (led by Parks Canada)	Yes

From fragmented accounting to effective and inclusive conservation outcomes

Although this paper focuses primarily on spatial accounting and reporting, the fragmentation, duplication and omissions identified have implications for conservation outcomes. Fragmented reporting systems can obscure gaps in ecological representation, mask inconsistencies in management authority, and create uncertainty about who is responsible for implementing, monitoring and enforcing conservation objectives (Dudley & Parish, 2006). Overlapping mandates may produce duplication on paper while leaving practical responsibilities unresolved on the ground or water (Ardito et al., 2023).

These challenges are especially important in relation to Target 3 of the Kunming-Montreal Global Biodiversity Framework, which calls for expanded spatial coverage and for areas to be effectively conserved and managed (Fu et al., 2024). A reporting system that prioritises designation and spatial extent without adequately capturing governance quality, management responsibilities, ecological connectivity, and Indigenous governance may overstate progress towards conservation targets (Borrini-Feyerabend et al., 2013). Conversely, the omission or under-recognition of IPCAs, Indigenous-led stewardship, and culturally significant land–sea relationships may understate existing conservation contributions while reinforcing colonial distinctions between state-designated protection and Indigenous systems of care, responsibility and authority (Heidt & Jones, 2023).

While this analysis is grounded in the Canadian context, the issues it identifies are not unique to Canada. Many countries face similar challenges where administrative divisions between land and sea, fragmented jurisdictional authority, and inadequate recognition of Indigenous and community-led conservation shape how progress towards global biodiversity targets is reported (Ban et al., 2018; Jonas et al., 2024; Pittman & Armitage, 2016; Singh et al., 2021). The Canadian case therefore offers a useful example of how spatial accounting can reveal deeper governance questions. Similar assessments in other national contexts could help determine whether reported progress towards area-based conservation targets reflects meaningful, effectively governed, and socially legitimate conservation outcomes.

CONCLUSION

Canada's current MPA accounting system is hampered by jurisdictional fragmentation, inconsistent data integration, and statutory exclusions that undermine comprehensive reporting and may weaken conservation effectiveness (Lemieux et al., 2023). CPCAD's strict biome classification can result in artificial division of coastal and estuarine conservation areas by separating terrestrial and marine components and excluding terrestrial portions of sites recorded as marine. These technical challenges intersect with broader institutional silos, as conservation measures established under the Oceans Act MPAs, Fisheries Act Marine Refuges, and NMCAs are administered by different agencies and reported through distinct pathways to the CPCAD and the WDPA (Hubert & Gray, 2020). Indigenous-led designations such as IPCAs remain largely excluded from national reporting frameworks because they are required to conform to WDPA governance typologies and CPCAD DST data requirements (Boyd & Lorefice, 2018; Durand, 2020). As a result, Canada's official MPA accounting may overstate the coherence of the conservation network while undercounting ecologically significant and culturally important areas, particularly those at the land–sea interface or under Indigenous governance.

Addressing these gaps requires a multi-faceted and actionable approach, including: harmonising terrestrial and marine reporting systems; creating cross-jurisdictional protocols for areas that span land, freshwater, coast and sea; incorporating governance and management-effectiveness attributes into spatial datasets; establishing transparent procedures for addressing duplicate and overlapping designations; and co-developing reporting pathways with Indigenous governments, Nations, and communities. These reforms would help ensure that Canada's contributions to Target 3 reflect not only the spatial extent of designated areas, but also their effectiveness, legitimacy and alignment with Indigenous rights and responsibilities.

While this paper focuses on Canada, the challenges extend well beyond Canada, and the framework developed here may inform comparable assessments in other jurisdictions and contribute to more accurate, inclusive and effective conservation reporting on a global scale.

ABOUT THE AUTHORS

Leila Vaziri Zanjani holds a PhD in Geography, Urban and Environmental Studies from Concordia University. She is the Research Lab Coordinator of the Technoscience Research Unit at the University of Toronto.

Monica Mulrennan is a Full Professor and Graduate Program Director of the Environmental Assessment Program (MEnv) in the Department of Geography, Planning & Environment at Concordia University. She holds a PhD in Geography from University College Dublin, Ireland.

Christine Grossutti is a staff member at the Frontenac Arch Biosphere Network in Lansdowne, Ontario and an adjunct assistant professor at Queen's University in Kingston, Ontario, Canada.

REFERENCES

Ardito, G., Andreone, G., & Rovere, M. (2023). Overlapping and fragmentation in the protection and conservation of the marine environment in areas beyond national jurisdiction. *Frontiers In Marine Science*, 9, 1094266. https://doi.org/10.3389/fmars.2022.1094266

Artelle, K. A., Zurba, M., Bhattacharyya, J., Chan, D. E., Brown, K., Housty, J., & Moola, F. (2019). Supporting resurgent Indigenous-led governance: A nascent mechanism for just and effective conservation. *Biological Conservation*, 240, 108284. https://doi.org/10.1016/j.biocon.2019.108284

Ban, N. C., Frid, A., Reid, M., Edgar, B., Shaw, D., & Siwallace, P. (2018). Incorporate Indigenous perspectives for impactful research and effective management. *Nature Ecology & Evolution*, 2, 1680–1683. https://doi.org/10.1038/s41559-018-0706-0

Borrini-Feyerabend, G., Dudley, N., Jaeger, T., Lassen, B., Pathak Broome, N., Phillips, A., & Sandwith, T. (2013). *Governance of Protected Areas: From understanding to action*. Best Practice Protected Area Guidelines Series No. 20, Gland, Switzerland: IUCN.

Boyd, B., & Lorefice, S. (2018). Understanding consultation and engagement of Indigenous Peoples in resource development: A policy framing approach. *Canadian Public Administration*, 61(4), 587–610. https://doi.org/10.1111/capa.12301

CPCAD. (2024). Canadian Protected and Conserved Areas Database. Environment and Climate Change Canada.DFO. (2024). *Oceans Act Marine Protected Areas*. Fisheries and Oceans Canada.

Dudley, D., & Parish, J. (2006). *Closing the gap. Creating ecologically representative protected area systems: A guide to conducting the gap assessments of protected area systems for the Convention on Biological Diversity.* Technical Series no. 24. Montreal: Secretariat of the Convention on Biological Diversity.

Durand, E. (2020). *Indigenous protected and conserved area: A tool for marine conservation and steps towards reconciliation in the Canadian Arctic* (Master's thesis, Université de Sherbrooke). https://usherbrooke.scholaris.ca/items/c21ba310-dcd5-4d03-982b-75577033d152

Environment and Climate Change Canada (ECCC). (December, 2024). Protected and Conserved Areas database shapefiles. https://data-donnees.az.ec.gc.ca/data/species/protectrestore/canadian-protected-conserved-areas-database/Databases

Esri. (2024). *Union (Analysis)—ArcGIS Pro tool reference*. Environmental Systems Research Institute. https://pro.arcgis.com/en/pro-app/latest/tool-reference/analysis/union.htm

Fu, C., Steckbauer, A., Mann, H., & Duarte, C. M. (2024). Achieving the Kunming–Montreal global biodiversity targets for blue carbon ecosystems. *Nature Reviews Earth and Environment*, *5*(7), 538–552. https://doi.org/10.1038/s43017-024-00566-6

Government of Canada. (2025). Oceans Act Marine Protected Areas. Government of Canada; Fisheries and Oceans Canada; Marine Planning and Conservation Directorate. Shapefiles. https://open.canada.ca/data/dataset/a1e18963-25dd-4219-a33f-1a38c4971250

Government of Canada, Crown-Indigenous Relations and Northern Affairs Canada. (2005). *Land Claims Agreement Between the Inuit of Labrador and Her Majesty the Queen in Right of Newfoundland and Labrador and Her Majesty the Queen in Right of Canada*. https://www.rcaanc-cirnac.gc.ca/eng/1293647179208/1542904949105

Government of Nova Scotia. (2023, January 25). *Province, Mi'kmaq share governance of Kluskap Wilderness Area* [News release]. https://news.novascotia.ca/en/2023/01/25/province-mikmaq-share-governance-kluskap-wilderness-area

Gunasinghe, T. (2023). *Indigenous governance and the Decision Support Tool*. Brock University Thesis. http://hdl.handle.net/10464/17432

Heidt, A., & Jones, R. (2023). *Marine Indigenous Protected and Conserved Areas: Opportunities and recommendations for realizing Canada's commitments to reconciliation and marine conservation.* Prepared for: Assembly of First Nations. https://share.google/ZTeHGLpdkDSNIfNy9

Hubert, A. M., & Gray, T. S. (2020). Area-based marine protection in Canada. In R. Long, M. Ntona, & E. Johansen (Eds.), *Marine protected areas: Science, policy and management* (pp. 107–126). Routledge. https://doi.org/10.4324/9780429460206-7

Indigenous Circle of Experts. (2018). *We rise together: achieving pathway to Canada target 1 through the creation of Indigenous protected and conserved areas in the spirit and practice of reconciliation: the Indigenous Circle of Experts' report and recommendations*. Parks Canada. ISBN: 9780660255712

Jay, S., Ellis, G., & Kidd, S. (2016). Marine spatial planning: A new frontier? *Marine Policy*, 61, 1–5. 10.1080/1523908X.2012.664327

Jessen, S., Chan, K., Côté, I., Dearden, P., De Santo, E., Fortin, M. J., Guichard, F., Haider, W., Jamieson, G., … Woodley, A. (2011). *Science-based guidelines for MPAs and MPA networks in Canada*. Vancouver: Canadian Parks and Wilderness Society.

Jonas, H. D., Bingham, H. C., Bennett, N. J., Woodley, S., Zlatanova, R., Howland, E., Belle, E., Upton, J., Gottlieb, B., … Ruiz, L. (2024). Global status and emerging contribution of other effective area-based conservation measures (OECMs) towards the '30x30' biodiversity Target 3. *Frontiers in Conservation Science, 5*, 1447434. https://doi.org/10.3389/fcosc.2024.1447434

Ḵwiḵwa̱sut'inuxw Ha̱xwa'mis First Nation. (2021). *Hada (Bond Sound) & Kakweikan (Thompson Sound) Indigenous Protected and Conserved Area declaration.* Kwikwasut'inuxw Haxwa'mis First Nation. https://share.google/CSZvxpyVKx7b8DTpG

Lemieux, C. J., Gray, P. A., Parker, S. R., & Kraus, D. T. (2023). Protected and conserved coastal areas in Canada: Insights with respect to Target 3 of the Kunming-Montreal Global Biodiversity Framework. *PARKS*, 29, 6–18. https://doi.org/10.2305/RZVD9721

Mansuy, N., Staley, D., Alook, S., Parlee, B., & Thomson, A. (2023). Indigenous protected and conserved areas (IPCAs): Canada's new path forward for biological and cultural conservation and Indigenous well-being. *FACETS*, 8(1), 1–20. https://doi.org/10.1139/facets-2022-0118

Mullen, J. L. L. (2022). *The (in) ability to develop Indigenous protected and conserved areas in Canada: A literature review* [Master's thesis, University of Saskatchewan]. University of Saskatchewan Repository. https://harvest.usask.ca/items/eb6e4240-bbe1-4cee-8cc5-a904854d374b

Mulrennan, M., & Scott, C. (2000). *Mare Nullius* : Indigenous Rights in Saltwater Environments. *Development and Change*, *31*(3), 681–708. https://doi.org/10.1111/1467-7660.00172

Mulrennan, M. E., Mark, R., & Scott, C. H. (2019). *Knowing the land, losing the land: Indigenous environmental stewardship in Canada*. Routledge. https://doi.org/10.4324/9780429029581

Nova Scotia Environmental Network. (2021, March 19). *Indigenous protected and conserved areas (IPCAs)*. NSEN Blog. https://www.nsenvironmentalnetwork.com/blog/indigenous-protected-and-conserved-areas-ipcas

Nunatsiavut Government. (n.d.). *Imappivut – Our Waters*. https://imappivut.com/about/

Pathway to Canada Target 1. (2021, March). *Decision Support Tool for assessing areas against pan-Canadian Standards for Protected Areas and Other Effective Area-based Conservation Measures (OECMs) for terrestrial and inland waters* (Version March 2021). Government of Canada. https://canadaconservation.ca/wp-content/uploads/DST_03-2021-EN.pdf

Pittman, J., & Armitage, D. (2016). Governance across the land-sea interface: A systematic review. *Environmental Science & Policy*, 64, 9–17. https://doi.org/10.1016/j.envsci.2016.05.022

Reid, M., Collins, M. L., Hall, S. R. J., Mason, E., McGee, G., & Frid, A. (2022). Protecting our coast for everyone's future: Indigenous and scientific knowledge support marine spatial protections proposed by Central Coast First Nations in Pacific Canada. *People and Nature*, 4, 1052–1070. https://doi.org/10.1002/pan3.10380

Singh, G. G., Cottrell, R. S., Eddy, T. D., & Cisneros-Montemayor, A. M. (2021). Governing the land-sea interface to achieve sustainable coastal development. *Frontiers in Marine Science, 8*, 709947. https://doi.org/10.3389/fmars.2021.709947

Smith, L. T. (2021). *Decolonizing methodologies: Research and Indigenous peoples* (3rd ed.). Zed Books. Bloomsbury Publishing. ISBN: 9781786998125

Todd, Z. (2016). An Indigenous feminist's take on the ontological turn: 'Ontology' is just another word for colonialism. *Journal of Historical Sociology*, 29(1), 4–22. https://doi.org/10.1111/johs.12124

United Nations Environment Programme. (2025). Word Database on Protected and Conserved Areas (WDPA). World Conservation Monitoring Centre: Canada shapefiles. https://www.protectedplanet.net/country/CAN

Warrior, M., Fanning, L., & Metaxas, A. (2022). Indigenous peoples and marine protected area governance: AMi'kmaq and Atlantic Canada case study. *FACETS* 7, 1298–1327. doi: 10.1139/facets-2021-0128

Wilson, S., Smith, P., Kenchington, E., Ballard, M., & Buxton, R. (2024). *Science and knowledge needs to support Canada's implementation of the Kunming-Montreal Global Biodiversity Framework*. Environment and Climate Change Canada. https://open-science.canada.ca/items/63b3e12a-91ed-4e84-bae6-ab47a8360a6e

RESUMEN

La capacidad de Canadá para cumplir sus compromisos internacionales en materia de conservación marina, en particular la Meta 11 de Aichi, depende de un seguimiento transparente, coherente e inclusivo de las áreas marinas protegidas (AMP). Este estudio identifica discrepancias persistentes entre la Base de Datos Canadiense de Áreas Protegidas y Conservadas (CPCAD), la Base de Datos Mundial sobre Áreas Protegidas (WDPA) y las AMP de la Ley de los Océanos, a pesar de los recientes esfuerzos por establecer una referencia nacional para las áreas protegidas y conservadas costeras. Mediante un análisis de superposición espacial y un marco de herramienta de apoyo a la toma de decisiones (DST), mostramos cómo la gobernanza fragmentada y la falta de coherencia en la presentación de informes dificultan la evaluación de los objetivos de cobertura, especialmente en la interfaz entre tierra y mar. Los resultados ponen de relieve la infrarrepresentación de las áreas protegidas y conservadas gestionadas por comunidades indígenas, así como la necesidad de armonizar la presentación de informes terrestres y marinos, establecer procedimientos más claros para las designaciones superpuestas y crear vías impulsadas por las comunidades indígenas para reconocer las Áreas Protegidas y Conservadas Indígenas (IPCA) en las bases de datos nacionales e internacionales.

RÉSUMÉ

La capacité du Canada à respecter ses engagements internationaux en matière de conservation marine, notamment l'objectif 11 d'Aichi, dépend d'un suivi transparent, cohérent et inclusif des aires marines protégées (AMP). Cette étude met en évidence des divergences persistantes entre la base de données canadienne sur les aires protégées et conservées (CPCAD), la base de données mondiale sur les aires protégées (WDPA) et les AMP relevant de la Loi sur les océans, malgré les efforts récents visant à établir une référence nationale pour les aires protégées et conservées côtières. À l'aide d'une analyse de superposition spatiale et d'un cadre d'outil d'aide à la décision (OAD), nous montrons comment une gouvernance fragmentée et des rapports incohérents entravent l'évaluation des objectifs de couverture, en particulier à l'interface terre-mer. Les résultats mettent en évidence la sous-représentation des aires protégées et conservées gérées par les peuples autochtones, ainsi que la nécessité d'harmoniser les rapports terrestres et marins, de clarifier les procédures relatives aux désignations qui se chevauchent et de mettre en place des processus menés par les peuples autochtones pour reconnaître les aires protégées et conservées autochtones (IPCA) dans les bases de données nationales et internationales.

Traduit avec DeepL.com (ver*sion gratuite*



COLLABORATIVE GOVERNANCE SUPPORTS BANTENG HABITAT RECOVERY IN THAILAND'S WORLD HERITAGE BUFFER ZONES

Nantachai Pongpattananurak[1,2], Nuttapong Kongraphan[1,3], Natthanicha Chookaew[1], Sangsan Phumsathan[2,4]*

*Corresponding author: Sangsan Phumsathan (fforssp@ku.ac.th)

[1] Department of Forest Biology, Faculty of Forestry, Kasetsart University, Bangkok 10900, Thailand, [2] Thai Long-Term Forest Ecological Research Project, Kasetsart University, Bangkok 10900, Thailand, [3] Huai Thap Salao–Huai Rabam Non-Hunting Area, Department of National Parks, Wildlife and Plant Conservation, Uthai Thani, 61160, Thailand, [4] Department of Conservation, Faculty of Forestry, Kasetsart University Bangkok, 10900, Thailand

ABSTRACT

Managing human–wildlife interactions in buffer zones is essential for megafauna conservation where conservation objectives overlap with local livelihoods. We evaluated management interventions in Thailand's Huai Kha Khaeng World Heritage landscape after livestock removal by comparing endangered banteng (*Bos javanicus*) responses under unregulated access (Year 1) and daytime-only access through registration (Year 2). Using operating cameras at 99 locations, we assessed banteng relative abundance, diel activity and habitat use in relation to human activity. Banteng activity shifted from primarily nocturnal in Year 1 to less nocturnal in Year 2, with wider distribution including areas with less canopy cover and better forage near the reservoir edge. Banteng activity peaked during the dry season when villagers were less likely to forage for mushrooms. Banteng activity was negatively associated with human activity and more likely further from the village. Despite daytime ranger patrols, villagers were less active at a distance from patrol routes and continued night activities during mushroom harvesting. These findings indicate that regulated access, community agreement and meaningful incentives can support behavioural recovery and habitat use by threatened wildlife. Collaborative governance, supported by community-based wildlife tourism, offers a pathway for balancing conservation, livelihoods and long-term stewardship in World Heritage buffer landscapes.

Key words: *Bos javanicus*; camera-trap surveys; relative abundance index; ranger patrols; human–wildlife coexistence; buffer-zone management

INTRODUCTION

Huai Kha Khaeng and Thung Yai Naresuan Wildlife Sanctuaries were inscribed on the UNESCO World Heritage List in 1991 (IUCN, 2025; UNESCO, 1991). The most recent IUCN Conservation Outlook Assessment describes the property as "good with some concerns", recognising improvements in law enforcement while highlighting continuing risks from boundary pressures, potential development and renewed illegal offtake (IUCN, 2025). Safeguarding the property's Outstanding Universal Value (OUV) therefore depends not only on effective protection within the core zone, but also on how human access and ecological processes are governed across the wider buffer landscape (Martin & Piatti, 2008; UNESCO, 2023). In Huai Kha Khaeng Wildlife Sanctuary (HKK), these pressures are particularly evident along the periphery, where forest product collection and human–wildlife conflict continue to challenge protected area management (IUCN, 2025).

The HKK buffer zone is a critical landscape for examining how management can balance conservation objectives with local livelihood use. Management effectiveness in such areas should be assessed not only through law enforcement, but also through the capacity of interventions to reduce disturbance, maintain ecological functions and support local participation. The mainland banteng (*Bos javanicus birmanicus*) is a useful indicator species for evaluating these outcomes (Jornburom et al., 2020; Phumsathan et al., 2024; Phumsathan, Pongpattananurak et al., 2022). Banteng populations have declined substantially across Southeast Asia due to habitat loss, agricultural expansion, poaching and human disturbance (Gardner et al., 2016; Gray et al., 2012), leaving the species critically endangered (Groenenberg &

Gray, 2025). HKK and its buffer landscape remain Thailand's primary banteng stronghold (Chaiyarat et al., 2024; Simcharoen et al., 2014). Although recent studies report positive trends for ungulates following strengthened patrolling within the sanctuary (Saisamorn et al., 2024), human pressures persist in the wider landscape (IUCN, 2025). Understanding how specific management interventions influence banteng behaviour and habitat use is therefore important for adaptive management and for demonstrating that OUV is supported beyond the protected core.

In the north-eastern buffer of HKK, non-timber forest product (NTFP) collection and livestock grazing have long been major sources of disturbance in large-herbivore habitats (Jornburom et al., 2020; Phumsathan et al., 2024; Phumsathan, Pongpattananurak et al., 2022). The Huai Thap Salao–Huai Kok Kwai National Forest (HTSHKK) experiences intense seasonal mushroom harvesting, mainly between May and November, alongside a history of livestock grazing (Phumsathan, Pongpattananurak et al., 2022). Livestock infrastructure, including pens, camps and trails, creates persistent localised disturbance that overlaps with open foraging habitats used by banteng (Chookaew et al., 2026; Phumsathan et al., 2024). Previous studies have therefore recommended regulating high-impact activities without eliminating livelihood access (Chookaew et al., 2026; Jornburom et al., 2020; Phumsathan, Daonurai et al., 2022; Phumsathan et al., 2024; Pongpattananurak, 2020). Unregulated access involving motor vehicles, multiple entry routes and day-and-night activity can increase noise, artificial lighting and human–wildlife encounters near critical resources. Such chronic disturbance may trigger avoidance behaviour, alter banteng habitat use and diel activity, and weaken the buffer's function as a seasonal refuge and movement corridor (Gaynor et al., 2018).

To address these challenges, a stepwise, community-supported management response was implemented in the Huai Thap Salao buffer. Following public engagement in 2020, villagers agreed to remove livestock and pens from HTSHKK and to support the Department of National Parks, Wildlife and Plant Conservation (DNP) in establishing a new non-hunting area. The long-term goal was to reduce high-impact extractive use and develop community-participatory wildlife tourism (Phumsathan et al., 2025; Phumsathan, Pongpattananurak et al., 2022; Pongpattananurak, 2020). The DNP subsequently designated the Huai Thap Salao–Huai Rabam Non-Hunting Area (HTSHR) under Thailand's Wildlife Preservation and Protection Act B.E. 2562 (Royal Gazette, 2019). HTSHR functions as an IUCN Category IV protected area where resource use is actively regulated (Dudley, 2008). Management was phased: livestock grazing was prohibited in late 2020, leading to the removal of thousands of domestic animals and associated infrastructure (Chookaew et al., 2026; Phumsathan, Daonurai et al., 2022; Pongpattananurak, 2020). An initial DNP patrolling programme followed in 2021–2022, but was constrained by limited budgets and largely unregistered NTFP entry. By 2022–2023, increased funding supported more systematic patrol coverage and the introduction of a formal registration system that restricted forest resource collection to daytime hours.

This study evaluates the early effectiveness of this management transition by analysing banteng responses before and after management intensification in HTSHR. Using camera-trap data collected between March 2021 and April 2023, we: (1) examined whether banteng occurrence and diel activity shifted in response to human activity, including NTFP collectors, researchers and patrol operations; (2) quantified banteng relative abundance and habitat use across environmental covariates and seasons; and (3) compared spatial and temporal patterns between the pre- and post-intensification phases to assess whether standardised patrolling, NTFP registration and daytime-only access reduced disturbance at sensitive times and improved conditions for banteng to use buffer-zone habitats. The findings provide practical guidance for patrol timing and access regulation during peak NTFP periods, and offer early evidence of whether HTSHR is functioning as an effective buffer zone that supports participatory wildlife tourism, local livelihoods and the protection of OUV.

METHODS

Study area

This study was conducted in the HTSHR establishment area in Lan Sak District, Uthai Thani Province, western Thailand. The area adjoins the north-eastern boundary of Huai Kha Khaeng Wildlife Sanctuary and includes part of the Huai Thap Salao Reservoir (Figure 1). Field data were collected between March 2021 and April 2023, during a transitional phase in buffer-zone management. Key management interventions during this period included livestock removal, the removal of associated infrastructure, the initiation of ranger patrolling and the subsequent implementation of a formal registration system that restricted forest resource collection to daytime hours, from 6.00 am to 6.00 pm (Phumsathan, Pongpattananurak et al., 2022; Pongpattananurak, 2020). Additional details on the study area and management history are provided in the Supplementary Online Material.

Environmental and anthropogenic covariates

Environmental and accessibility covariates were extracted from the landscape raster database developed by Pongpattananurak (2020). These included vegetation structure, slope and distances to water, villages and patrol roads. Survey month represented seasonality. Variable definitions and data sources are detailed in the Supplementary Online Material under Methods and Table S1.

Data collection and statistical analysis

We monitored banteng and human activity using 99 continuously operating camera traps on a 500 × 500 m grid during Year 1 (March 2021–March 2022) and Year 2 (April 2022–April 2023). Camera deployment followed standard protocols (Chutipong et al., 2014; TEAM, 2008); detection criteria and human-activity classification are detailed in the Supplementary Online Material. Monthly relative abundance indices (RAIs) were calculated as independent detections per 100 trap nights (Azlan & Sharma, 2006; Kawanishi et al., 1999). Diel periods were daytime (6:00 am–6:00 pm) and night-time (6:00 pm–6:00 am). Overall and diel RAIs were compared between phases using Multi-Response Permutation Procedures (MRPP). Station-level RAI maps provided descriptive spatial context.

Generalised Linear Mixed Models (GLMMs) with a Tweedie distribution and log link evaluated banteng habitat use and villager intrusion. Banteng models included environmental, accessibility and anthropogenic covariates, survey month and a station random effect. Interactions among NTFP collection, research and ranger activity were evaluated to account for potentially interdependent associations with habitat use. Villager-intrusion models included distance to patrol roads and seasonal variables. Final banteng habitat-use models were selected through backward elimination using likelihood ratio tests ($\alpha = 0.10$). Akaike information criterion (AIC) values were reported to compare model performance. Full statistical procedures, including model diagnostics, effect-size estimation and R packages, are provided in the Supplementary Online Material.

RESULTS

We obtained 3,798 independent detections of banteng and 3,158 detections of human activity across 27,723 trap nights. Domestic livestock were not recorded by camera traps during the study period. Comparison of relative abundance index (RAI) values between the pre-intensification phase (Year 1) and post-intensification phase (Year 2) using MRPP showed distinct temporal shifts (Table 1). Overall banteng RAI decreased from 14.8 ± 0.61 in Year 1 to 12.7 ± 0.63 in Year 2. In contrast, overall human activity remained consistently high across

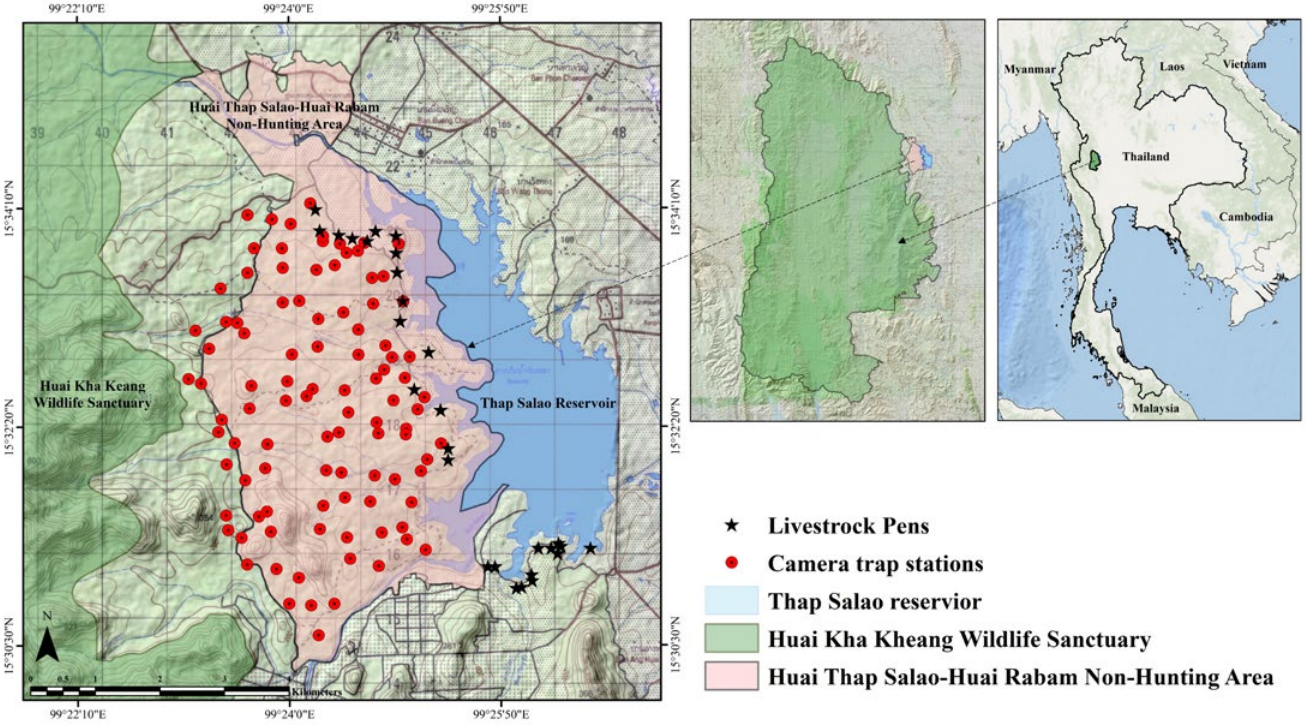


Figure 1. Study area and locations of camera trap stations (n = 99) within the Huai Thap Salao–Huai Rabam Non-Hunting Area, western Thailand.

Table 1. Comparison of banteng relative abundance, diel activity and human activity between the pre-intensification management phase (Year 1) and post-intensification management phase (Year 2).

Activity type	Time period	Year 1 (mean ± SE)	Year 2 (mean ± SE)	MRPP p-value
Banteng	Total (24 h)	14.8 ± 0.61	12.7 ± 0.63	0.01
	Day-time	5.84 ± 0.29	6.05 ± 0.36	0.66
	Night-time	9.01 ± 0.44	6.61 ± 0.42	< 0.01
Human activity overall	Total (24 h)	11.9 ± 0.62	11.9 ± 0.69	0.20
	Day-time	11.4 ± 0.60	11.5 ± 0.66	0.14
	Night-time	0.45 ± 0.06	0.39 ± 0.08	0.30
NTFP collection	Total (24 h)	4.42 ± 0.40	4.63 ± 0.49	0.76
	Day-time	4.02 ± 0.37	4.34 ± 0.44	0.45
	Night-time	0.40 ± 0.06	0.29 ± 0.07	0.06
Ranger patrol	Total (24 h)	3.28 ± 0.34	3.35 ± 0.38	0.55
	Day-time	3.22 ± 0.34	3.27 ± 0.37	0.53
	Night-time	0.06 ± 0.02	0.08 ± 0.02	0.24
Research activity	Total (24 h)	4.17 ± 0.19	3.96 ± 0.24	< 0.01
	Day-time	4.17 ± 0.19	3.96 ± 0.24	< 0.01
	Night-time	0.00 ± 0.00	0.01 ± 0.01	0.08

Note: SE = standard error; MRPP = Multi-Response Permutation Procedure; NTFP = non-timber forest product, Daytime: 6.00 am–6.00 pm; Night-time: 6.00 pm–6.00 am.

both phases, with similar mean RAI values in Year 1 and Year 2 (11.9 ± 0.62 vs. 11.9 ± 0.69; p = 0.20). Night-time NTFP collection decreased from 0.40 ± 0.06 in Year 1 to 0.29 ± 0.07 in Year 2, although this difference was marginal (p-value = 0.06). Banteng night-time activity declined significantly from 9.01 ± 0.44 to 6.61 ± 0.42 (p-value < 0.01). In Year 1, banteng night-time RAI was significantly higher than daytime RAI (5.84 ± 0.29; p-value < 0.01), indicating a strongly nocturnal activity pattern. In Year 2, this difference disappeared: daytime RAI remained stable (6.05 ± 0.36), while lower night-time activity resulted in no significant difference between daytime and night-time RAI (p-value = 0.40). Ranger patrol activity remained similar across the two years (3.28 ± 0.34 vs. 3.35 ± 0.38; p-value = 0.55), whereas research activity declined significantly from 4.17 ± 0.19 to 3.96 ± 0.24 (p-value < 0.01).

Temporal patterns of monthly activity

Analysis of monthly activity patterns showed an inverse relationship between banteng and human activity across the two study years (Figure 2). Banteng RAI was highest during the dry season (December–April), when human activity in the landscape was lowest. In contrast, banteng RAI declined between September and November, coinciding with the period of highest daytime anthropogenic activity. However, the magnitude of this seasonal decline differed between years. In Year 1, banteng RAI reached its lowest level during the peak human-activity months. In Year 2, banteng RAI also declined during the same period, but the reduction was less severe and remained higher than in Year 1. This suggests that banteng continued to respond to seasonal human disturbance, but the post-intensification management phase may have reduced the extent of avoidance.

Spatial distribution patterns

Visualisation of station-level RAI suggested differences in the spatial distribution of banteng between the two management phases, including more detections near the reservoir edge in Year 2 (Figure 3). In Year 1, banteng RAI was relatively evenly distributed across the central and western parts of the study site (Figure 3a), while human activity was concentrated along the eastern forest edge and reservoir boundary (Figure 3c). In Year 2, banteng distribution became more widespread across the northern, central and southern areas, with high-intensity clusters emerging along the eastern boundary, particularly near the Thap Salao Reservoir (Figure 3b).

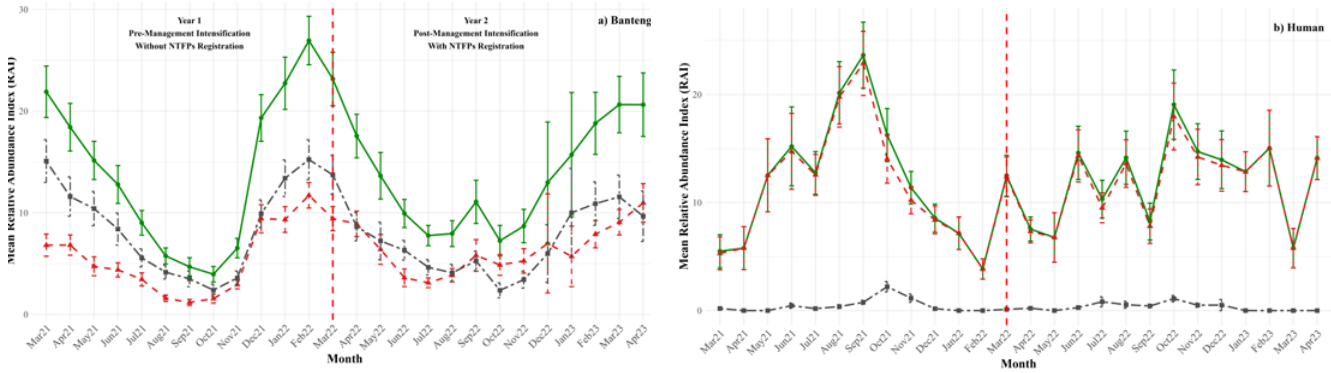


Figure 2. Monthly diel activity patterns based on mean relative abundance index (RAI) during the pre-intensification management phase (Year 1) and post-intensification management phase (Year 2) for (a) banteng and (b) human activity.

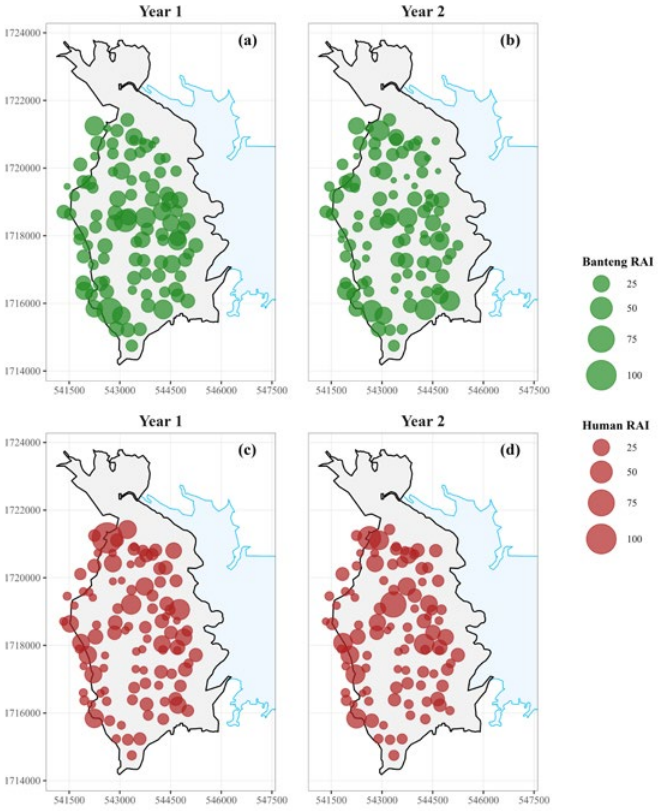


Figure 3. Spatial distribution of banteng and human activity (RAI) in the Huai Thap Salao-Huai Rabam Non-Hunting Area for banteng in the pre-intensification management phase (Year 1) (a) and post-intensification management phase (Year 2) (b), and human activity in Year 1 (c) and Year 2 (d).

This clustering occurred despite the continued presence of human activity in the same eastern areas (Figure 3d). These visual patterns provide landscape context for the subsequent model-based assessment of habitat use.

Factors influencing habitat use

GLMMs and AIC-based model selection were used to identify predictors of banteng habitat use (Table 2). In both years, models based only on static environmental variables performed poorly and did not improve model fit relative to the null model (Year 1: ΔAICnull = 7.1; Year 2: ΔAICnull = 5.8). Among the single-category anthropogenic disturbance models, the NTFP activity model showed the greatest improvement over the null model in both Year 1 (ΔAICnull = -109.8) and Year 2 (ΔAICnull = -27.3). The top-ranked models had the lowest AIC values among the candidate models in both phases, although their predictor structures differed. In Year 1, the top-ranked model (AIC = 6412.9) included seasonal factors and anthropogenic variables, and improved model fit compared with the seasonal model alone (AIC = 6455.4). Banteng RAI was negatively associated with NTFP collector activity, researcher activity and the three-way interaction among NTFP collector activity, researcher activity and ranger patrols. In contrast, distance from the nearest village and the two-way interaction between NTFP collector activity and researcher activity were positively associated with banteng RAI. Both interaction terms retained in the Year 1 top-ranked model were statistically significant ($p < 0.01$ for each; Table 2), indicating that the associations between human activities and banteng RAI depended on the levels of other activities.

In Year 2, the top-ranked model had the lowest AIC among the candidate models (AIC = 4350.7), but the two-way and three-way interaction terms were no longer retained. The Year 2 top-ranked model therefore represented anthropogenic activities through additive terms, in contrast to the interaction terms retained in Year 1. The model included forest basal area alongside seasonal and anthropogenic variables, indicating that habitat structure became a more important predictor in the post-intensification phase. The ΔAICnull difference between the top-ranked and seasonal models was also smaller in Year 2 than in Year 1, suggesting that seasonal variation remained important, but anthropogenic interactions were less influential after access regulation. However, these differences in the selected models do not constitute



Wildlife use of reservoir-edge habitat following livestock removal and habitat improvement in the Huai Thap Salao–Huai Rabam Non-Hunting Area, within the buffer landscape of the Huai Kha Khaeng World Heritage Site, Thailand © Nantachai Pongpattananurak

a formal test of between-year differences in interaction effects or establish that access regulation caused those effects to weaken. Detailed parameter estimates for the top-ranked models are provided in Tables S2 and S3.

Drivers of villager intrusion

Modelling the drivers of NTFP collection (Table S3) showed that active ranger patrols were not significantly associated with reduced villager activity in either Year 1 or Year 2 (p-value = 0.49 and p-value = 0.69, respectively). However, the spatial distribution of villager activity was significantly associated with distance to patrol roads in both years. In Year 1, villager activity was concentrated closer to patrol roads (estimated coefficient = -1.82, p-value < 0.01) and was negatively associated with researcher activity (p-value < 0.01). In Year 2, the negative relationship with distance to patrol roads remained significant (estimated coefficient = -1.32, p-value = 0.04), while the association with researcher activity was no longer significant (p-value = 0.16). Villager activity also showed strong seasonal variation in both phases, peaking between September and November. The magnitude of this seasonal effect was higher in Year 2, with estimated coefficients ranging from 2.92 to 4.21, compared with 1.27 to 2.08 in Year 1. These results suggest that ranger patrols alone did not substantially reduce livelihood-driven forest entry, particularly during the peak NTFP collection season.

DISCUSSION

This study provides empirical evidence that regulated access and collaborative governance can improve conditions for threatened wildlife in a World Heritage buffer landscape where conservation objectives overlap with local livelihood use. The establishment and management of the Huai Thap Salao–Huai Rabam Non-Hunting Area (HTSHR) created a practical mechanism for reducing high-impact disturbance while maintaining negotiated access for local communities. Our findings extend the baseline established by Chookaew et al. (2026), who documented seasonal banteng displacement associated with livestock grazing, by showing that banteng habitat use and activity patterns began to recover after livestock removal and access regulation. Together with elephant-focused research from the same landscape (Phumsathan et al., 2024), these findings highlight the importance of managing buffer zones as active socio-ecological spaces, where conservation outcomes depend on both ecological recovery and community compliance.

The comparison between Year 1 and Year 2 suggests that early conservation responses in HTSHR were expressed mainly through changes in diel activity and habitat use rather than evidence of population recovery. The decline in overall banteng RAI from 14.8 ± 0.61 to 12.7 ± 0.63 should therefore be interpreted cautiously. Camera-trap

RAIs measure detection rates rather than directly estimating animal abundance or the intensity of human activity. Changes in these indices may reflect variation in abundance or human visitation, spatial distribution, movement behaviour, activity levels or detection probability. Consequently, the decline in banteng RAI alone does not establish a population decline. Similarly, the less strongly nocturnal pattern in Year 2 reflected a significant decline in nighttime RAI without a corresponding increase in daytime RAI. This pattern should not be interpreted as evidence that nocturnal activity was simply redistributed to daytime. Longer-term monitoring and independent demographic information would be needed to assess whether the observed changes were accompanied by population recovery.

Behavioural response to conservation management

The implementation of formal registration and daytime-only access in Year 2 was associated with a clear shift in banteng behaviour. In Year 1, unregulated human access occurred during both day and night, especially during the peak mushroom-harvesting season. This chronic and unpredictable disturbance likely created a landscape of fear, causing banteng to avoid periods of high human activity (Laundré et al., 2010). The Year 1 results showed a strongly nocturnal activity pattern, suggesting temporal avoidance of human presence. Similar behavioural plasticity has been reported for other threatened ungulates exposed to intense anthropogenic pressure (Pan et al., 2011).

The Year 2 management system altered this pattern. The management transition coincided with a shift in banteng activity from a strongly nocturnal pattern to a less strongly nocturnal pattern, driven by a decline in nighttime activity while daytime activity remained relatively stable. The changes in banteng diel activity coincided with several management interventions, including daytime-only access regulation, livestock removal, removal of livestock-related infrastructure and ranger patrols. Because these interventions occurred concurrently, their individual effects cannot be separated using the present study design. Reduced competition with livestock or changes in spatial use following livestock removal could also have contributed to the observed activity pattern. These findings are therefore interpreted as associations with the broader conservation-management transition rather than as evidence of the effect of daytime-only access alone.

The recovery of banteng activity was also linked to habitat conditions. During the dry season, receding water levels in the Huai Thap Salao Reservoir expose drawdown zones that regenerate with nutrient-rich forage (Chookaew et al., 2026; Pongpattananurak, 2020). By returning to these open edges, which had previously been used by domestic cattle (Chookaew et al., 2026; Phumsathan et al., 2025), banteng appeared to regain access to important foraging patches following livestock removal (Figure S7). This pattern may reflect improved access to seasonal forage after livestock competition was reduced, although the present study cannot separate this effect from other concurrent management changes. This pattern was supported by our Year 2 models, in which forest basal area was a key environmental covariate. The negative association with basal area indicates that banteng increasingly used less densely forested environments, consistent with broader landscape models showing that large tiger prey species favour seasonally dry forests with low-slope, open-canopy terrain (Chankhao et al., 2022; Chookaew et al., 2026; Jornburom et al., 2020).

Collaborative governance: Beyond the limits of patrolling and local stewardship

Our findings also show that patrolling alone is unlikely to be sufficient in a buffer zone where forest entry is strongly linked to local livelihoods. This contrasts with Saisamorn et al. (2024), who reported that systematic patrolling contributed to large-herbivore recovery within the HKK core area and surrounding landscapes. In HTSHR, ranger patrol activity showed a negative association with banteng relative abundance. This association should be interpreted cautiously because patrol deployment may have been targeted towards areas with greater human disturbance or conservation concern, creating potential endogeneity or reverse causality. This result should therefore not be interpreted as evidence that patrols are unimportant. Patrols remain essential for law enforcement, visitor safety and the prevention of illegal activities. However, patrols need to be embedded within a broader governance system that includes agreed access rules, community participation and targeted regulation of high-impact activities.

The improved conditions observed in Year 2 were closely linked to formal regulation, community agreement and locally meaningful conservation incentives. The removal of livestock and related infrastructure reduced a major source of disturbance in open foraging habitats. At the same time, the designation of HTSHR as a key area for community-based wildlife tourism helped create a practical reason for local communities to support banteng recovery. This incentive structure helped shift the buffer landscape from a contested resource-use area towards a shared conservation asset.

Table 2. Model selection results comparing candidate GLMMs for banteng occurrence in pre-intensification management phase (Year 1) and post-intensification management phase (Year 2). Models are ranked by AIC.

Phase/model candidate	Formula	df(K)	AIC	ΔAICnull
Year 1				
Null model	~ 1 + (1|Station)	4	6878.7	0.0
Environmental model	~ tree_rf + BA_rf + canopy_rf + slope + DIS_water + (1|Station)	9	6885.8	7.1
Ranger patrol model	~ RAI_ranger + (1|Station)	5	6878.9	0.2
Accessibility threat model	~ village_DIS + patrol_DIS + (1|Station)	6	6873.6	-5.1
Research activities model	~ RAI_ researcher + (1|Station)	5	6853.6	-25.1
NTFP activities Disturbance model	~ RAI_villager + (1|Station)	5	6768.9	-109.8
Seasonal model	~ month_char + (1|Station)	15	6455.4	-423.3
Top-ranked model	~ RAI_villager + RAI_researcher + RAI_villager: RAI_ researcher : RAI_ Ranger + RAI_ Villager : RAI_ researcher + village_DIS + month_char + (1|Station)	20	6412.9	-465.8
Year 2				
Null model	~ 1 + (1|Station)	4	4478.7	0.00
Environmental model	~ tree_rf + BA_rf + canopy_rf + slope + DIS_water + (1|Station)	10	4484.5	5.8
Accessibility threat model	~ village_DIS + patrol_DIS + (1|Station)	6	4481.0	2.3
Research activities model	~ RAI_researcher + (1|Station)	5	4479.7	1.0
Ranger patrol model	~ RAI_ranger + (1|Station)	5	4478.0	-0.7
NTFP activities Disturbance model	~ RAI_villager + (1|Station)	5	4451.4	-27.3
Seasonal model	~ month_char + (1|Station)	15	4362.7	-116.0
Top-ranked model	~ RAI_villager + RAI_ranger + BA_rf + month_ char + (1|Station)	18	4350.7	-128.0

Note: NTFP = non-timber forest product; df = degrees of freedom; AIC = Akaike's Information Criterion; RAI = relative abundance index. canopy_rf = percentage canopy cover; BA_rf = tree basal area (m²/ha); tree_rf = tree density (tree/ha); DIS_water = distance to the nearest water source (m); village_DIS = distance to the nearest village (m); patrol_DIS = distance to patrol roads (m); RAI_villager = NTFP collector activity; RAI_ranger = ranger patrol activity; RAI_researcher = researcher activity.

This ecological and social transition suggests a broader change in local attitudes towards wildlife and protected area management (Newmark et al., 1994; Phumsathan, 2026). By linking banteng recovery with future livelihood opportunities, HTSHR has begun to strengthen local support for access rules, reduce high-risk forest use and encourage participation in long-term stewardship. This does not imply that all resource-use pressures have been resolved. Rather, it shows that legal designation is more likely to be effective when combined with negotiated rules, community participation and incentives that make conservation meaningful to local people.

Implications for World Heritage buffer-zone management

From a protected area management perspective, the HTSHR case shows that buffer-zone designation can function as more than a legal boundary adjustment. When combined with practical access regulation, community agreements and locally relevant incentives, buffer-zone management can support the recovery of habitat use by threatened wildlife while maintaining socially acceptable forms of resource access. This is particularly important in Southeast Asian conservation landscapes, where protected areas often overlap with long-standing livelihood practices.

The findings suggest that management should prioritise temporal predictability in human activities. In HTSHR, the registration system and daytime-only access helped reduce nocturnal disturbance and created more predictable conditions for banteng. Future management should therefore maintain clear access rules, agreed entry times and regular monitoring during peak NTFP collection periods. Patrols should support these access arrangements by monitoring compliance, preventing illegal activities and reducing high-risk use, rather than functioning as the only conservation intervention.

A phased management approach is also needed to align banteng recovery with local socio-economic aspirations. In the short term, NTFP collection should be managed through spatial zoning and quotas. High-value wildlife areas, particularly reservoir-edge foraging habitats, should be prioritised for habitat recovery and carefully regulated wildlife tourism. NTFP collection should be directed towards areas where banteng occurrence is lower and disturbance risk is less severe. Quotas for both resource users and visitors should be reviewed using camera-trap data, registration records, patrol observations and community compliance monitoring.

In the longer term, community-based wildlife tourism should be developed as a complementary livelihood pathway that gradually reduces dependence on high-impact forest use. According to the 2025 annual report of the Wildlife Tourism Community Enterprise of Rabam Subdistrict, tourism-related activities generated THB 2.46 million in revenue in 2025 (Wildlife Tourism Community Enterprise of Rabam Subdistrict, 2025). Although this does not yet demonstrate a full transition away from forest resource dependence, it shows that wildlife recovery has begun to create tangible local benefits that can strengthen access compliance, reduce high-risk forest use and support long-term stewardship.

Tourism development must also be carefully regulated. Visitor numbers, vehicle movements, viewing distances, viewing duration and access times should be managed through clear operating procedures and adaptive monitoring. Carrying capacity should be assessed not only in terms of visitor experience, but also in relation to banteng behaviour, habitat use and disturbance thresholds. Wildlife tourism should remain predictable, low-impact and non-lethal, without causing displacement, over-habituation or dependence on human presence.

Overall, HTSHR offers a practical model for reconciling endangered wildlife recovery, local livelihoods and the protection of the OUV of the Thung Yai–Huai Kha Khaeng World Heritage property. Effective buffer-zone management should combine clear rules, targeted patrolling, community participation, transparent benefit-sharing, local guide training and continued ecological monitoring. This approach can help transform the buffer zone from a contested resource-use landscape into a shared conservation asset that supports both wildlife recovery and local stewardship.

CONCLUSIONS

This study evaluated buffer-zone management interventions in the HTSHR and showed that the transition from unregulated access to a registration system was associated with positive behavioural and spatial responses by endangered banteng. By restricting forest access to daylight hours and reducing nocturnal disturbance, the management system created more predictable conditions for wildlife. Banteng shifted from a strongly nocturnal activity pattern under high human disturbance to a more cathemeral pattern, suggesting reduced temporal avoidance and greater use of open-canopy foraging habitats along the reservoir edge. The findings also highlight the limitations of relying on enforcement alone in landscapes where conservation objectives overlap with livelihood-based forest use. Active patrolling remains important for law enforcement, safety and the prevention of illegal activities, but may be insufficient to reduce livelihood-driven forest entry and may contribute to disturbance if not carefully targeted. In HTSHR, improved conditions for banteng were more closely linked to regulated access, livestock removal, community adherence to agreed rules and locally meaningful incentives from community-based wildlife tourism. Overall, this study demonstrates that temporally predictable human access, when embedded within collaborative governance, can support wildlife habitat recovery in a World Heritage buffer landscape. The HTSHR case provides a practical model for balancing sustainable resource use, local livelihoods and threatened species conservation while contributing to the protection of the Outstanding Universal Value of the Thung Yai–Huai Kha Khaeng World Heritage property.

ABOUT THE AUTHORS

Nantachai Pongpattananurak is an Associate Professor in the Department of Forest Biology, Faculty of Forestry, Kasetsart University, Thailand. His research focuses on tropical forest ecology, wildlife ecology, habitat management and protected area management.

Nuttapong Kongraphan is the Superintendent of the Huai Thap Salao–Huai Rabam Non-Hunting Area, Department of National Parks, Wildlife and Plant Conservation, and a Master's student at Kasetsart University. His research focuses on wildlife habitat management and plant–herbivore dynamics.

Natthanicha Chookaew is a Master's student in Forest Biological Science at Kasetsart University, Thailand. Her research focuses on mammal ecology, wildlife management and conservation.

Sangsan Phumsathan is an Associate Professor in Parks, Recreation, and Tourism, Department of Conservation, Faculty of Forestry, Kasetsart University, Thailand. Her research focuses on protected area tourism, wildlife tourism management, and community participation in conservation landscapes.

REFERENCES

Azlan, J. M. & Sharma, D. S. K. (2006). The diversity and activity patterns of wild felids in a secondary forest in Peninsular Malaysia. *Oryx*, 40(1), 36–41. https://doi.org/10.1017/S0030605306000147

Chaiyarat, R., Sriphonkrang, N., Khamsirinan, P., Nakbun, S. & Youngpoy, N. (2024). *Morphology manual of banteng (Bos javanicus) in Thailand*. Nakhon Pathom: Mahidol University. (In Thai)

Chankhao, A., Kraichak, E., Phumsathan, S. & Pongpattananurak, N. (2022). Dynamics of forage and management implications for large herbivore habitat in seasonally dry forest of Southeast Asia. *Forests*, 13(9), 1463. https://doi.org/10.3390/f13091463

Chookaew, N., Phumsathan, S., Simcharoen, A., Duangchantrasiri, S. & Pongpattananurak, N. (2026). Seasonal variation in banteng density and habitat use across protected areas and buffer zones in western Thailand. *Nature Conservation, [In press]*.

Chutipong, W., Lynam, A. J., Steinmetz, R., Savini, T. & Gale, G. A. (2014). Sampling mammalian carnivores in western Thailand: issues of rarity and detectability. *Raffles Bulletin of Zoology*, 62, 521–535.

Dudley, N. (Ed.) (2008). *Guidelines for applying protected area management categories*. Gland, Switzerland: IUCN. https://portals.iucn.org/library/node/9243

Gardner, P., Hedges, S., Pudyatmoko, S., Gray, T. N. E. & Timmins, R. J. (2016). *Bos javanicus*. *The IUCN Red List of Threatened Species* 2016, e. T2888A46362970. https://doi.org/10.2305/IUCN.UK.2016-2.RLTS.T2888A46362970.en

Gaynor, K. M., Hojnowski, C. E., Carter, N. H. & Brashares, J. S. (2018). The influence of human disturbance on wildlife nocturnality. *Science*, 360(6394), 1232–1235. https://doi.org/10.1126/science.aar7121

Gray, T. N. E., Prum, S., Pin, C. & Phan, C. (2012). Distance sampling reveals Cambodia's Eastern Plains landscape supports the largest global population of the endangered banteng *Bos javanicus*. *Oryx*, 46(4), 563–566. https://doi.org/10.1017/S0030605312000567

Groenenberg, M. & Gray, T. N. E. (2025). *Bos javanicus* (amended version of 2024 assessment). The IUCN Red List of Threatened Species 2025, e.T2888A270543638. https://doi.org/10.2305/IUCN.UK.2025-1.RLTS.T2888A270543638.en

IUCN. (2025). Conservation Outlook Assessment: Thungyai - Huai Kha Khaeng Wildlife Sanctuaries. IUCN World Heritage Outlook. Gland, Switzerland: IUCN. Retrieved from https://worldheritageoutlook.iucn.org/explore-sites/thungyai-huai-kha-khaeng-wildlife-sanctuaries

Jornburom, P., Duangchantrasiri, S., Jinamoy, S., Pattanavibool, A., Hines, J., Arnold, T., Fieberg, J. & Smith, J. (2020). Habitat use by tiger prey in Thailand's Western Forest Complex: what will it take to fill a half-full tiger landscape? *Journal for Nature Conservation*, 58, 125896. https://doi.org/10.1016/j.jnc.2020.125896

Kawanishi, K., Sahak, A. M. & Sunquist, M. (1999). Preliminary analysis on abundance of large mammals at Sungai Relau, Taman Negara. *Journal of Wildlife and Parks (Malaysia)*, 17, 62–82.

Laundré, J. W., Hernández, L. & Ripple, W. J. (2010). The landscape of fear: Ecological implications of being afraid. *The Open Ecology Journal*, 3(3), 1–7. https://doi.org/10.2174/1874213001003030001

Martin, O. & Piatti, G. (2008). *World Heritage and Buffer Zones* (World Heritage Papers 25). Paris: UNESCO World Heritage Centre.

Newmark, W. D., Leonard, N. L., Sariko, H. I. & Gamassa, D. G. M. (1994). Conservation attitudes of local people living adjacent to protected areas in Tanzania. *Biological Conservation*, 63(2), 177–183. https://doi.org/10.1016/0006-3207(94)90003-5

Pan, D., Teng, L., Cui, F., Zeng, Z., Bravery, B. D., Zhang, Q. & Song, Y. (2011). Eld's deer translocated to human-inhabited areas become nocturnal. *Ambio,* 40, 60–67. https://doi.org/10.1007/s13280-010-0108-2

Phumsathan, S. (2026). *High-value wildlife tourism: Management under the dynamics of sustainability.* Chulalongkorn University Press. (In Thai).

Phumsathan, S., Daonurai, K., Kraichak, E., Sungkaew, S., Teerawatananon, A. & Pongpattananurak, N. (2022). Effects of fire on diversity and aboveground biomass of understory communities in seasonally dry tropical forest in western Thailand. *Sustainability*, 14(22), 15067. https://doi.org/10.3390/su142215067

Phumsathan, S., Pongpattananurak, N., Udomwitid, S., Chaisawasaree, T., Chotiwuttakorn, K., Kraichak, E., Chaiyarat, R., Tunhikorn, S., Waipanya, S. & Simcharoen, A. (2025). *Strategies and policy recommendations for sustainable wildlife tourism management in the area of Huai Thap Salao – Huai Rabam Development Project*, Uthai Thani Province, Bangkok: Faculty of Forestry, Kasetsart University. (In Thai)

Phumsathan, S., Pongpattananurak, N., Udomwitid, S., Chaisawataree, T., Kraichak, E. & Sungkaew, S. (2022). *Research for strengthening government policy in buffer zone management in the establishing area of Huai Thab Salao–Huai Ra Bam Non-Hunting Area, Uthai Thani Province. Final report*. Bangkok, Thailand: National Science and Technology Development Agency (NSTDA). (In Thai)

Phumsathan, S., Thongwijit, K., Simcharoen, A., Suksavate, W., Kraichak, E., Chankhao, A. & Pongpattananurak, N. (2024). Factors affecting habitat use of Asian elephants for buffer zone management and conservation of the Huai Kha Khaeng World Heritage Site, Thailand. *Global Ecology and Conservation*, 56, e03302. https://doi.org/10.1016/j.gecco.2024.e03302

Pongpattananurak, N. (2020). *Wildlife habitat management plan for Nang Ram Valley and the Thap Salao Valley in Huai Kha Khaeng Wildlife Sanctuary and Thap Salao Forest – Huai Khok Kwai National Forest.* Bangkok, Thailand: Faculty of Forestry, Kasetsart University. (In Thai)

Royal Gazette. (2019). *Wildlife Preservation and Protection Act, B.E. 2562 (2019).* Thailand: Royal Gazette. https://www.ratchakitcha.soc.go.th/DATA/PDF/2562/ A/071/T_0001.PDF

Saisamorn, A., Duangchantrasiri, S., Sornsa, M., Suksavate, W., Pattanavibool, A. & Duengkae, P. (2024). Recovery of globally threatened ungulate species in Huai Kha Khaeng Wildlife Sanctuary, Thailand. *Global Ecology and Conservation*, 53, e03012. https://doi.org/10.1016/j.gecco.2024.e03012

Simcharoen, A., Savini, T., Gale, G. A., Simcharoen, S., Duangchantrasiri, S., Pakpien, S. & Smith, J. L. D. (2014). Female tiger *Panthera tigris* home range size and prey abundance: important metrics for management. *Oryx*, 48(3), 370–377. https://doi.org/10.1017/S0030605312001408

Tropical Ecology, Assessment and Monitoring Network (TEAM) (2008). *Terrestrial vertebrate (camera trap) monitoring protocol implementation manual*. Arlington, VA, USA: Conservation International.

UNESCO. (1991). Huai Kha Khaeng Wildlife Sanctuary. *World Heritage List*. https://whc.unesco.org/en/list/591/

UNESCO. (2023). *Operational Guidelines for the Implementation of the World Heritage Convention*. Paris: UNESCO World Heritage Centre.

Wildlife Tourism Community Enterprise of Rabam Subdistrict. (2025). *Annual operation report 2025.* Rabam Subdistrict Administrative Organization, Lan Sak District, Uthai Thani Province, Thailand.

RESUMEN

La gestión de las interacciones entre las personas y la fauna silvestre en las zonas de amortiguación es esencial para la conservación de la megafauna en aquellos lugares donde los objetivos de conservación se solapan con los medios de vida locales. Evaluamos las intervenciones de gestión en el paisaje de Huai Kha Khaeng, en Tailandia, declarado Patrimonio de la Humanidad, tras la retirada del ganado, comparando las respuestas del banteng (Bos javanicus), especie en peligro de extinción, en condiciones de acceso no regulado (Año 1) y de acceso solo durante el día mediante registro (Año 2). Mediante el uso de cámaras de vigilancia en 99 ubicaciones, evaluamos la abundancia relativa del banteng, su actividad diurna y nocturna y el uso del hábitat en relación con la actividad humana. La actividad del banteng pasó de ser principalmente nocturna en el Año 1 a ser menos nocturna en el Año 2, con una distribución más amplia que incluía zonas con menor cobertura del dosel arbóreo y mejor forraje cerca del borde del embalse. La actividad del banteng alcanzó su punto álgido durante la estación seca, cuando los aldeanos eran menos propensos a salir a recolectar setas. La actividad del banteng se asoció negativamente con la actividad humana y era más probable que se produjera a mayor distancia de la aldea. A pesar de las patrullas diurnas de los guardabosques, los aldeanos eran menos activos a cierta distancia de las rutas de patrulla y continuaban con sus actividades nocturnas durante la recolección de setas. Estos hallazgos indican que el acceso regulado, el acuerdo comunitario y los incentivos significativos pueden favorecer la recuperación del comportamiento y el uso del hábitat por parte de la fauna silvestre amenazada. La gobernanza colaborativa, respaldada por el turismo de fauna silvestre de base comunitaria, ofrece una vía para equilibrar la conservación, los medios de vida y la gestión a largo plazo en los paisajes de zona de amortiguación del Patrimonio Mundial.

RÉSUMÉ

La gestion des interactions entre l'homme et la faune sauvage dans les zones tampons est essentielle pour la conservation de la mégafaune lorsque les objectifs de conservation entrent en conflit avec les moyens de subsistance locaux. Nous avons évalué les mesures de gestion mises en œuvre dans le site du patrimoine mondial de Huai Kha Khaeng, en Thaïlande, après le retrait du bétail, en comparant les réactions du banteng (Bos javanicus), espèce menacée, dans un contexte d'accès non réglementé (année 1) et d'accès autorisé uniquement pendant la journée et soumis à enregistrement (année 2). À l'aide de caméras de surveillance installées à 99 emplacements, nous avons évalué l'abondance relative des bantengs, leur activité diurne et nocturne ainsi que leur utilisation de l'habitat en fonction de l'activité humaine. L'activité des bantengs, principalement nocturne au cours de la première année, est devenue moins nocturne au cours de la deuxième année, avec une distribution plus étendue incluant des zones présentant un couvert forestier moins dense et un meilleur fourrage près des berges du réservoir. L'activité des bantengs a atteint son pic pendant la saison sèche, lorsque les villageois étaient moins enclins à partir à la cueillette de champignons. L'activité des bantengs était négativement corrélée à l'activité humaine et plus fréquente à mesure que l'on s'éloignait du village. Malgré les patrouilles diurnes des gardes forestiers, les villageois étaient moins actifs à distance des itinéraires de patrouille et poursuivaient leurs activités nocturnes pendant la cueillette des champignons. Ces résultats indiquent qu'un accès réglementé, un accord communautaire et des incitations significatives peuvent favoriser le rétablissement des comportements et l'utilisation de l'habitat par la faune menacée. Une gouvernance collaborative, soutenue par un tourisme faunique communautaire, offre une voie permettant de concilier conservation, moyens de subsistance et gestion durable dans les zones tampons des sites du patrimoine mondial.



ANIMATION-BASED COMMUNICATION, EDUCATION AND PUBLIC AWARENESS FOR COLLABORATIVE MANAGEMENT IN HOANG LIEN NATIONAL PARK, VIETNAM

Ho Ngoc Son*, Nguyen Dang Cuong

* Corresponding author: hongocson@tuaf.edu.vn

Institution: Thai Nguyen University of Agriculture and Forestry

ABSTRACT

Effective communication, education and public awareness (CEPA) are essential for collaborative management of protected areas, particularly in culturally and linguistically diverse contexts where conventional, lecture-based approaches often have limited impact. This paper presents a practice-based case study from Hoang Lien National Park, an ASEAN Heritage Park in northern Vietnam, examining the use of animation-based communication as a CEPA tool to support biodiversity awareness and stakeholder engagement. Between 2023 and 2025, a short, multilingual animation was co-developed using locally relevant storytelling and visual representations of the park's ecosystems and was integrated into training and outreach activities with park staff, teachers, and ethnic minority communities in the buffer zone. Data from pre- and post-training assessments, participant evaluations, focus group discussions and direct observations indicate improved understanding of biodiversity values and climate change impacts, high levels of engagement, and positive perceptions of the approach compared to conventional communication methods. The animation also supported dialogue between park authorities and local communities by providing an accessible basis for discussion. The findings suggest that culturally adapted animation can be a useful and scalable addition to CEPA strategies in protected areas facing linguistic diversity and varying literacy levels, when embedded within facilitated and participatory engagement processes.

Keywords: biodiversity awareness, protected area management, ASEAN Heritage Parks

INTRODUCTION

Protected areas are central to global biodiversity conservation efforts and their effectiveness increasingly depends on the quality of engagement between management authorities and local communities (Bennett et al., 2017; Carlsson & Berkes, 2005; Sterling et al., 2017). Beyond biodiversity protection, contemporary protected area governance is expected to address social equity, cultural heritage and climate resilience, particularly in landscapes where people and nature are closely intertwined (Sangha et al., 2025). In such contexts, communication, education and public awareness (CEPA) practices are widely recognised as foundational mechanisms for fostering shared understanding, trust and collaborative management *(Bennett et al., 2017; CBD, 2020; UNESCO, 2017)*. By integrating storytelling, visuals and emotions, animation makes complex ecological concepts more accessible and engaging, especially for non-specialist audiences (Dahlstrom, 2014; Sowards et al., 2017). Evidence suggests that locally context-driven, visual and story-based messages are more effective than abstract, text-heavy methods in capturing attention and encouraging engagement (Bennett et al., 2017).

Despite growing awareness of the importance of participatory communication, CEPA activities in many protected areas still rely on traditional methods such as presentations, printed materials and one-way information delivery. These methods prioritise information delivery over participation and often overlook linguistic diversity, varying literacy levels and culturally relevant learning approaches (Bennett et al., 2017; Reed et al., 2018). Consequently, they often have limited impact on stakeholder engagement, perceived

https://doi.org/10.2305/ZVKB2763

legitimacy and long-term governance (Bennett et al., 2017; Reed et al., 2018; Sterling et al., 2017).

In culturally diverse contexts, animation offers additional advantages by incorporating local languages, symbols and storytelling traditions, thereby connecting scientific and Indigenous Knowledge Systems (Bloomfield & Manktelow, 2021). This could strengthen trust and legitimacy – key elements of cooperative governance (Dahlstrom, 2014; Fischhoff & Scheufele, 2014; Tsang, 2023). Despite this potential, the use of animation as a CEPA tool in protected area management has not been fully studied in the conservation field (Bloomfield & Manktelow, 2021; Sowards et al., 2017).

These limitations are particularly evident in developing countries, especially Southeast Asia, where protected areas often overlap with the territories of Indigenous Peoples and ethnic minority communities (Berkes, 2009; Sikor & Chan, 2007). In such a context, communication must adapt to a multilingual environment, strong oral traditions and diverse knowledge systems. This requires CEPA approaches that are participatory, culturally-driven and emotionally engaging, rather than purely technical (Bennett et al., 2017). However, empirical evidence for such approaches in ASEAN Heritage Parks remains limited (Sterling et al., 2017).

Hoang Lien National Park (HLNP) in northern Vietnam provides a relevant context to address this gap. Designated as an ASEAN Heritage Park, the park is characterised by high biodiversity and significant cultural and linguistic diversity. The park and its buffer zone are home to multiple ethnic minority groups whose livelihoods and cultural identities are closely linked to forest ecosystems. HLNP faces increasing pressures from climate change, tourism development and resource use, underscoring the need for inclusive and effective conservation communication (Hoang & Wesseler, 2024; Sikor & Chan, 2007).

Previous CEPA activities in the park largely relied on standardised training materials and lecture-based approaches (Bennett et al., 2017; Reed et al., 2018). Stakeholder consultations prior to this study indicated that these methods were often perceived as overly theoretical, insufficiently engaging, and poorly adapted to local realities, particularly for community members with limited Vietnamese language proficiency. Similar challenges have been documented in other protected areas, where communication approaches fail to resonate with local audiences and reinforce perceptions of top-down management (Kirschke & Kosow, 2025).

This paper presents a case study of an animation-based communication initiative implemented in HLNP as part of a broader CEPA and capacity-building programme. The paper is intended as a practical contribution for protected area managers, CEPA practitioners, and educators working in culturally and linguistically diverse contexts. It examines how a culturally adapted, multilingual animation was designed, implemented and used in real management settings, and what outcomes were observed in terms of understanding, engagement and dialogue among park staff, teachers and local communities. The paper examines what worked and did not work, and why, and reflects on the conditions under which animation-based communication can add value to existing CEPA approaches. By documenting applied experience from an ASEAN Heritage Park, the study aims to provide transferable lessons to inform the design and integration of innovative, inclusive CEPA tools in protected areas facing similar communication and governance challenges, and is one of the first empirical, practice-based evaluations of animation-based CEPA tools in an ASEAN Heritage Park context.

METHODS

Research design

The study was implemented between December 2023 and May 2025 in HLNP and its buffer zone. A mixed-methods approach was employed, combining descriptive quantitative data from training assessments with qualitative insights from participant feedback, focus group discussions and direct observation.

Given the project timeframe, the study focused on short-term and intermediate CEPA outcomes, including improved understanding, engagement and willingness to participate in collaborative conservation efforts.

Study area and context

HLNP is located in Lao Cai Province in northern Vietnam, within the Hoang Lien Son mountain range near the border with China (Figure 1). The park covers approximately 29,845 hectares and encompasses steep mountainous terrain, diverse forest ecosystems, and elevations ranging from low montane areas to the summit of Mount Fansipan, the highest peak in Indochina. Owing to its outstanding ecological significance, HLNP was designated as an ASEAN Heritage Park, reflecting its regional importance for biodiversity conservation and ecosystem services.

The park and its surrounding buffer zone are home to several ethnic minority groups, notably the H'Mong, Dao, Giay and Tay. These communities maintain close socio-cultural and economic relationships with forest

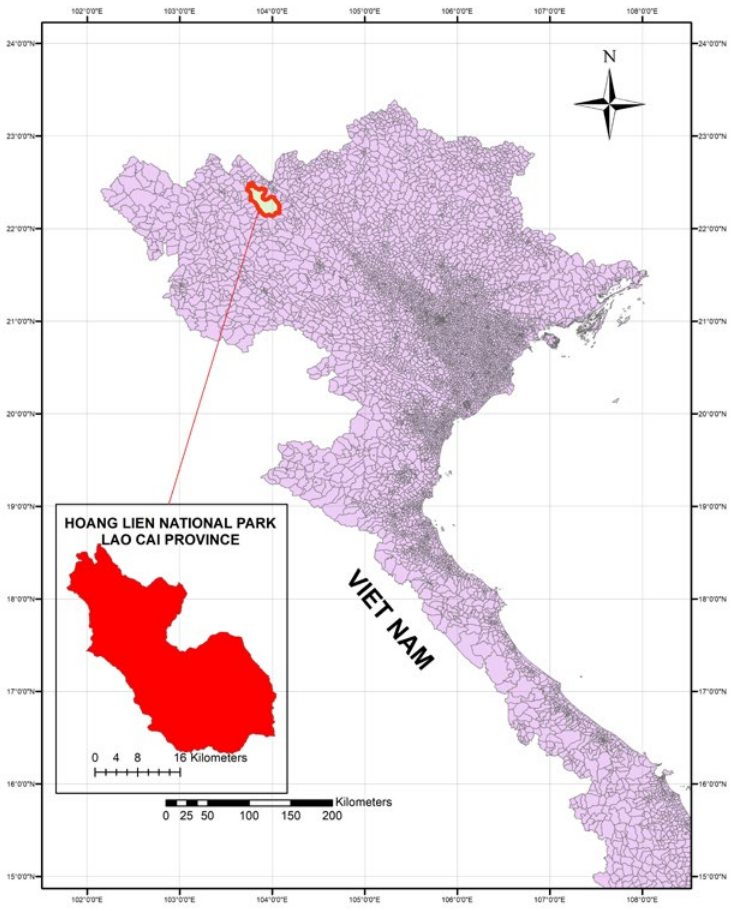


Figure 1. Study location. Acknowledgement: This work was supported by the funding from ASEAN Centre for Biodiversity: [Grant Number 2023 VNM HLNP 28].

ecosystems through traditional agricultural practices, collection of non-timber forest products, and cultural rituals linked to natural landscapes. Livelihood options in the buffer zone remain limited, and many households are classified as poor or near-poor, with increasing dependence on natural resources and vulnerability to environmental and economic shocks.

Management of HLNP faces the dual challenge of conserving biodiversity while addressing the livelihood needs and aspirations of local communities. While community-based forest protection groups and ecotourism initiatives have contributed to improved relations in recent years, tensions persist due to restrictions on resource use and limited participation of local people in decision-making processes. These challenges are further compounded by climate change, which has intensified extreme weather events, affected agricultural productivity, and increased pressures on forest ecosystems (Dudley, 2008; Ervin et al., 2010).

Communication and engagement between park authorities and local communities have historically relied on conventional training and awareness-raising activities, often delivered through lectures, printed materials and technical language. Stakeholder consultations conducted prior to this study indicated that these approaches were frequently perceived as overly theoretical, insufficiently engaging and poorly adapted to local contexts. Language barriers posed a particular challenge, as many community members have limited proficiency in Vietnamese and rely primarily on oral communication.

Teachers and local educators were identified as potential multipliers for conservation awareness, however they reported limited access to engaging and locally relevant teaching materials on biodiversity and climate change. Park staff similarly highlighted constraints in communication skills and tools when working with diverse stakeholder groups. These gaps underscored the need for alternative CEPA approaches capable of addressing linguistic diversity, varying literacy levels and culturally embedded ways of learning.

Development of the animation-based CEPA tool

An animation-based communication tool was developed and implemented as part of a broader capacity-building and community outreach initiative in HLNP between 2023 and 2025. The animation was integrated into a series of training and awareness-raising activities targeting three main stakeholder groups: (i) park management staff and personnel from associated conservation and tourism units; (ii) primary and secondary school teachers; and (iii) local households living in the park's buffer zone. The tool was developed through an iterative and participatory process involving conservation practitioners, educators, and representatives from HLNP. The design process was guided by three core principles: cultural relevance, accessibility, and clarity of conservation messages *(Dahlstrom, 2014; Fischhoff & Scheufele, 2014)*.

The animation aimed to communicate (i) the natural and cultural values of HLNP, (ii) observed and projected impacts of climate change on local biodiversity, and (iii) the importance of collective action and collaboration in conservation. Storytelling techniques were used to translate scientific concepts into relatable narratives, drawing on local ecological symbols and culturally familiar elements. Key characters were inspired by emblematic species and landscapes of the park, serving as narrative anchors to convey conservation messages.

To address linguistic diversity and literacy constraints, the animation was produced in multiple language formats: a H'Mong-language version with Vietnamese

Table 1. Overview of the animation-based CEPA

Component	Description
Study period	December 2023 – May 2025
Protected area	Hoang Lien National Park (ASEAN Heritage Park)
Target groups	Park staff; teachers; buffer-zone community members
Number of participants	90 (53 men, 37 women)
Animation format	7-minute animated film
Languages	H'Mong (with Vietnamese subtitles); Vietnamese (with English subtitles); Vietnamese
Key themes	Biodiversity values; climate change impacts; collaborative conservation
Delivery mode	Animation screening followed by facilitated discussion
Complementary materials	Posters, leaflets, discussion prompts

subtitles, a Vietnamese-language version with English subtitles, and a Vietnamese-only version (Table 1). The narrative structure and visual symbolism are intentionally designed to reflect the local cultural context, supporting both understanding and intercultural coexistence among different ethnic groups.

The animation lasted approximately seven minutes, balancing content richness with attention spans identified during preliminary consultations.

Despite efforts to ensure diverse participation, the proportion of men participating remains slightly higher (59 per cent). This reflects local dynamics, where men are more frequently involved in formal training activities. However, this imbalance is acknowledged as a limitation, particularly considering the significant role women play in household-level decision-making regarding the use of natural resources.

Data collection

Data collection focused on capturing changes in understanding, engagement and perceptions related to the animation-based CEPA intervention. *Community perception surveys are a robust approach to understanding local attitudes and tailoring communication strategies (Parker et al., 2022).* Four main data sources were used:

Simple assessment tools were administered before and after training sessions to gauge changes in participants' understanding of biodiversity values, climate change impacts and conservation concepts. Pre- and post-training assessments consisted of short, structured tools with 6–8 questions covering key concepts on biodiversity values, climate change impacts and conservation roles. Depending on participant literacy, assessments were administered either orally or in simple written form using a three-point self-assessment scale ("do not understand", "partly understand", "understand well"). End-of-training evaluation forms used similar structured questions and open-ended prompts to capture perceptions of clarity, engagement and usefulness of the animation compared to previous communication approaches.

Focus group discussion (FGD) participants were purposively selected to represent different stakeholder groups and gender balance, and each discussion lasted approximately 60–90 minutes. FGDs with community members were conducted primarily in H'Mong with support from local facilitators, while those with teachers and park staff were conducted in Vietnamese. Qualitative data from FGDs and observation notes were coded thematically by the research team, with coding categories discussed and refined jointly to ensure consistency and shared interpretation. Given the practice-based aim of the study, analysis focused on identifying clear patterns and recurring themes rather than exhaustive qualitative saturation.

Researchers documented observations during training sessions, noting participant engagement, interaction patterns, and responses to the animation and facilitated discussions. These observations provided contextual insights that complemented self-reported data.

Data analysis

Quantitative data from pre- and post-training assessments and evaluation forms were analysed using descriptive statistics, focusing on changes in reported understanding and perceived effectiveness across stakeholder groups. Given the exploratory and practice-based nature of the study, no inferential statistical tests were applied.

Qualitative data from FGDs and observations were analysed using thematic analysis (Clarke & Braun, 2017). Transcripts and notes were coded inductively to identify recurring themes related to comprehension, engagement, cultural relevance and implications for collaborative management. Themes were then compared across stakeholder groups to identify convergences and differences in perceptions.



Figure 2. Teachers' training workshop using animation screening. Credit: Authors.

RESULTS

Participant profile and stakeholder coverage

The animation-based CEPA intervention reached 90 participants across three key stakeholder groups involved in protected area management and conservation outreach in HLNP. These included 30 park staff, 20 teachers and 40 community members from buffer zone villages of Hoang Lien commune. Participants represented a mix of genders and age groups, with ethnic minority participants constituting all community participants and a substantial proportion of teachers and park staff.

Community participants were predominantly from H'Mong ethnic groups and were largely dependent on small-scale agriculture and forest-related livelihoods. Many reported limited formal education and relied primarily on oral communication in their daily lives.

Teachers and park staff generally had higher education levels but reported limited access to engaging, locally adapted materials for biodiversity and climate change communication.

Perceived effectiveness of animation-based communication

Across all stakeholder groups, participants rated the animation-based approach as more effective and engaging than previous communication methods used in the park.

Participants consistently reported that the visual storytelling format made information easier to understand. Community members emphasised that seeing familiar landscapes, species and cultural elements helped them grasp abstract concepts such as biodiversity loss and climate change. Teachers and park staff noted that animation reduced reliance on technical language and facilitated clearer explanations.

The animation was described as holding participants' attention more effectively than lectures or printed materials. Participants reported higher levels of discussion and interaction following the animation screening, particularly during community training sessions (Figure 2). Observations during training confirmed increased participation, with more questions and shared reflections compared to sessions relying solely on verbal explanations.

The use of local symbols, culturally resonant narratives and multilingual formats was highlighted as a key strength. Community participants, especially those with limited Vietnamese proficiency, reported that the H'Mong-language version enabled them to fully understand conservation messages without relying on translation. Teachers and park staff similarly valued the ability to switch between language versions depending on audience needs.

Overall, participants across all groups expressed strong support for continued use of animation-based tools in future awareness-raising and training activities.

Table 2. Summary of key outcomes by stakeholder group

Stakeholder group	Main outcomes observed	Illustrative implications
Park staff	Improved confidence in communication; better engagement	Use animation in routine outreach
Teachers	Enhanced understanding; high teaching potential	Integrate into school curricula
Community members	Improved awareness; reduced resistance	Use as entry point for dialogue

Differences in responses across stakeholder groups

While all groups responded positively to the animation-based approach, differences emerged in how participants perceived and intended to use the tool.

Park staff viewed the animation primarily as a strategic communication tool to support outreach, training and engagement with communities and visitors. Many reported increased confidence in communicating conservation messages and expressed intentions to integrate the animation into routine training and public awareness activities (Table 2).

Teachers emphasised the animation's potential as an educational resource. They highlighted its suitability for short classroom sessions and extracurricular activities and noted that students were likely to respond positively to the visual and narrative format. Some teachers, however, indicated the need for supplementary teaching guides to maximise educational impact.

Community members focused on the animation's role in improving understanding and trust. Participants reported that the animation made conservation messages feel less directive and more relatable, reducing perceptions of top-down instruction. Several participants noted that the animation helped them better understand why conservation rules exist and how environmental changes affect their livelihoods. These differences reflect the varied roles and expectations of stakeholder groups but also illustrate the flexibility of animation-based communication as a CEPA tool.

Contribution to collaborative management and dialogue

Beyond individual learning outcomes, the animation-based intervention contributed to improved dialogue and collaboration between stakeholders. Park staff and community participants reported that the animation created a shared reference point for discussion, making conversations about conservation more open and less confrontational. Facilitated discussions following animation screenings revealed increased willingness among community members to share concerns, ask questions and discuss practical challenges related to conservation and livelihoods.

Teachers and park staff highlighted that the animation helped bridge gaps between scientific knowledge and local experience, fostering mutual respect and understanding. In several training sessions, discussions extended beyond biodiversity awareness to broader issues of climate resilience, sustainable livelihoods and community participation in park management. While these outcomes do not constitute direct evidence of behavioural change, they indicate positive intermediate CEPA outcomes that support collaborative management processes.

Observed limitations and challenges

Despite the overall positive reception, several limitations and challenges were identified. First, while awareness and understanding improved, translation into immediate action was limited among some community participants, particularly where livelihood constraints and external pressures persisted. Second, the effectiveness of facilitated discussions depended on the skills of trainers and the availability of local translators, highlighting the importance of complementary capacity building. Finally, participants noted that animation alone is insufficient and should be embedded within a broader CEPA strategy that includes follow-up activities, practical demonstrations and institutional support.

DISCUSSION

Animation-based communication as an effective CEPA tool

This study demonstrates that animation-based communication can serve as an effective CEPA tool for protected area management in ethnically and linguistically diverse contexts. Across all stakeholder groups including park staff, teachers and local communities, the animation improved understanding of biodiversity values and climate change impacts, enhanced engagement and facilitated more constructive dialogue (Berkes, 2009; Carlsson & Berkes, 2005). These outcomes align with the core objectives of CEPA, which emphasise not only information transfer but also participation, mutual learning and empowerment (Dahlstrom, 2014; Green et al., 2004; Tsang, 2023).

Conventional CEPA approaches in protected areas often rely on technical language and unidirectional communication, which can alienate non-specialist

audiences and reinforce power imbalances between authorities and communities. Research has emphasised the value of accessible, culturally grounded, and participatory approaches to environmental knowledge communication (Carlsson & Berkes, 2005; Reed et al., 2018; Sterling et al., 2017). Consistent with these perspectives, the animation used in this study translated scientific concepts into accessible narratives grounded in local cultural and ecological contexts. This supports previous findings that visual storytelling can improve comprehension and retention of environmental information, particularly where literacy levels are uneven and oral traditions are strong (Dahlstrom, 2014).

Beyond accessibility, animation contributes to intercultural learning by integrating symbols, stories and perspectives with local significance into conservation communication. The use of culturally familiar narrative structures allows participants from different ethnic groups to relate conservation messages to their own experiences and knowledge systems (Dahlstrom, 2014; Green et al., 2004). Visual elements reduce reliance on written explanations, enabling communication to overcome language barriers and facilitating mutual understanding among stakeholders with diverse linguistic backgrounds (Bennett et al., 2017; Bloomfield & Manktelow, 2021). In this sense, animation serves not only as a communication tool but also as a vehicle for intercultural dialogue and a bridge of knowledge (Berkes, 2009; Sowards et al., 2017; Tsang, 2023).

The effectiveness of the animation did not stem solely from its visual appeal, but from its cultural adaptation and multilingual design. The use of the H'Mong language and locally meaningful symbols enabled community participants to engage directly with conservation messages, rather than receiving them through intermediaries. This suggests that animation-based tools can help address long-standing challenges in CEPA related to language barriers and cultural disconnects (Dahlstrom, 2014; Green et al., 2004; Tsang, 2023).

Changes in understanding of biodiversity and climate change

Park staff (n = 30), 100 per cent reported improved understanding after training, with 67 per cent stating they could understand and apply the knowledge, and 33 per cent reporting improved conceptual understanding. No participants reported difficulty in understanding the content after the training. Teachers (n = 20), 55 per cent reported confidence in applying the knowledge to teaching, while 45 per cent reported improved understanding but needed further support. Teachers consistently highlighted the animation as a useful teaching aid that simplified complex ecological concepts and stimulated student interest. Community participants (n = 40), over 80 per cent reported a clear understanding of the key messages after the intervention, compared to less than 30 per cent before training. No participants reported a lack of understanding, suggesting that the animation effectively communicated core concepts even in low-literacy contexts.

Implications for collaborative protected area management

Beyond awareness-raising, the animation-based intervention contributed to improved dialogue and perceptions of collaboration between park authorities and local communities (Berkes, 2009; Sowards et al., 2017). This suggests that animation can act as a boundary object, facilitating communication between different knowledge systems, languages and cultural contexts, while maintaining a common point of reference for discussion (Da Silva et al., 2024).

Protected area governance increasingly recognises the importance of collaborative management approaches that involve local communities as partners rather than passive recipients of conservation rules (Sangha et al., 2025). However, meaningful collaboration requires mutual understanding and trust, which are often undermined by communication gaps (Baldauf, 2020). By providing a non-confrontational and relatable medium for discussing conservation issues, the animation helped create a more open space for dialogue.

The observed increase in community willingness to ask questions and share concerns suggests that animation-based CEPA tools may help reduce perceptions of top-down management. While the study did not assess long-term governance outcomes, these intermediate CEPA effects, such as improved communication, trust and shared understanding, are widely recognised as necessary precursors to effective collaboration and compliance in protected area management (de Koning et al., 2016).

These findings suggest that animation-based communication not only improves comprehension but also reshapes the way stakeholders interact. By shifting from information transmission to interactive learning, this approach aligns with participatory communication models that emphasise dialogue, collaborative learning and social learning processes (Reed et al., 2018). This reinforces the role of CEPA not only as an awareness-raising tool but also as a mechanism for enhancing governance processes.

Table 3. What worked, what did not, and why

Aspect	What worked	What did not work	Explanation
Animation content	Visual storytelling; local symbols	Some concepts still abstract	Requires facilitation
Language	H'Mong version highly effective	Translation time-consuming	Needs local support
Engagement	High participation	Limited immediate action	Livelihood constraints
Facilitation	Interactive discussion	Uneven facilitation quality	Staff capacity varies

Education, multipliers and scaling potential

Teachers emerged as a particularly important stakeholder group in this study, highlighting the potential of animation-based tools to support conservation education beyond the boundaries of the protected area. Teachers reported that the animation simplified complex concepts and stimulated interest, making it suitable for classroom use and extracurricular activities. This reinforces the role of educators as key multipliers in CEPA strategies (Ballard et al., 2024; UNESCO, 2017).

Integrating animation-based communication into formal and informal education systems can extend the reach and longevity of conservation messages. In the context of ASEAN Heritage Parks, where resources for continuous outreach are often limited, such tools offer cost-effective opportunities for scaling. Once developed, animations can be reused, adapted and shared across different contexts with relatively low additional costs.

However, teachers also noted the need for complementary materials, such as lesson plans and discussion guides. This underscores that animation should not be viewed as a standalone solution, but as part of a broader CEPA toolkit that supports different learning styles and institutional contexts.

Addressing climate change communication in protected areas

Community participants' improved understanding of climate-related impacts suggests that animation can support more grounded and locally relevant climate communication (Parker et al., 2022). By linking climate change to familiar landscapes and livelihoods, the animation made abstract concepts more tangible. This is consistent with research showing that place-based climate communication enhances relevance and engagement (Bloomfield & Manktelow, 2021; Tsang, 2023).

Improved understanding does not automatically translate into adaptive action. As observed in this study, livelihood constraints and structural factors limit communities' capacity to respond to climate risks, regardless of awareness levels. This highlights the need to integrate CEPA with broader livelihood support, adaptation planning and policy measures (Rakotobe et al., 2023).

What worked, what did not, and why

Several factors contributed to the success of the animation-based approach in this case. These included its cultural relevance, multilingual design, short and focused format, and integration into interactive sessions. The animation worked particularly well as a conversation starter, lowering barriers to participation and enabling more inclusive dialogue.

However, awareness gains did not consistently translate into immediate action among community participants, reflecting broader livelihood and institutional constraints. The quality of outcomes also varied depending on facilitation skills and local support (Kirschke & Kosow, 2025) (Table 3). These findings reinforce that animation-based communication is not a substitute for participatory governance or livelihood interventions, but rather a complementary tool that can strengthen communication within existing management frameworks (de Koning et al., 2016; Rakotobe et al., 2023).

Contribution to conservation practice

This study contributes to conservation practice by providing empirical, practice-based evidence on the use of animation as a CEPA tool in protected area management. It moves beyond theoretical discussions of communication by demonstrating how culturally adapted animation can be designed, implemented and integrated into real-world conservation contexts.

By documenting both strengths and limitations, the study supports more informed decision-making by protected area managers and practitioners. It also highlights the value of documenting and publishing applied conservation experiences, which are often underrepresented in peer-reviewed literature despite their practical significance.

While this study is grounded in the specific socio-cultural and institutional context of HLNP, many of the conditions shaping its outcomes are shared by other ASEAN Heritage Parks, including high cultural and linguistic diversity, increasing tourism pressures and

growing exposure to climate-related risks. Context-specific elements of the intervention include the choice of language, cultural symbols and locally meaningful narratives, all of which must be adapted to the histories and identities of individual parks and communities.

The process of co-developing animation-based CEPA tools, grounded in local consultation, multilingual delivery and facilitated dialogue, is transferable across protected areas facing similar communication challenges. In parks where staff must engage with multiple stakeholder groups and balance conservation objectives with livelihood and tourism concerns, animation can provide a flexible entry point for discussion and learning (Parker et al., 2022). While language and cultural content must be locally adapted, the design principles, implementation process and integration of animation into broader CEPA strategies can be applied across ASEAN Heritage Parks and protected areas beyond the region, provided adequate facilitation capacity and institutional support are in place (Rakotobe et al., 2023).

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

This study demonstrates that animation-based communication can play a valuable role in strengthening CEPA in protected areas characterised by cultural and linguistic diversity. Using HLNP as a case study, the research provides practice-based evidence that culturally adapted animation can improve understanding of biodiversity values and climate change impacts, enhance stakeholder engagement, and support more constructive dialogue between park authorities and local communities.

The findings suggest that animation is particularly effective in overcoming common barriers to conservation communication, including language differences, uneven literacy levels and limited familiarity with technical concepts. By combining visual storytelling with locally relevant narratives and multilingual formats, the animation enabled diverse stakeholder groups to engage more directly with conservation messages.

From a management perspective, several implications emerge. First, protected area authorities should consider integrating animation-based tools into formal CEPA strategies, rather than treating them as stand-alone products (CBD, 2020; Reed et al., 2018). Animation can complement existing approaches, such as community meetings, school-based education and visitor interpretation, by providing a consistent and accessible communication resource.

Second, cultural and linguistic adaptation should be prioritised in the design of CEPA tools. The effectiveness of the animation in this study was closely linked to its use of local languages, symbols and storytelling traditions. Protected area managers working in ethnically diverse settings should allocate time and resources for participatory design processes that involve local stakeholders from the outset.

Third, capacity building for facilitators and educators is essential. The animation proved most effective when embedded within interactive sessions that encouraged discussion and reflection. Investment in communication and facilitation skills among park staff and partner organisations can significantly enhance the impact of such tools.

While this study focused on short-term CEPA outcomes, it highlights the potential of animation-based communication to contribute to longer-term conservation objectives when combined with supportive policies, livelihood interventions and participatory governance mechanisms. Future research could explore the long-term effects of animation-based CEPA on behaviour change, compliance with conservation regulations and ecological outcomes.

In conclusion, animation-based communication offers a flexible, inclusive and scalable CEPA tool for protected area management. For ASEAN Heritage Parks and other protected areas facing similar challenges, investing in culturally adapted visual storytelling can enhance conservation communication, strengthen collaboration and support more resilient and socially inclusive conservation outcomes.

ABOUT THE AUTHORS

Dr Ho Ngoc Son is currently a Professor in Indigenous knowledge and Climate change adaptation at the Thai Nguyen University of Agriculture and Forestry. In addition to university teaching, Dr Son leads research and development projects related to climate change, forestry and biodiversity conservation.

Dr Nguyen Dang Cuong is a researcher at Thai Nguyen University of Agriculture and Forestry, Vietnam focussing on the application of GIS and remote sensing in biodiversity conservation, forest management, and sustainable land-use planning.

REFERENCES

Baldauf, C. (Ed.). (2020). *Participatory biodiversity conservation: Concepts, experiences, and perspectives*. Springer.

Ballard, H. L., Lindell, A. J., & Jadallah, C. C. (2024). Environmental education outcomes of community and citizen science: a systematic review of empirical research. *Environmental Education Research*, *30*(6), 1007–1040. https://doi.org/10.1080/13504622.2024.2348702

Bennett, N. J., Roth, R., Klain, S. C., Chan, K. M. A., Christie, P., Clark, D. A., Cullman, G.,

Curran, D., Durbin, T. J., Epstein, G.,… Wyborn, C. (2017). Conservation social science: Understanding and integrating human dimensions to improve conservation. *Biological Conservation, 205*, 93–108. https://doi.org/10.1016/j.biocon.2016.10.006

Berkes, F. (2009). Community conserved areas: Policy issues in historic and contemporary context. *Conservation Letters, 2*(1), 19–24. https://doi.org/10.1111/j.1755-263X.2008.00040.x

Bloomfield, E. F., & Manktelow, C. (2021). Climate communication and storytelling. *Climatic Change,* 167 (34). https://doi.org/10.1007/s10584-021-03199-6

Carlsson, L., & Berkes, F. (2005). Co-management: Concepts and methodological implications.

Journal of Environmental Management, 75(1), 65–76. https://doi.org/10.1016/j.jenvman.2004.11.008

Clarke, V., & Braun, V. (2017). Thematic analysis. *Journal of Positive Psychology*, 12 (3), 297–298.

Convention on Biological Diversity. (2020). *Communication, education, and public awareness (CEPA) programme*. CBD Secretariat. https://www.cbd.int/cepa/

Dahlstrom, M. F. (2014). Using narratives and storytelling to communicate science with nonexpert audiences. *Proceedings of the National Academy of Sciences, 111*(Suppl. 4), 13614–13620. https://doi.org/10.1073/pnas.1320645111

Da Silva, M. J. F., Minhos, T., & Sampaio-Dias, S. (2024). News for nature: Communicating biodiversity importance and conservation challenges in Guinea-Bissau, West Africa, through local media and online platforms. *Conservation Science and Practice*, 6 (1), e13051. https://doi.org/10.1111/csp2.13051

de Koning, M., Dobbelsteijn, R., Phommasane, S., & Sengchanthavong, S. (2016). Collaborative governance in Hin Nam No National Protected Area, Lao PDR: Lessons for multi-level protected area management. *PARKS, 22*(2). https://doi.org/10.2305/IUCN.CH.2016.PARKS-22-2MdK.en

Dudley, N. (Ed.) (2008). *Guidelines for applying protected area management categories*. Gland, Switzerland: IUCN. With Stolton, S., P. Shadie & N. Dudley (2013). *IUCN WCPA best practice guidance on recognising protected areas and assigning management categories and governance types*, Best Practice Protected Area Guidelines Series No. 21, Gland, Switzerland: IUCN.

Ervin, J., Sekhran, N., Dinu, A., Gidda, S., Vergeichik, M., & Mee, J. (2010**).** *Protected areas for the 21st century: Lessons from UNDP/GEF's portfolio. UNDP*. https://www.undp.org/sites/g/files/zskgke326/files/publications/PA_21Century.pdf

Fischhoff, B., & Scheufele, D. A. (2014). The science of science communication. *Proceedings of the National Academy of Sciences, 110*(Suppl. 3), 14031–14032. https://doi.org/10.1073/pnas.131208011

Green, M. C., Brock, T. C., & Kaufman, G. F. (2004). Understanding media enjoyment: The role of transportation into narrative worlds. *Communication Theory, 14*(4), 311–327. https://doi.org/10.1111/j.1468-2885.2004.tb00317.x

Hoang, H. D., & Wesseler, J. (2024). Decentralization of Vietnam's forestlands: The policy process and impact. *Land Use Policy*, 143, 107194. https://doi.org/10.1016/j.landusepol.2024.107194.

Kirschke, S., & Kosow, H. (2025). Exploring impacts of participatory science communication on science, society, and policy. *Frontiers in Communication, 10*. https://doi.org/10.3389/fcomm.2025.1566429

Parker, E., Allnutt, T. F., Aung, T. D., & Swe, T. (2022). Exploring community satisfaction around protected areas in Myanmar. *PARKS, 28*(2), 77–90. https://doi.org/10.2305/IUCN.CH.2022.PARKS-28-2BP.en

Rakotobe, D. J., Dabelko, G. D., & Stevens, N. J. (2023). Strengthening a resilient protected area workforce to advance the 30x30 goal: The case of Madagascar. *PARKS, 29*(2), 94–104. https://parksjournal.com/wp-content/uploads/2023/12/10.2305-KETW5223-Rakotobe.pdf

Reed, M. S., Vella, S., Challies, E., de Vente, J., Frewer, L., Hohenwallner-Ries, D., Huber, T.,

Neumann, R. K., Oughton, E. A., … van Delden, H. (2018). A theory of participation: What makes stakeholder and public engagement in environmental management work? *Restoration Ecology, 26*(S1), S7–S17. https://doi.org/10.1111/rec.12541

Sangha, K. K., Leyton-Flor, S. A., Conner, N., Bhardwaj, A., & Bhardwaj, A. K. (2025). Transforming conservation by understanding the role of Indigenous peoples and local communities and their economies. *Global Ecology and Conservation*, 64, e03949. https://doi.org/10.1016/j.gecco.2025.e03949.

Sikor, T., & Tran, N. T. (2007). Exclusive versus inclusive devolution in forest management: Insights from forest land allocation in Vietnam's Central Highlands. *Land Use Policy*, 24 (4), 644–653. https://doi.org/10.1016/j.landusepol.2006.04.006.

Sowards, S. K., Tarin, C. A., & Upton, S. D. (2017). Place-based dialogics: Adaptive cultural and interpersonal approaches to environmental conservation. *Frontiers in Communication, 2*. https://doi.org/10.3389/fcomm.2017.00009

Sterling, E. J., Betley, E., Sigouin, A., Gomez, A., Toomey, A., Cullman, G., Malone, C., Pekor, A., Arengo, F.,… Porzecanski, A. L. (2017). Assessing the evidence for stakeholder engagement in biodiversity conservation. *Biological Conservation, 209*, 159–171. https://doi.org/10.1016/j.biocon.2017.02.008

Tsang, S. J. (2023). Communicating climate change: The impact of animated data visualizations on perceptions of journalistic motive and media bias. *Journal of Broadcasting & Electronic Media*, *67*(2), 161–182. https://doi.org/10.1080/08838151.2023.2182788

UNESCO. (2017). *Education for Sustainable Development Goals: Learning objectives*. UNESCO Publishing. https://doi.org/10.54675/CGBA9153

RESUMEN

La comunicación, la educación y la sensibilización del público (CEPA) son esenciales para la gestión colaborativa de las áreas protegidas, especialmente en contextos cultural y lingüísticamente diversos, donde los enfoques convencionales basados en charlas suelen tener un impacto limitado. Este artículo presenta un estudio de caso basado en la práctica del Parque Nacional de Hoang Lien, un Parque del Patrimonio de la ASEAN situado en el norte de Vietnam, en el que se analiza el uso de la comunicación mediante animaciones como herramienta de CEPA para fomentar la sensibilización sobre la biodiversidad y la participación de las partes interesadas. Entre 2023 y 2025, se desarrolló conjuntamente una breve animación multilingüe utilizando narraciones relevantes para el contexto local y representaciones visuales de los ecosistemas del parque, que se integró en actividades de formación y divulgación dirigidas al personal del parque, al profesorado y a las comunidades de minorías étnicas de la zona de amortiguación. Los datos procedentes de evaluaciones previas y posteriores a la formación, valoraciones de los participantes, debates en grupos focales y observaciones directas indican una mejor comprensión de los valores de la biodiversidad y los impactos del cambio climático, altos niveles de participación y percepciones positivas del enfoque en comparación con los métodos de comunicación convencionales. La animación también favoreció el diálogo entre las autoridades del parque y las comunidades locales, al proporcionar una base accesible para el debate. Los resultados sugieren que la animación adaptada culturalmente puede ser un complemento útil y escalable de las estrategias de CEPA en áreas protegidas que se enfrentan a la diversidad lingüística y a distintos niveles de alfabetización, cuando se integra en actividades facilitadas y participativas.

RÉSUMÉ

Une communication, une éducation et une sensibilisation du public (CEPA) efficaces sont essentielles à la gestion collaborative des aires protégées, en particulier dans des contextes marqués par une grande diversité culturelle et linguistique où les approches conventionnelles, axées sur les exposés, ont souvent un impact limité. Cet article présente une étude de cas fondée sur la pratique, menée dans le parc national de Hoang Lien, un parc du patrimoine de l'ASEAN situé dans le nord du Vietnam, qui examine l'utilisation de la communication par l'animation comme outil CEPA pour favoriser la sensibilisation à la biodiversité et l'engagement des parties prenantes. Entre 2023 et 2025, une courte animation multilingue a été élaborée conjointement à partir de récits adaptés au contexte local et de représentations visuelles des écosystèmes du parc ; elle a ensuite été intégrée à des activités de formation et de sensibilisation destinées au personnel du parc, aux enseignants et aux communautés ethniques minoritaires de la zone tampon. Les données issues des évaluations avant et après la formation, des retours des participants, des discussions en groupes de réflexion et des observations directes indiquent une meilleure compréhension des valeurs de la biodiversité et des impacts du changement climatique, un niveau d'engagement élevé et des perceptions positives de cette approche par rapport aux méthodes de communication conventionnelles. L'animation a également favorisé le dialogue entre les autorités du parc et les communautés locales en fournissant une base accessible pour la discussion. Les résultats suggèrent qu'une animation adaptée à la culture locale peut constituer un complément utile et évolutif aux stratégies de CEPA dans les aires protégées confrontées à la diversité linguistique et à des niveaux d'alphabétisation variables, lorsqu'elle est intégrée dans des activités animées et participatives.

Traduit avec DeepL.com (version gratuite)
Traducción realizada con la versión gratuita del traductor DeepL.com



STATUS, PRESSURES AND MANAGEMENT PRIORITIES IN UPEMBA NATIONAL PARK, DEMOCRATIC REPUBLIC OF THE CONGO

Manuel Weber

* Corresponding author: manuel.weber@forgottenparks.org

Department of Research and Biomonitoring, Upemba National Park, Democratic Republic of the Congo

ABSTRACT

Upemba National Park in southern Democratic Republic of the Congo remains a high-conservation-value protected area for which recent ecological evidence has not been comprehensively synthesised. This paper assesses the park's current condition using published sources, grey literature, recent field records, camera-trap data, aerial observations and expert field knowledge. Upemba has lost multiple large mammals over the past seven decades, and surviving populations are small, localised and unevenly distributed. These remnant populations indicate partial resilience rather than ecological integrity. Available evidence suggests that depletion extends below visible megafauna and is associated with bushmeat extraction, recurrent anthropogenic fire, encroachment and wetland degradation, especially where effective control is weak. Under these conditions, the immediate conservation task is stabilisation rather than comprehensive recovery. Near-term management should prioritise protection of confirmed strongholds and recurrent -use areas for priority taxa, repeated monitoring of large mammals and hunting pressure, systematic fire monitoring, and targeted wetland sentinel sites. Research should focus on uncertainties that affect short-term management decisions. Upemba is highly endangered, but not yet lost; what remains is sufficient to justify focused stabilisation.

Key words: faunal depletion, bushmeat hunting, fire regime, wetland conservation, adaptive monitoring

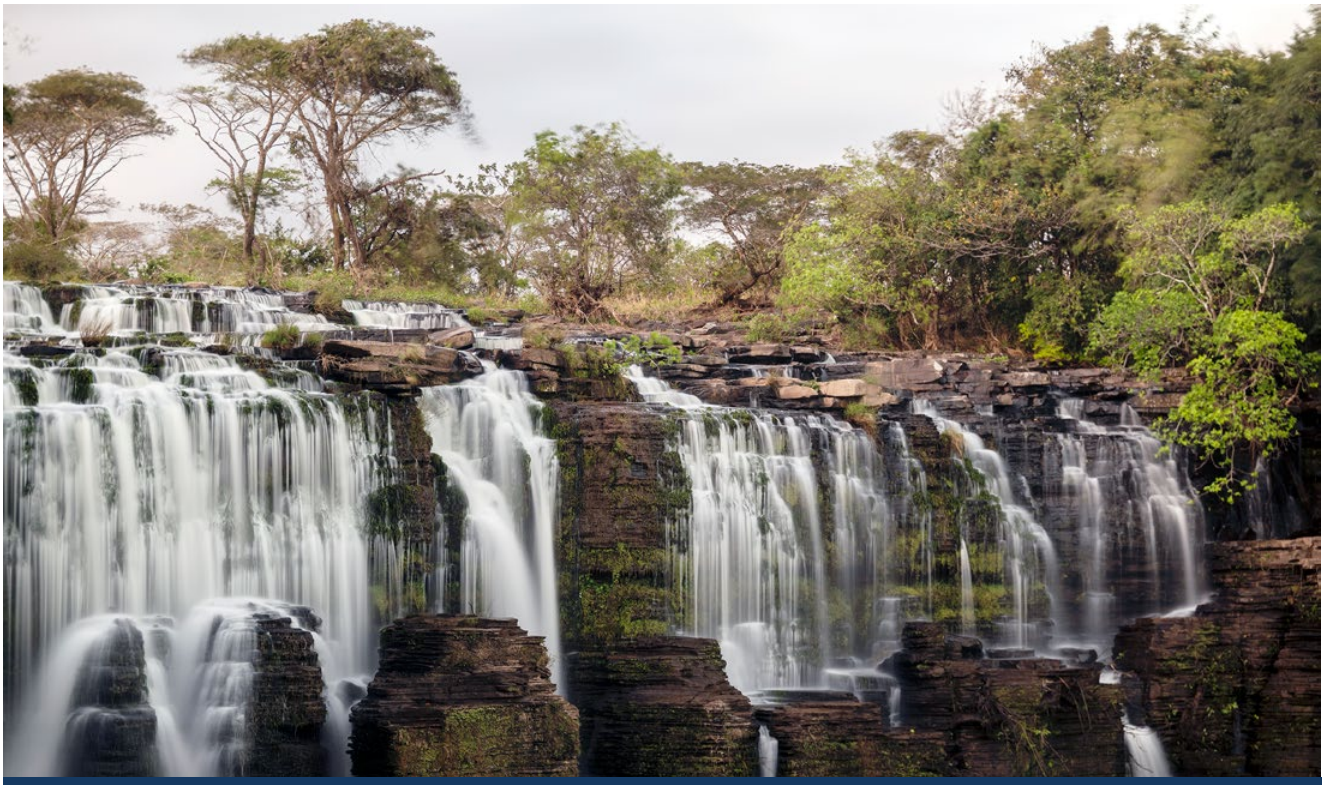
INTRODUCTION

Biodiversity continues to decline, even in protected areas, especially where management operates under insecurity, weak monitoring and poor information infrastructure (Craigie et al., 2010; Pulido-Chadid et al., 2023). In such contexts, the key conservation problem is not only biological but evidentiary: how should managers interpret ecosystem condition when the available knowledge is sparse, heterogeneous and biased towards a few visible species?

Upemba National Park is an acute example of that problem. This one-million-hectare national park in southern Democratic Republic of the Congo has high conservation value, but recent evidence on its ecological condition remains scattered across published sources, grey literature, internal records and field knowledge. Upemba still retains African elephant (*Loxodonta africana*), Grant's zebra (*Equus quagga boehmi*), sable (*Hippotragus niger kirkii*), Cape buffalo (*Syncerus caffer*), hippo (*Hippopotamus amphibius*) and the endemic Upemba lechwe (*Kobus anselli*), and for that reason can appear more intact than it is. However, several large mammals have been extirpated, surviving populations are small and localised, and there are strong indications that ecological erosion extends well below the level of visible megafauna.

Upemba's conservation significance is not limited to its surviving large mammals. The park comprises at least two biologically distinct systems, the Kibara and Manika grassland plateaus and the Kamalondo Depression wetlands (Fig. 1), which have localised and, in some cases, endemic biodiversity that remains much less well documented than the megafauna (Broadley & Cotterill, 2004; Cotterill, 2003, 2004, 2005, 2006; de Witte et al., 1966). Current evidence may therefore understate not only the degree of ecological erosion, but also the conservation importance of areas of the park whose value lies in neglected taxa.

https://doi.org/10.2305/WPJK4601



Falls on the Kalule Nord River near the Kayo substation, on the southern margin of Upemba National Park © Gwenn Dubourthoumieu/ Upemba National Park

Upemba's present condition reflects a long mismatch between legal protection and effective territorial control. Created by decree on 15 May 1939 as a *réserve naturelle intégrale* of approximately 1.15 million ha, its boundaries were already a compromise balancing wildlife protection, fisheries, concessionary mining interests and pre-existing local use rights (Décret du 15 mai, 1939; Derkinderen, 1955; Van Schuylenbergh, 2006). The 1946–1949 exploration of Upemba resulted in exceptionally detailed taxonomic documentation for the park, but did not address weak legitimacy (de Witte et al., 1966). After independence, Upemba was the Congolese park most affected by administrative collapse, reoccupation of former lands and intensified poaching (Prigogine, 1967; Verschuren, 1975). The 1975 boundary reform during a brief period of renaissance under Mobutu's Zaire partly acknowledged continued wetland use in the Kamalondo Depression by formalising the distinction between more enforceable plateau areas and a weakly controlled wetland periphery (Ordonnance No. 75/241, République du Zaïre, 1975; Verschuren, 1971). Since the early 2000s, the presence of Mai-Mai militia has strongly reduced management presence and wildlife populations, explaining why current evidence is spatially uneven and why conservation now depends on stabilising remnant biological cores, defined here as confirmed strongholds and recurrent-use areas for priority taxa, while rebuilding operational control (d'Huart, 1991; Hasson, 2003, 2015; Van Leeuwe et al., 2009).

This paper synthesises the current ecological state of the park by asking: what does the currently available evidence already justify in terms of assessing protected-area condition, identifying immediate management priorities, and defining targeted monitoring needs in Upemba? It reviews the status of the park's surviving large mammals, examines the main interacting pressures, and proposes a triaged management and research agenda. The central argument is that Upemba is neither intact nor lost, but a depleted, resilient and incompletely known protected area in which conservation must proceed before uncertainty is resolved.

METHOD

This study uses published literature, grey and internal reports, patrol and survey records, aerial observations, camera-trap records, and expert field knowledge accumulated through work in and around Upemba between September 2023 and February 2026 to synthesise the current condition of the park. The analysis addresses three linked questions: the current status of large mammals in and immediately around the park, the principal pressures currently affecting ecological condition, and the near-term management and research priorities justified by the available evidence. The aim is to derive a transparent, evidence-weighted interpretation of park condition and management priorities from incomplete and uneven knowledge.

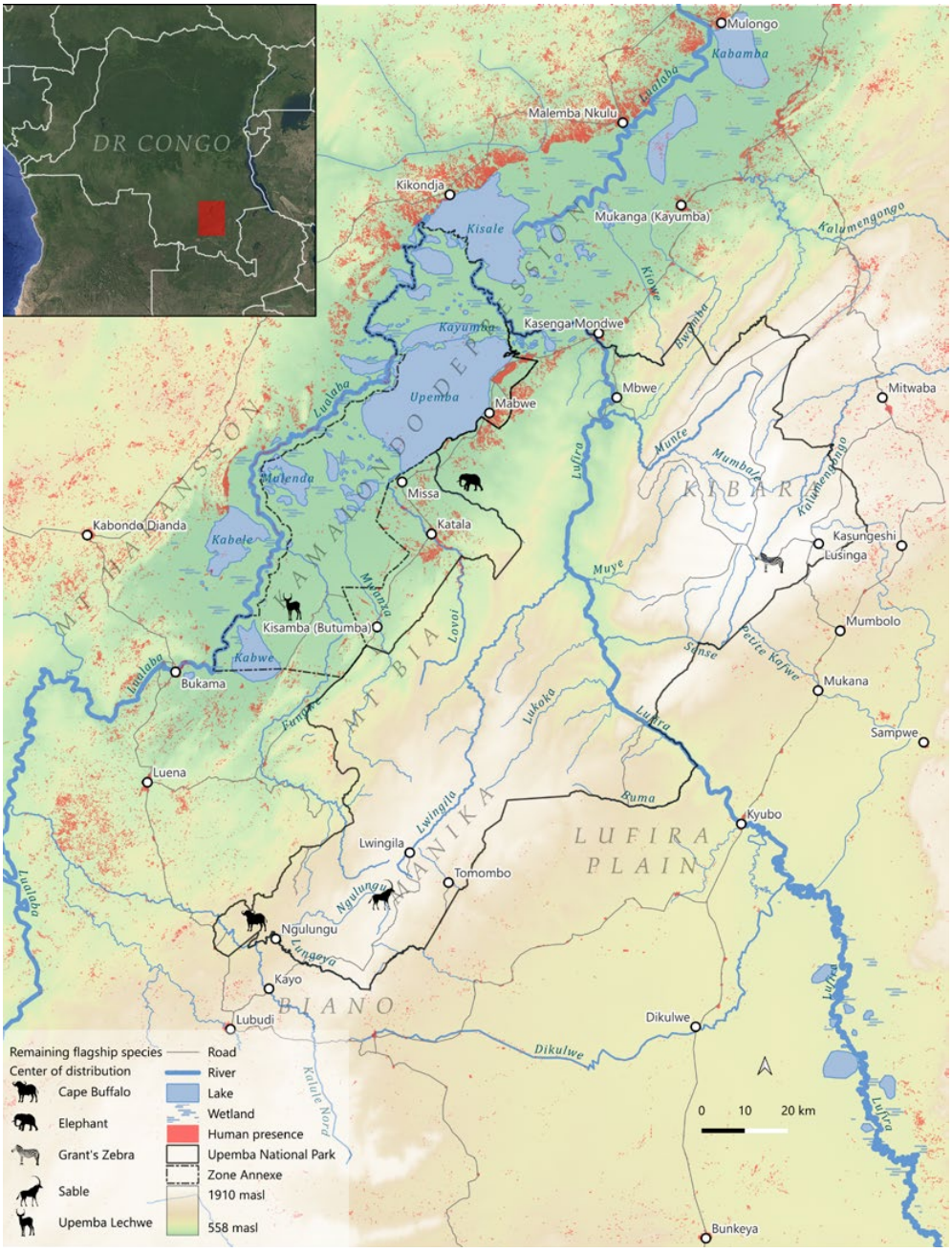


Figure 1. Main locations referred to in the text, protected-area boundaries in the Upemba landscape, and recent anthropogenic land-use signatures. Human-pressure areas combine mapped forest loss (2001–2024), built-up areas (2023) and cropland extent (2022) from Hansen et al. (2013), Sirko et al. (2024) and Lou et al. (2025). Species icons indicate approximate current centres of distribution rather than precise occurrence limits.

Figure 1 locates the principal places referred to in the text and situates recent human pressure within the wider Upemba landscape.

Recent evidence included camera-trap records from 27 sites on the Kibara Plateau, representing 14,203 camera-days accumulated between November 2023 and November 2025 (Alenga, 2025). Because these deployments were concentrated in plateau gallery-forest sites and were not designed as a park-wide occupancy or abundance survey, they were used only to confirm mammal persistence and describe detected species composition at sampled sites. Spatial context for recent anthropogenic pressures was derived from published geospatial works on forest loss, cropland extent and built-up areas, using Google Earth Engine (Gorelick et al., 2017), and used to visualise broad patterns of recent land-use pressure in the wider Upemba landscape. These layers were interpreted as spatial proxies for human pressure rather than as direct measures of ecological effect.

Species status assignments were expressed in five categories: extant, probably extant, possibly extant, probably extirpated and extirpated. ‘Extant’ was reserved for taxa with recent confirmed presence based on direct observations, photographs, camera-trap records, aerial counts or other documentary evidence judged reliable. ‘Probably extant’ was used where recent evidence remained credible but limited, indirect or spatially ambiguous. ‘Possibly extant’ was used for weak, isolated or unconfirmed recent records insufficient to

support stronger inference. 'Probably extirpated' was used where no recent confirmed record existed despite some residual uncertainty arising from older records or nearby occurrences. 'Extirpated' was used where no credible recent evidence existed over a period sufficient to make persistence highly unlikely in management terms. Evidentiary confidence was assigned independently of status category and reflects the strength, recency, directness and convergence of the available records. High confidence indicates recent confirmed records and/or repeated counts from reliable sources; moderate confidence indicates limited but credible recent evidence or convergence among several weaker sources; and low confidence indicates sparse, indirect, spatially ambiguous or weakly confirmed evidence. Where records were contradictory, greater weight was given to the most recent direct and spatially attributable evidence. Management priorities were derived from pressures that are spatially attributable, operationally actionable, and likely to cause further contraction of surviving biological cores. This approach does not rank all conservation needs in Upemba, but identifies the minimum set of stabilisation actions and monitoring targets justified by the current evidence.

This approach has several limitations. Detectability is uneven across taxa, observation effort has been spatially biased towards accessible areas of the park and known or suspected wildlife strongholds, and the evidentiary base is temporally discontinuous, with long gaps between periods of more systematic observation. Many recent records derive from targeted field presence rather than standardised sampling, so non-detection was not treated as evidence of absence except where supported by long-term absence of credible records, historical evidence of decline and management-relevant interpretation. Personal communications and expert field knowledge were used to update, contextualise or corroborate documentary evidence, but were not treated as sufficient on their own for high-confidence status assignments unless supported by direct observations, photographs, repeated observer agreement, aerial counts, camera-trap records or other independently interpretable evidence. The results should therefore be read as a triaged management synthesis.

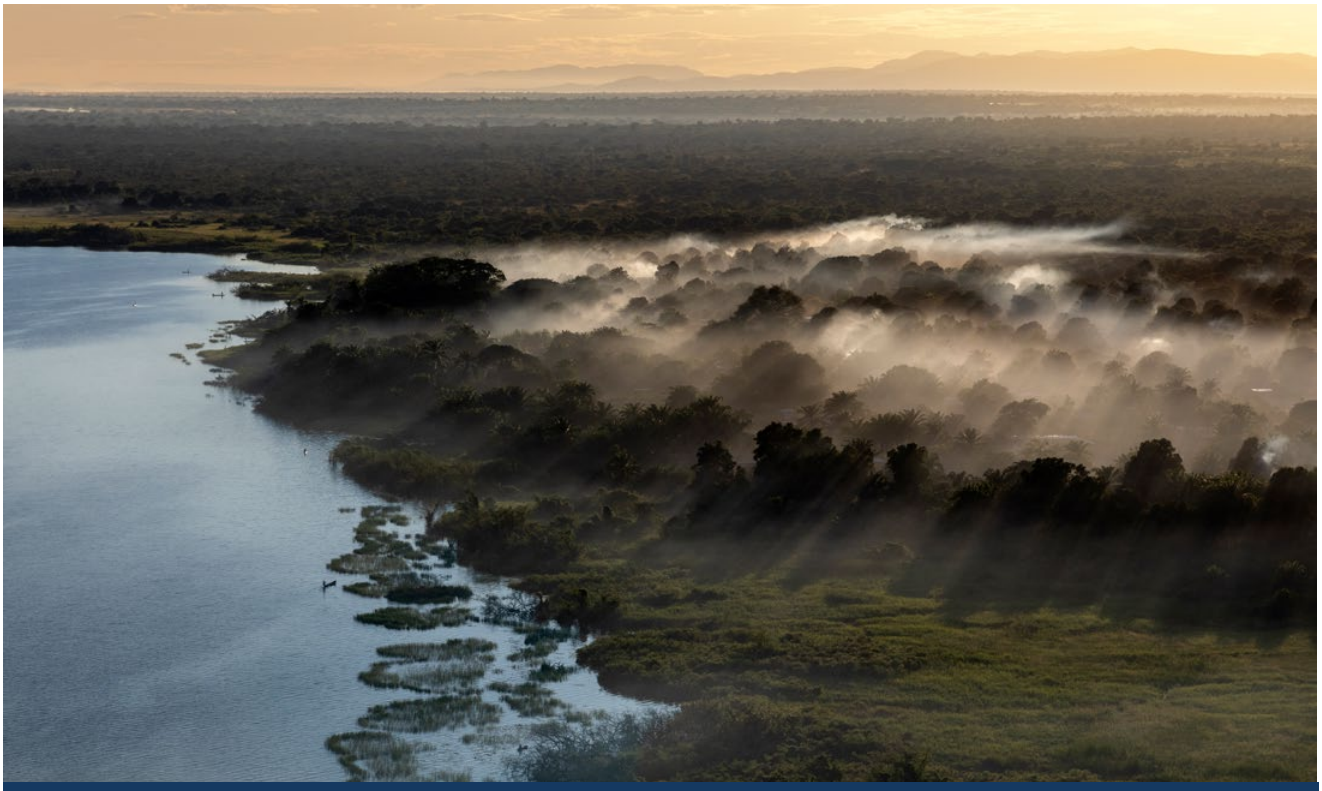
RESULTS

Upemba's large-mammal assemblage is severely reduced. Over roughly seven decades, the park appears to have lost black rhino (*Diceros bicornis*) first, followed by the large carnivores during the 1980s and 1990s, and then several large herbivores during the 1990s and 2000s (d'Huart, 1991; Hasson, 2003, 2015; Verschuren, 1975, 1987). No large-mammal population (>100 kg) is currently known to substantially exceed 200 individuals within this one-million-hectare park. Recent evidence confirms the persistence of elephant (*Loxodonta africana*), Upemba lechwe (*Kobus anselli*), hippo (*Hippopotamus amphibius*), Cape buffalo (*Syncerus caffer*), Grant's zebra (*Equus quagga boehmi*) and sable (*Hippotragus niger kirkii*), but all are small, localised or unevenly distributed. Elephants continue to move within and around the park despite the apparent breakdown of the former movement system through the Lufira Valley by the early 1990s (d'Huart, 1991; Hasson, 2015; Katembo, 2016, 2017; Mululwa, 2008). Upemba Lechwe remain highly localised and number fewer than 100 individuals according to the most recent aerial survey available to this assessment (Cotterill, 2005; Makabuza, 1972; Weber et al., 2025). Zebra show limited recovery from an extreme low point, although numbers remain far below historical levels (d'Huart, 1991; Hasson, 2003; Verschuren, 1975). Table 1 summarises the current management interpretation of large-mammal status, estimated population size within the park, and evidentiary confidence for each taxon, while Table S1 provides the principal species-specific evidence underlying those assignments and Figure S1 visualises the pattern.

Evidence from camera traps, field observations, historical mammal lists and bushmeat studies suggests that depletion is not limited to conspicuous large mammals, but non-detection should not be read as extinction. Historical mammal lists provide a wider baseline for the park's mammal community than is currently detected or regularly observed in recent fieldwork (Frechkop, 1954; Verheyen, 1951). Between November 2023 and November 2025, camera traps deployed across 27 gallery-forest sites on the Kibara Plateau accumulated 14,203 camera-days and recorded 7,596 detections of 22 mammal species, dominated by a relatively small set of medium-sized generalists including bushpig (*Potamochoerus larvatus*), warthog (*Phacochoerus africanus*), yellow baboon (*Papio cynocephalus*) and common reedbuck (*Redunca arundinum*; Alenga, 2025). Field observations indicate that extraction also includes low-value resources such as rodents and termites (Mbulanga, pers. comm.; pers. obs.). Regional demand is substantial: in Lubumbashi, the nearest major city, Tshikung et al. (2019) found that 86.6 per cent of respondents consumed bushmeat at least monthly. Historical accounts from the period of deepest institutional collapse also describe park rangers and their families competing with poachers for rodents as food (Van Leeuwe et al., 2009). These sources indicate that

Table 1. Current management interpretation of large-mammal status in Upemba National Park, based on the most recent available evidence, approximate current population size within the park, and evidentiary confidence. Status categories reflect current management interpretation. 'Extant' indicates recent confirmed presence; 'probably extant' indicates credible but limited recent evidence; 'possibly extant' indicates weak or unconfirmed recent evidence; 'probably extirpated' indicates no recent confirmed records despite residual uncertainty; and 'extirpated' indicates no credible recent evidence over a period sufficient to make persistence highly unlikely. 'Most recent evidence' refers to the latest credible record used in the assessment. Population estimates are approximate and confidence reflects the strength, recency and directness of the available evidence: high = recent confirmed records and/or repeated counts; moderate = limited but credible recent records; low = sparse, indirect or weakly confirmed recent evidence.

Species	Current status	Most recent evidence	Estimated current population in Upemba	Confidence
Black rhino (*Diceros bicornis*)	Extirpated	Last confirmed evidence in 1957; tracks in 1961	0	High
Cheetah (*Acinonyx jubatus*)	Extirpated	Last report from Upemba: 1983	0	High
African wild dog (*Lycaon pictus*)	Extirpated	Last confirmed report: 1986	0	High
Lion (*Panthera leo bleyenberghi*)	Extirpated	Last regular reports: 1991	0	High
Lichtenstein's hartebeest (*Alcelaphus lichtensteini*)	Probably extirpated	Last sighting in Upemba: 2003	0	Moderate
Livingstone's eland (*Taurotragus oryx livingstonii*)	Probably extirpated	Last tracks in/near park: 2013	0	Moderate
Roan antelope (*Hippotragus equinus cottoni*)	Possibly extant, unconfirmed	Tracks photographed near Lusinga in 2023	Unknown; if extant, very low	Low
Waterbuck (*Kobus ellipsiprymnus defassa*)	Possibly extant, very low numbers	Sighting in 2023; tracks in 2024	Very low; probably <20	Low
Spotted hyena (*Crocuta crocuta*)	Possibly extant, very low numbers	Sighting on southern plateau in 2024	Very low; probably <20	Low
Leopard (*Panthera pardus*)	Probably extant	No confirmed record after 2008	Unknown; probably very low	Low
Impala (*Aepyceros melampus katangae*)	Probably extant	Reports from Dikulwe area outside the park in 2018 and 2024	Unknown; probably very low	Low
Greater kudu (*Tragelaphus strepsiceros*)	Probably extant	No firm recent park record; latest evidence indirect	Unknown; probably low	Low
Sable (*Hippotragus niger kirkii*)	Extant	Repeated herd reports, 2021–2025	Probably <150	Moderate
Upemba lechwe (*Kobus anselli*)	Extant, highly threatened and localised	Aerial survey in March 2025	<100	High
Hippo (*Hippopotamus amphibius*)	Extant, very reduced and localised	Eight counted in January 2025; occasional additional reports	Probably <20	High
Elephant (*Loxodonta africana*)	Extant, mostly outside park	Sightings in and around park; regional pattern current to 2026	<100 in park	High
Cape buffalo (*Syncerus caffer*)	Extant, localised	Track counts and camera traps in 2024–2025	<50	High
Grant's zebra (*Equus quagga boehmi*)	Extant	Counts in 2024 and 2025	c. 200	High



Lake Upemba in the Kamalondo Depression is part of an extensive system of shallow lakes, marshes and seasonally flooded plains drained by the Lualaba (upper Congo). These wetlands have supported fishing, settlement and regional exchange for centuries, long before the creation of the national park. © Gwenn Dubourthoumieu/Upemba National Park

bushmeat extraction is not limited to large mammals and may continue even after larger-bodied wildlife has already been heavily reduced.

Fire is frequent, widespread and strongly seasonal in Upemba. Burning was already frequent on the Kibara Plateau in the 1940s (de Witte et al., 1966), and seasonal fire has likely shaped Katangan vegetation for centuries (Louette & Hasson, 2011). Current fire patterns, however, appear predominantly anthropogenic: the park is rich in water and intersected by gallery forests that act as firebreaks, while the annual concentration of fires during the dry season points strongly to human ignition due to the absence of lightning. The montane grasslands of Upemba are likely ancient, and drainage may be more decisive than fire in maintaining their openness (Meerts, pers. comm.). Remote-sensing indicates that annually burned area has increased since the beginning of the century, with over 80 per cent of the park now burning every year and hundreds of dry-season ignitions affecting the park annually (derived from Chuvieco et al., 2018). Published photographs from the 1940s do not show the same extent of tall, dense, unpalatable grasses that now dominate large parts of the plateau, and these grasses were probably less abundant in the 1980s than they are today (Hasson, pers. comm.). Field observations suggest an association between frequent burning and tall woody grasses, especially *Hyparrhenia* spp., which are not preferred by large herbivores, can suppress geophytes of conservation significance, and create high fuel loads (Balole, pers. comm.; Mujinga, pers. comm.; Munro, pers. comm.).

Fire is also linked to hunting. Historical sources describe fire being used to flush game (Delvaux, 1950), and recent field observations indicate that burning is used to smoke rodents out of burrows and to attract animals to fresh regrowth (Kabengele, pers. comm.; Mbulanga, pers. comm.; pers. obs.). These observations suggest that fire in Upemba functions both as a habitat disturbance and a hunting technology. Its ecological consequences remain incompletely understood, but repeated burning may reduce cover and food resources for rodents, reptiles and invertebrates, remove seeds and insect biomass used by birds, damage gallery-forest edges, and contribute to long-term nutrient loss or erosion. Because herbivore populations are now reduced, the interaction between fire, fuel accumulation and diminished grazing pressure is likely to differ from historical conditions.

Beyond poaching and fire, Upemba is affected by deforestation, charcoal extraction, agricultural expansion, settlement growth and wetland use, especially in and around the Kamalondo Depression. Current rates of deforestation, cultivation and urbanisation remain relatively low at landscape scale, but recent geospatial analyses suggest increasing local pressure, with road



Gallery forests following watercourses across the open grasslands of the Kibara Plateau. © Gwenn Dubourthoumieu/Upemba National Park

development likely to increase future risk (derived from Hansen et al., 2013; Lou et al., 2025; Sirko et al., 2024). These pressures are spatially important because several surviving wildlife populations are not concentrated in a remote park interior. Buffalo and zebra persist near the park's margins, elephants occur on and beyond the boundary along the Kamalondo Depression (Katembo, 2016, 2017), and the Upemba lechwe survives in the non-enforced Zone Annexe (Weber et al., 2025). Agricultural expansion, settlement growth and woody biomass extraction therefore overlap with areas used by remaining priority taxa.

Wetland pressure is important in the Kamalondo Depression. Although the Depression remains a highly productive fish landscape, decades of artisanal exploitation and destructive gears are associated with reduced fish biomass and size structure (Katemo Manda et al., 2022, 2023). Papyrus and other wetland plants are harvested for construction materials, weaving, food and medicine, adding pressure to marsh-edge habitats (Ilunga et al., 2023; Kasongo et al., 2022). Nutrient loading from settlements, upstream land use and mining may also be affecting the wetland. Given the shallow character of the lakes, with Lake Upemba not exceeding 3.2 metres during the dry season (Van Meel, 1953), nutrient enrichment, eutrophication and associated ecological shifts should be treated as plausible risks, although their current extent and trajectory remain poorly quantified (Walker et al., 2006). These processes are less visible than the decline of large mammals, but they may affect endemic and localised taxa, fisheries productivity, water quality and habitat suitability for both wildlife and people.

Historically, effective park control has been weak outside the plateau areas. The plateaus were fully controlled only during the 1940s, 1950s and 1970s. Around Lake Upemba and the Kamalondo Depression, the park was only present between 1947–1960, 1986–2004, and again since 2016. Park control gradually faded with each phase of absence and under increasing conditions of settlement growth, weak enforcement, and access negotiated through local chiefs (Mujinga, pers. comm., Hasson, pers. comm.; pers. obs.). The wetland periphery therefore differs from the plateau areas not only ecologically, but also institutionally. Current pressures and available evidence should therefore be interpreted against this spatially uneven history of access, use and control.

DISCUSSION

Upemba does not currently require a comprehensive recovery blueprint so much as a triaged programme for stabilisation. The large-mammal results show that the park is not biologically empty, but they also represent only the most visible component of a more depleted system. Elephants, Upemba lechwe, zebra, sable, buffalo and hippo remain important for management prioritisation, repeated monitoring and public communication, but their persistence should be interpreted as evidence of partial survival rather than

Table 2. Priority management pressures in Upemba National Park and corresponding near-term stabilisation responses. The table is intended as a triaged framework for stabilisation and monitoring rather than a comprehensive recovery plan.

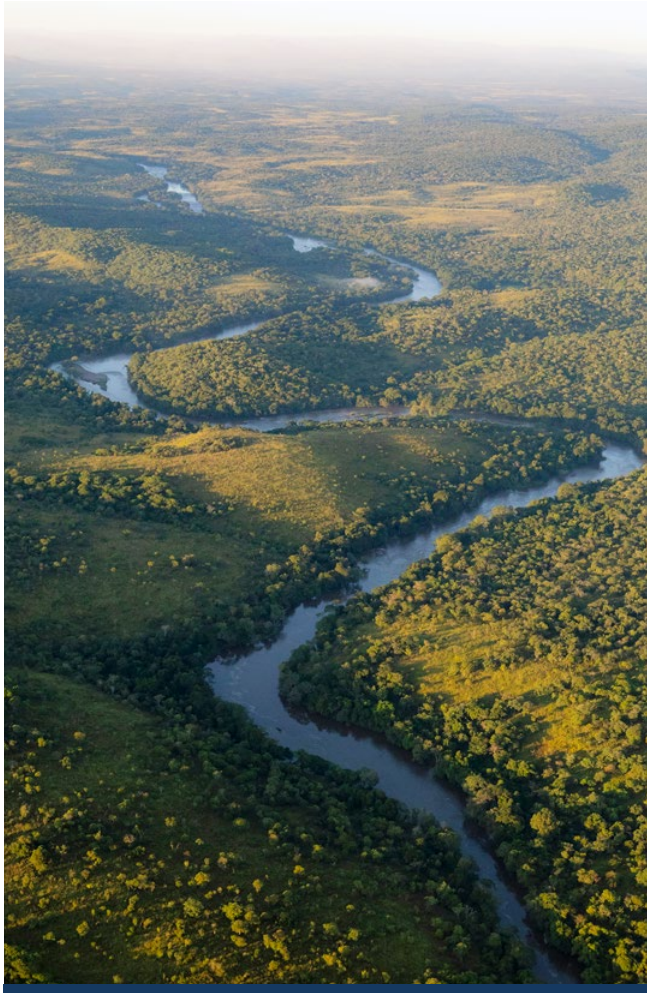
Pressure	Current indication in Upemba	Why it matters ecologically and managerially	Immediate management response
Large-mammal depletion and fragmentation	Multiple large mammals are extirpated, remaining populations persist at fractions of historical abundance (Hasson, 2003, 2015; Van Leeuwe et al., 2009).	Large mammal persistence shows that Upemba is not biologically empty, but current assemblages indicate severe simplification and fragmentation rather than ecological integrity.	Prioritise protection of confirmed strongholds and spatial connections; standardise surveys; avoid treating remnant presence as evidence of broad recovery.
Snaring and bushmeat extraction	Large-mammal status likely understates wider faunal erosion. The available material indicates strong dependence on bushmeat (Hasson, 2003; Tshikung et al., 2019; van Velden et al., 2018).	This is likely a major mechanism of faunal depletion below the level of conspicuous megafauna, affecting medium-sized mammals, prey bases and trophic interactions.	Treat likely prey-base depletion as a core management pressure, not only a subsistence issue; incorporate hunting indicators beyond large mammals.
Fire as hunting tool and habitat pressure	Fire is a key disturbance indicator and strongly associated with poaching (Amoako & Gambiza, 2022; Delvaux, 1950).	Fire is simultaneously an ecological, detectable, spatially attributable and operationally actionable pressure.	Zoning into control blocks delimited by gallery forests; integrate near-real-time detection with repeated seasonal review of burn patterns.
Deforestation, agricultural expansion, and settlement pressure	Deforestation, cultivation and settlement growth remain spatially concentrated, but increasing pressure (Hansen et al., 2013; Lou et al., 2025; Sirko et al., 2024).	Surviving fauna is often concentrated in boundary areas, encroachment thus affects refuge zones, movement routes and wildlife–human interfaces.	Develop participatory land-use planning and delimitation of encroachment fronts where full territorial reclamation is unrealistic, to prevent further expansion into the park.
Wetland degradation and eutrophication	The Kamalondo Depression is under pressure from artisanal fishing, papyrus harvesting, settlement growth and nutrient loading (Ilunga et al., 2023; Kasongo et al., 2022; Katemo Manda et al., 2022, 2023).	Wetland change could remain undetected, but may affect endemic and localised taxa (e.g. Weber et al., 2024), fisheries productivity, water quality, and habitat suitability for both wildlife and people.	Establish wetland sentinel sites and combine remote sensing with in-situ monitoring of water extent and condition, vegetation change, visible anthropogenic pressure, and key taxa where feasible.

ecological integrity. The immediate management task is therefore to prevent further contraction of the surviving biological core, especially confirmed strongholds and recurrent-use areas for priority taxa, while improving the evidentiary basis for future recovery.

The first implication is that monitoring should not remain centred only on conspicuous large mammals. The evidence reviewed here suggests that hunting pressure extends into smaller-bodied mammals and low-value resources, indicating that faunal depletion may continue below the level captured by elephant, zebra or lechwe records. Snaring and bushmeat extraction should therefore be treated as core ecological pressures. A minimal monitoring system should retain large mammals as priority indicators, but should also include hunting signs, snare encounter rates, camera-trap detections of medium-sized mammals, and repeated observations from areas where small-fauna depletion is suspected.

Fire should be treated as both a habitat pressure and an operational indicator. The results suggest that current burning is frequent, largely anthropogenic, and linked at least partly to hunting practices. Its ecological effects remain insufficiently quantified, but repeated dry-season burning may interact with reduced herbivory, tall grass fuel accumulation, geophyte loss, gallery-forest edge damage, and small-fauna depletion. Because fire can be mapped repeatedly and spatially attributed, it is one of the few pressures in Upemba that can support adaptive management at small spatial and temporal scales. A practical stabilisation strategy should combine satellite-based fire monitoring with ground checks of ignition points, burn recurrence, fuel structure, and post-burn habitat condition.

The Kamalondo Depression requires a different management logic from the plateau areas. On the plateaus, especially where field presence and access are stronger, stabilisation can focus on protection of



The Lufira River, the principal waterway in the park linking Upemba's plateau catchments to the wetlands of the Kamalondo Depression and the upper Lualaba. The Lufira served as elephant migration corridor until the 1990s. © Gwenn Dubourthoumieu/ Upemba National Park

remaining large-mammal strongholds, fire management and repeated patrol-linked monitoring. In the wetland periphery and Zone Annexe, where settlement, fishing, papyrus harvesting, agricultural expansion and negotiated access are more important, conservation cannot credibly be framed only as the recovery of full territorial control. The more realistic near-term objective is damage limitation through participatory land-use planning, protection of critical lechwe and wetland habitats, and sentinel monitoring of water, vegetation, fishing pressure and localised taxa.

Uncertainty should be treated selectively. For taxa such as leopard, impala, greater kudu, waterbuck, spotted hyena and possibly roan antelope, the immediate need is targeted confirmation rather than broad survey ambition. For wetlands, the priority is not an exhaustive limnological programme, but a small number of sentinel sites capable of detecting whether habitat condition in the most important areas is stable, deteriorating or approaching plausible thresholds of change. For fire, the priority is to link repeated burn patterns to fuel structure, herbivore absence, geophyte persistence, gallery-forest damage and small-fauna condition. Table 2 summarises these pressures and the corresponding near-term stabilisation responses.

Longer-term recovery will require a broader research and management agenda, especially on plateau vegetation change, landscape connectivity, wetland function, and endemic or otherwise neglected biodiversity whose status could alter conservation priorities. However, that agenda should follow stabilisation rather than substitute for it. Any future large-mammal reintroduction would probably be limited to the plateau areas and would require substantially stronger protection than currently exists. Natural recolonisation from remnant herbivore populations outside the park may be possible for some taxa (Hasson, pers. comm., Mujinga, pers. comm.).

CONCLUSIONS

Upemba is highly endangered, but not yet lost. It has lost multiple large mammals, its surviving populations are small and localised, and current pressures extend below the level of visible megafauna. Elephants, Upemba lechwe, zebra, sable, buffalo and hippo still persist, but their survival indicates partial resilience rather than ecological integrity. Bushmeat extraction, recurrent anthropogenic fire, encroachment and wetland degradation continue to erode the ecological base on which those remnant populations depend.

Upemba remains a high-priority protected area because a small but significant biological core persists under strong and interacting pressures. The most defensible near-term strategy is stabilisation: protecting surviving strongholds, monitoring the pressures most likely to contract them further, and concentrating research on uncertainties that affect short-term management decisions. Recovery may remain possible in parts of the system, but only if further erosion is first slowed or prevented.

ABOUT THE AUTHORS

Manuel Weber is research and biomonitoring advisor for Upemba National Park, Democratic Republic of Congo. His work focuses on the historical and contemporary ecology of the Upemba landscape and on measuring conservation management impact using interdisciplinary approaches in Upemba and beyond.
The author reports no financial conflict of interest. No external funding was received specifically for the preparation of this manuscript. orcid.org/0009-0002-4494-3708

REFERENCES

Alenga, Y. E. (2025). *Rapport du suivi de la biodiversité dans le Parc national de l'Upemba par camera traps* [Report].

Amoako, E. E., & Gambiza, J. (2022). Fire use practices, knowledge and perceptions in a West African savanna parkland. *PLoS ONE*, *17*(5), e0240271. https://doi.org/10.1371/journal.pone.0240271

Broadley, D. G., & Cotterill, F. P. D. (2004). The reptiles of southeast Katanga, an overlooked 'hot spot'. *African Journal of Herpetology, 53*(1), 35–61. https://doi.org/10.1080/21564574.2004.9635497

Chuvieco, E., Pettinari, M. L., Lizundia-Loiola, J., Storm, T., & Padilla Parellada, M. (2018). *ESA Fire Climate Change Initiative (Fire_cci): MODIS Fire_cci burned area pixel product, version 5.1* [Data set]. Centre for Environmental Data Analysis. https://doi.org/10.5285/58f00d8814064b79a0c49662ad3af537

Cotterill, F. P. D. (2003). Geomorphological influences on vicariant evolution in some African mammals in the Zambezi basin: Some lessons for conservation. In A. Plowman (Ed.), *Ecology and conservation of small antelope: Proceedings of an international symposium on duiker and dwarf antelope in Africa* (pp. 11–58). Filander Verlag.

Cotterill, F. P. D. (2004). Drainage evolution in south-central Africa and vicariant speciation in swamp-dwelling weaver birds and swamp flycatchers. *Honeyguide, 50*, 7–25.

Cotterill, F. P. D. (2005). The Upemba Lechwe, *Kobus anselli*: An antelope new to science emphasizes the conservation importance of Katanga, Democratic Republic of Congo. *Journal of Zoology*, *265*(2), 113–132. https://doi.org/10.1017/S0952836904006193

Cotterill, F. P. D. (2006). Taxonomic status and conservation importance of the avifauna of Katanga (south-east Congo Basin) and its environs. *Ostrich, 77*(1–2), 1–21. https://doi.org/10.2989/00306520609485502

Craigie, I. D., Baillie, J. E. M., Balmford, A., Carbone, C., Collen, B., Green, R. E., & Hutton, J. M. (2010). Large mammal population declines in Africa's protected areas. *Biological Conservation*, *143*(9), 2221–2228. https://doi.org/10.1016/j.biocon.2010.06.007

d'Huart, J.-P. (1991). *Conservation et réhabilitation des parcs nationaux des Kundelungu et de l'Upemba*. https://bakasbl.org/news/zoom.php5?id=31 [Report].

de Witte, G.-F., Adam, W., Janssens, A., Van Meel, L., & Verheyen, R. (1966). *Exploration du Parc national de l'Upemba. Mission G.-F. de Witte (1946–1949), fascicule 1: Introduction*. Bruxelles: Institut des Parcs Nationaux du Congo Belge.

Décret du 15 mai 1939 relatif à la création du Parc national de l'Upemba. (1939). Bulletin officiel du Congo belge, 15 June 1939, 306–313.

Delvaux, H. (1950). *L'occupation du Katanga 1891–1900 : Notes et souvenirs du seul survivant.* Imbelco.

Derkinderen, G. (1955). *Atlas du Congo Belge et du Ruanda-Urundi*. Preface by Pierre Ryckmans. Paris and Brussels: Elsevier.

Frechkop, S. (1954). *Mammifères* (*Exploration du Parc National de l'Upemba. Mission G.-F. de Witte [1946–1949], fascicule 14*). Brussels: Institut des Parcs Nationaux du Congo Belge.

Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D. & Moore, R. (2017). Google Earth Engine: Planetary-scale geospatial analysis for everyone. Remote Sensing of Environment, 202, 18–27. doi: 10.1016/j.rse.2017.06.031.

Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., Thau, D., Stehman, S. V., Goetz, S. J., … Townshend, J. R. G. (2013). High-resolution global maps of 21st-century forest cover change. *Science, 342*(6160), 850–853. https://doi.org/10.1126/science.1244693

Hasson, M. (2003). *Upemba, le parc oublié*. Brussels: Nouvelles Approches.

Hasson, M. (2015). *Katanga: Des animaux et des hommes. Vol. 1: Les animaux et la société*. Tervuren: Musée royal de l'Afrique centrale.

Ilunga, P., Kitenge, S., & Kasongo, J. (2023). *Rapport flore Upemba* [Report]. Lubumbashi: Institut Congolais pour la Conservation de la Nature.

Kasongo, J., Kabuya, K., & Ilunga, P. (2022). *Rapport sur la diversité des produits forestiers non ligneux (PFNLs) du bassin du lac Upemba* [Report]. Lubumbashi: Institut Congolais pour la Conservation de la Nature.

Katembo, R. (2016). *Rapport technique sur l'opération de gardiennage et protection des derniers éléphants du Katanga 2016* [Report].

Katembo, R. (2017). *Rapport technique sur l'opération de gardiennage et protection des derniers éléphants du Katanga 2017* [Report].

Katemo Manda, B., Kasongo Ilunga, E., & Abwe, E. (2022). *Rapport projet UICN: Bassin du lac Upemba – évaluation de la diversité halieutique et pressions anthropiques* [Report].

Katemo Manda, B., Snoeks, J., Chocha Manda, A., Abwe, E., Mukweze Mulelenu, C., Ilunga Kayaba, M. K., Kiwele Mutambala, P., Ngoy Kalumba, L. & Vreven, E. J. W. M. N. (2023). The Upemba National Park (Upper Congo Basin, DR Congo): An updated checklist confirming its status as an African fish biodiversity hotspot. Diversity, 15(9), 966. doi: 10.3390/d15090966.

Lou, Z., Peng, D., Shi, Z., Wang, H., Liu, K., Zhang, Y., Yan, X., Chen, Z., Ye, S., … Zhang, B. (2025). *AFCD: An annual cropland extent dataset for Africa at 30 m spatial resolution from 2000 to 2022*. https://doi.org/10.5281/zenodo.14920706

Louette, M., & Hasson, M. (2011). *Oiseaux du Katanga* (*Studies in Afrotropical Zoology*, Vol. 296). Tervuren, Belgium: Musée royal de l'Afrique centrale.

Makabuza, K. (1972). *Les grands problèmes du Parc National de l'Upemba* [Report]. Région du Shaba: Parc National de l'Upemba.

Mululwa, J. (2008). *Rapport sur les éléphants: Mission effectuée par le conservateur Mululwa Kantanga dans la zone annexe du PNU-N du 16 juillet au 9 septembre 2008* [Report]. Institut Congolais pour la Conservation de la Nature.

Prigogine, A. (1967). Les parcs nationaux du Congo et du Rwanda, leur situation, statut et perspectives d'avenir. *Bulletin des séances de l'Académie royale des sciences d'outre-mer, 13*(3), 576–616.

Pulido-Chadid, K., Virtanen, E., & Geldmann, J. (2023). How effective are protected areas for reducing threats to biodiversity? A systematic review protocol. *Environmental Evidence, 12*(1), 18. https://doi.org/10.1186/s13750-023-00311-4

République du Zaïre. (1975). *Ordonnance no 75-241 du 22 juillet 1975 relative à la délimitation du Parc national de l'Upemba et au régime applicable dans son périmètre*. Kinshasa: Présidence de la République.

Sirko, W., Brempong, E. A., Marcos, J. T. C., Annkah, A., Korme, A., Hassen, M. A., Sapkota, K., Shekel, T., Diack, A., … Quinn, J. (2024). High-resolution building and road detection from Sentinel-2. *arXiv*. https://doi.org/10.48550/arXiv.2310.11622

Tshikung, K. M., Pongombo, S. E. W., Roland, L., & Hornick, J. L. (2019). Consumption of bushmeat in Lubumbashi, DR Congo: Sociocultural approaches. *Journal of Health Science, 7*(2). https://doi.org/10.17265/2328-7136/2019.02.003

van Velden, J., Wilson, K., & Biggs, D. (2018). The evidence for the bushmeat crisis in African savannas: A systematic quantitative literature review. *Biological Conservation, 221*, 345–356. https://doi.org/10.1016/j.biocon.2018.03.022

Van Leeuwe, H., Henschel, P., Pélissier, C., & Moyer, D. (2009). *Recensement des grands mammifères et impacts humains: Parcs nationaux de l'Upemba et de Kundelungu, République démocratique du Congo*. Kinshasa: ICCN/WCS/USFWS/Panthera.

Van Meel, L. (1953). Contribution à l'étude du lac Upemba. A. Le milieu physico-chimique. In *Exploration du Parc National de l'Upemba. Mission G.-F. de Witte (1946–1949), fascicule 9*. Brussels: Institut des Parcs Nationaux du Congo Belge.

Van Schuylenbergh, P. (2006). *De l'appropriation à la conservation de la faune sauvage: pratiques d'une colonisation: le cas du Congo belge (1885–1960)*. PhD thesis, Université catholique de Louvain, Louvain-la-Neuve.

Verheyen, R. (1951). *Contribution à l'étude éthologique des mammifères du Parc national de l'Upemba*. Brussels: Institut des Parcs Nationaux du Congo Belge.

Verschuren, J. (1971). Les parcs nationaux de la République du Zaïre près de cinquante ans après leur création. *Africa-Tervuren, 18*(2), 1–8.

Verschuren, J. (1975). Wildlife in Zaïre. *Oryx, 13*(2), 149–163. https://doi.org/10.1017/S0030605300013375

Verschuren, J. (1987). Liste commentée des mammifères des parcs nationaux du Zaïre, du Rwanda et du Burundi. *Bulletin de l'Institut royal des sciences naturelles de Belgique, Biologie, 57*, 17–39.

Walker, B., Salt, D., & Reid, W. (2006). *Resilience thinking: Sustaining ecosystems and people in a changing world*. Island Press.

Weber, M., Mpanga, R., Changwa, E., & Hasson, M. (2024). Rediscovery of Black-lored Waxbill *Estrilda nigriloris* in the southern Democratic Republic of Congo. *Bulletin of the African Bird Club*, *32*(2), 213–215.

Weber, M., Mpanga, R., Mbulanga, J., & Dobbie, C. (2025). Status update on the critically endangered Upemba lechwe (*Kobus anselli*). *African Journal of Ecology*, *63*(4), e70060. https://doi.org/10.1111/aje.70060

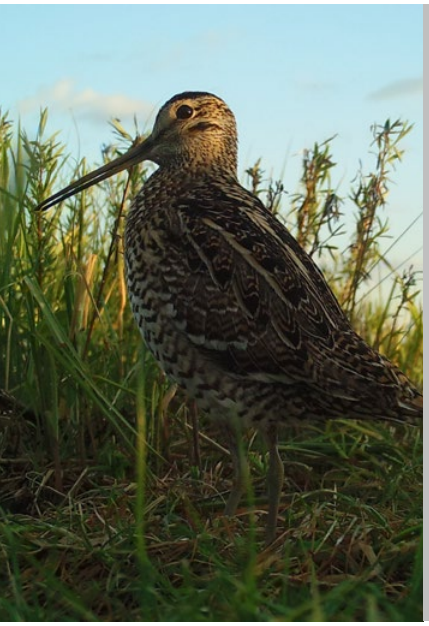
RESUMEN

El Parque Nacional de Upemba, situado en el sur de la República Democrática del Congo, sigue siendo un área protegida de alto valor de conservación sobre la que aún no se ha realizado una síntesis exhaustiva de los datos ecológicos recientes. Este artículo evalúa el estado actual del parque utilizando fuentes publicadas, literatura gris, registros de campo recientes, datos de cámaras trampa, observaciones aéreas y conocimientos de campo de expertos. Upemba ha perdido numerosas especies de mamíferos de gran tamaño en las últimas siete décadas, y las poblaciones supervivientes son pequeñas, localizadas y están distribuidas de forma desigual. Estas poblaciones remanentes indican una resiliencia parcial más que una integridad ecológica. Los datos disponibles sugieren que el agotamiento se extiende más allá de la megafauna visible y está asociado a la caza de animales silvestres para el consumo, los incendios antropogénicos recurrentes, la invasión de tierras y la degradación de los humedales, especialmente allí donde el control efectivo es débil. En estas condiciones, la tarea de conservación inmediata es la estabilización, más que la recuperación integral. La gestión a corto plazo debería dar prioridad a la protección de los bastiones confirmados y las zonas de uso recurrente para los taxones prioritarios, al seguimiento repetido de los grandes mamíferos y la presión cinegética, al seguimiento sistemático de los incendios y a los sitios centinela específicos en los humedales. La investigación debería centrarse en las incertidumbres que afectan a las decisiones de gestión a corto plazo. Upemba está en grave peligro de extinción, pero aún no se ha perdido; lo que queda es suficiente para justificar una estabilización específica.

RÉSUMÉ

Le parc national d'Upemba, situé dans le sud de la République démocratique du Congo, reste une aire protégée à haute valeur de conservation pour laquelle les données écologiques récentes n'ont pas fait l'objet d'une synthèse exhaustive. Cet article évalue l'état actuel du parc à l'aide de sources publiées, de la littérature grise, de relevés de terrain récents, de données issues de pièges photographiques, d'observations aériennes et des connaissances de terrain d'experts. Upemba a perdu de nombreux grands mammifères au cours des sept dernières décennies, et les populations survivantes sont peu nombreuses, localisées et inégalement réparties. Ces populations résiduelles témoignent d'une résilience partielle plutôt que d'une intégrité écologique. Les données disponibles suggèrent que le déclin s'étend au-delà de la mégafaune visible et est associé à l'exploitation de la viande de brousse, aux incendies d'origine anthropique récurrents, à l'empiétement et à la dégradation des zones humides, en particulier là où les mesures de contrôle efficaces sont insuffisantes. Dans ces conditions, la priorité immédiate en matière de conservation est la stabilisation plutôt qu'un rétablissement complet. La gestion à court terme devrait donner la priorité à la protection des bastions confirmés et des zones d'utilisation récurrente pour les taxons prioritaires, au suivi répété des grands mammifères et de la pression de chasse, à la surveillance systématique des incendies, ainsi qu'à la mise en place de sites sentinelles ciblés dans les zones humides. La recherche devrait se concentrer sur les incertitudes qui affectent les décisions de gestion à court terme. L'Upemba est gravement menacée, mais pas encore perdue; ce qui en reste est suffisant pour justifier une stabilisation ciblée.

Traducción realizada con la versión gratuita del traductor DeepL.com



EFFECTIVENESS OF CONSERVATION MEASURES FOR BIRDS IN 100 EUROPEAN UNION SPECIAL PROTECTION AREAS

Concha Olmeda[1]*, Viera Šefferová Stanová[2], Kerstin Sundseth[3], Lucia Millán Agudo[1], Marita Arvela[4], Barbara Calaciura[5], Alvaro García Herrero[1], Otars Opermanis[6], Pawel Pawlaczyk[7], Claire Pirat[8], Mihai Proca[9], Jasminka Radovic[10], Angela Ruiz[1], David Stroud[11] and Marc Thauront[12]

*Corresponding author: concha.olmeda@atecma.es

[1] ATECMA, Villalba, Spain, [2] DAPHNE-Applied Ecology Institute, Bratislava, Slovakia, [3] Ecosystems Ltd, Brussels, Belgium, [4] N2K Group/Finnish Environment Institute, Finland, [5] Comunità Ambiente srl, Rome, Italy, [6] N2K Group, Saulkrasti, Latvia, [7] Naturalists Club, Poland, [8] Ecosphère, Saint-Maurice, France, [9] Independent consultant, Sibiu County, Romania, [10] Sjajno Ltd, Zagreb, Croatia, [11] N2K Group, Scotland, [12] Ecosphère, Saint-Maurice, France

ABSTRACT

A two-year survey (2020-22) of 100 EU Birds Directive Special Protection Areas classified by ten Member States (MS) reviewed multiple aspects of their management. Good practices were found but there were major differences in management effectiveness within and between MS with scope for improvement in all aspects of the management process. Lack of adequate funding and stakeholder engagement were identified as significant constraints. Concerted and urgent effort is needed from all MS to enable the EU to achieve Objective 1 of its Biodiversity Strategy for 2030 to "effectively manage all protected areas, defining clear conservation objectives and measures, and monitoring them appropriately".

Key words: EU Birds Directive, Natura 2000 network, management effectiveness, conservation objectives, conservation measures, adaptive management, management planning, governance

INTRODUCTION

The European Union's (EU) core policy for biodiversity conservation has been the establishment of the Natura 2000 (N2K) network of protected areas, a "coherent European ecological network". The initial driver for establishing these sites were the threats facing many of Europe's most important areas for conservation in the 1970s and 1980s.

The 1979 'Birds' Directive on the conservation of wild birds (79/409/EEC – BD) was the EU's first law related to biodiversity. Article 4 requires Member States (MS) to classify Special Protection Areas (SPAs) for taxa listed in Annex I, as well as for regularly occurring migrants.

Together with Special Areas of Conservation (SAC)/Sites of Community Importance (SCI) classified under the 1992 'Habitats' Directive on the conservation of natural habitats and of wild fauna and flora (HD), SPAs are a major element of the N2K network.

Although planned for completion by 1981, the SPA network has taken much longer to create. Over this period, European jurisprudence has progressively required supporting policies, such as need for multiple aspects of site management (Cashman & Miron, 2023; Tucker et al., 2023). To date, there has been no published assessment of SPA network sufficiency, and over four decades later policies now focus on effective site management. The EU Biodiversity Strategy for 2030 (EC, 2020) now highlights requirements to "*effectively manage all protected areas, defining clear conservation objectives and measures, and monitoring them appropriately*".

Adaptive approaches to protected area management (Figure 1) typically involve: an explicit (and for N2K sites, legal) statement of reasons why the site has been established (species, habitats and/or processes); a statement of site conservation objectives (target state); defined conservation actions to be undertaken; implementation of those measures; and a process to monitor and review outcomes, as necessary adjusting future activities.

These adaptive elements all exist within legal requirements for N2K management (Tucker et al., 2023). HD Article 6 and BD Articles 3 and 4 together establish a protection and management regime for N2K sites. The obligations require protection and management beyond

https://doi.org/10.2305/ZNCU6523

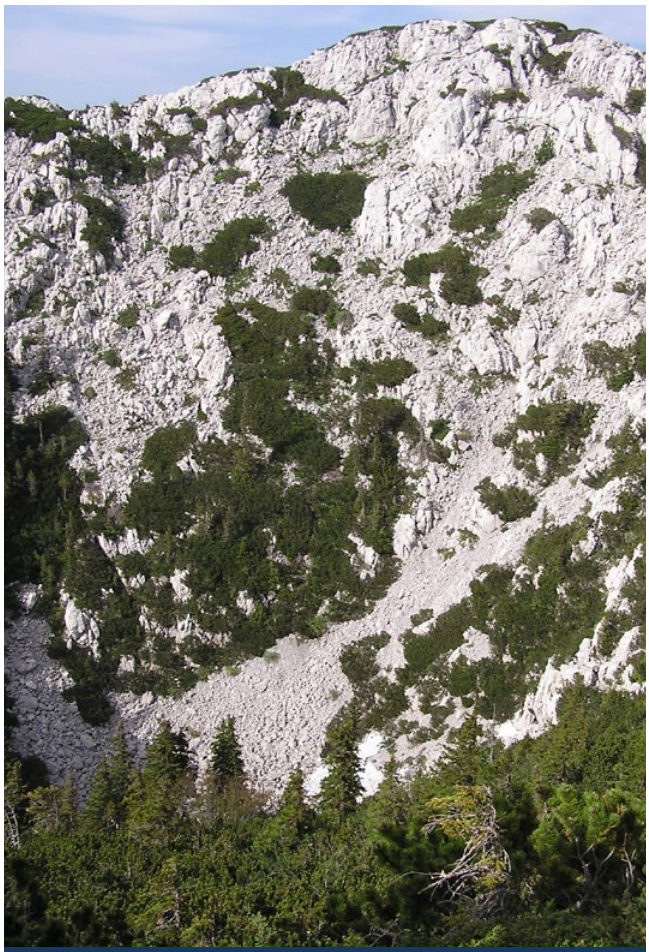
non-deterioration requirements, requiring MS to maintain and re-establish habitats of qualifying species in these sites. Fundamental for delivery is establishment of Conservation Objectives (COs) and Conservation Measures (CMs) for each site. The European Commission (EC) has issued guidance on preparing site-specific COs (EC, 2012a, 2019) and CMs (EC, 2012b, 2019).

Background to assessment

Between 2015–2016, the EC undertook a 'Fitness Check' of the two Nature Directives as part of its Regulatory Fitness and Performance Programme. It concluded that both remained fit for purpose, but their implementation needed to be significantly improved (EC, 2016). Among the issues identified as problematic were:

- inconsistent bases for SPA selection, leading to wide variations in size and total national extent, between different MS;
- variable adoption of buffer zones to limit impact of external influences, especially for small sites;
- wide national variation in whether N2K sites have management plans or other processes to direct conservation management; and
- chronic lack of both financial and human resources to protect and manage sites.

A subsequent Action Plan (EC, 2017) highlighted actions to better implement the Directives. This study contributes to the Action Plan by examining a sample of 100 SPAs across ten MS to assess the:



Velebit SPA, Croatia, a large coastal mountain with complexes of beech/fir forests set amongst scree. It consists of three protected areas (Nature Park Velebit, National Park Northern Velebit and National Park Paklenica). Management plans for these sites were adopted in 2007 but expired in 2017 leaving no current valid plan(s). © Jasminka Radovic

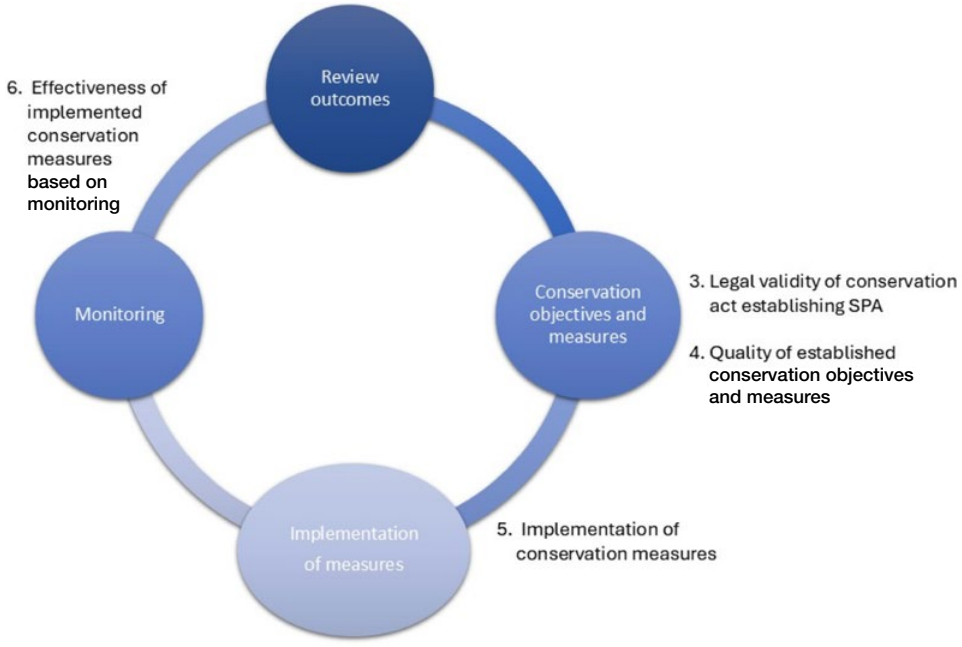


Figure 1. Conceptual outline of main elements of protected area management cycle (based on multiple authors) as related to this survey, and as urged by the EU (e.g. EC, 2013) (Numbers relate to the tasks addressed.)

- quality and sufficiency of SPA classification acts;
- quality of conservation objectives;
- conservation measures established to deliver objectives;
- level of implementation of the conservation measures; and
- their effectiveness.

We assessed implementation and efficacy of measures to maintain sites to benefit those species for which they were designated. We also set out to identify problems and obstacles most encountered in SPA management, as well as good practices. Olmeda et al. (2022) reported full methods and results (link in references). This paper summarises the main findings; unpublished final reports for each MS are held by EC.

The study was organised as six logically sequential tasks presented in Supplementary Online Material 1 for Tasks 1 and 2; and below for Tasks 3–6.

METHODS: OVERALL ASSESSMENT PROCESS AND TEAM

Data collection ran from November 2020 – June 2022. For each of ten MS selected (Croatia, Finland, France, Ireland, Italy, Latvia, Poland, Romania, Slovakia, Spain – Supplementary Online Material 1; Task 1), a nationally knowledgeable assessor (the authors) gathered information using the widest range of public information sources, and especially, although not exclusively, through confidential questionnaire surveys (Annex 2 of Olmeda et al., 2022). Correspondents, especially site managers and others with direct site knowledge, such as researchers, were selected as most able to inform on site status.

Approaches to elicit information from consultees varied: some were most effectively engaged via direct interviews. Ireland did not permit direct contact with site managers; headquarters staff provided replies for all ten questionnaires. Assessors also undertook their own research on sites using other available information sources.

Questionnaire responses

A total of 180 responses were received from 96 SPAs [of the 100 included sites] with an average of two per site although response rates varied by country (Table 1). Consultee response rate averaged 67 per cent, (100 per cent – Latvia to 41 per cent – Spain). Return quality and detail varied from those who filled in all 50 questions giving comprehensive site overviews, to only partial information provision. Most consultees were site managers, scientists, field practitioners, nature conservation authorities and non-government organisations (NGOs) and, where possible, responses from all these were sought at each site for different perspectives. Private owners and other land-users were poorly represented.



Marais Audomarois SPA, France. One of many sites in this study that was also a Ramsar Site. Whilst conservation Measures are set out in a site management plan, that document poorly relates to the ecological requirements of the qualifying species. These measures are nevertheless better suited to species' habitats (conservation of reedbeds and tall-herb communities, restoration of open areas by clearing brush, reprofiling of the banks of water bodies with gradual slopes), albeit with no specific targets. These measures are particularly effective for populations of Eurasian bittern (*Botaurus stellaris*) and bluethroat (*Luscinia svecica*). © Ecosphère/Prodrones

Table 1. Summary of questionnaire responses from site managers, experts and others both by country and type of respondent, one of the main sources of site-related information.

Country	Total people consulted	Total questionnaires received from					Total sites covered by questionnaires
		NGOs	Administration/ authority	Private experts/ scientists	Others (landowners, stakeholders)	**Total**	
Croatia	28	8	8	3		19	10
Finland	20	4	6	2	4	16	10
France	32	1	13			14	7
Ireland	54	3	16	3	4	26	10
Italy	31	3	8	5		16	10
Latvia	20	6	8	7	3	24	10
Poland	30	3	12	1		16	10
Romania	20	8	10	1		19	10
Slovakia	26	8	9	1	2	20	10
Spain	24	2	8			10	9
Total	**285**	46	98	23	13	**180**	**96**

Responses to questionnaires for the same SPA frequently differed: typically information provided by state agency employees was more positive than either private experts or staff of NGOs.

Detailed methods for each task are given in Supplementary Online Material 2.

RESULTS

Legal validity of classification acts (Task 3) was typically good but frequently poor in detail. Only one of 100 SPAs had an act fully compliant with requirements (EC, 2012c): name, location and site boundaries; a list of species motivating classification; purpose of classification; need for non-deterioration measures and prevention of impacts; and obligation to apply CMs where necessary to maintain or re-establish species habitats. All other sites lacked one or more of these elements (e.g. objective purpose of site classification was clearly stated only for 35 sites).

In some MS, all SPAs analysed were designated by a single act (e.g. Croatia and Poland), although for others, mostly name, location and site boundaries were included, together with a map. A full list of qualifying species was only included at 48 sites. Where such species were listed, these sometimes varied significantly between classification act, national legal statement of importance (sometimes called a citation), site management plan and/ or N2K Standard Data Form (SDF).

Classification acts could not be located for single Irish and Italian sites, and were lacking for three Spanish SPAs.

Definition of Conservation Objectives

Our assessment (under Task 4) found that 87 of the 100 SPAs had site-specific COs corresponding to the ecological requirements of birds for which the SPA had been classified ('qualifying species' as identified in the relevant SDF). However, only 51 SPAs had COs for all qualifying species. Only 43 SPAs had COs that clearly identified condition of species and their habitats to be achieved, and only 20 SPAs had COs that included quantitative and measurable targets. Finally, only 25 SPAs had COs reflecting their overall importance for species and network coherence. COs for many sites simply repeated the BD's high-level objectives and gave little direction for establishing site related CMs (Figure 2; Supplementary Online Material 3, Annex 2).

Establishment of Conservation Measures

Of 100 SPAs, 90 had CMs established in some kind of management plan or through statutory, administrative or contractual measures, noting that site selection (Supplementary Online Material 1; Task 2) favoured inclusion of SPAs with management plans.

Seventy-two SPAs had at least some CMs and fewer than half the sites (49) had complete CMs (i.e. covered all qualifying bird species for the SPA). Further, in only 29 SPAs were measures clear and precise, sufficiently specific, detailed and quantified (Figure 2). In most cases COs and CMs did not comply with Commission guidelines (EC, 2012a,b). Paradoxically, at some SPAs, reasonably good CMs were intuitively established without precise COs. However, these could not be effectively evaluated. Supplementary Online Material 3,

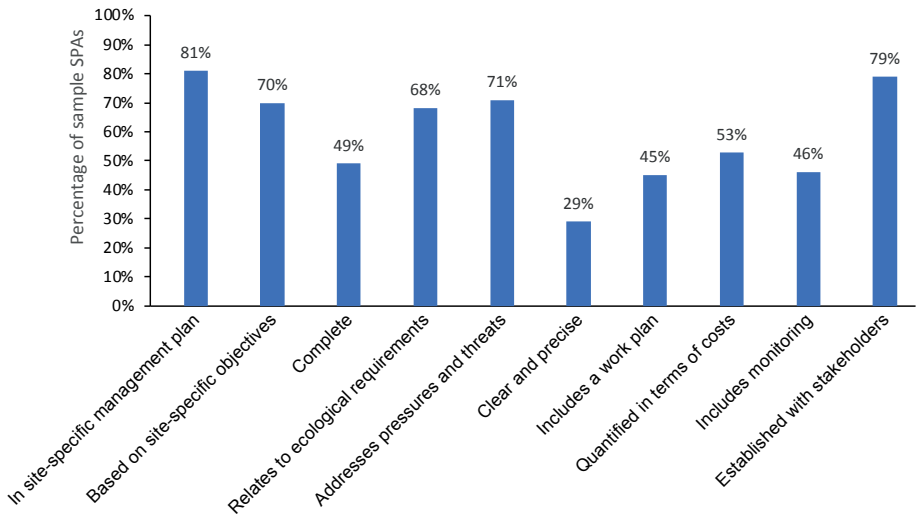


Figure 2. Assessment of Conservation Measures quality in a sample of 100 SPAs.

Annex 3 gives examples of different national procedures for establishing COs and CMs.

Implementation of management plan and conservation measures

Implementation of CMs (assessed in Task 5) was generally poor and varied substantially between MS. One seemed to rely solely on high level law or policy to deliver requirements – for example through constraints on development because of an area's status within spatial planning policy, thus relying on passive 'non deterioration' approaches without active requirements on landowners.

Management of publicly owned sites (also nationally protected) was generally better than on privately owned land (where typically limited habitat management was required other than to restrict overtly damaging activities). In some MS, such as France, voluntary financial incentives were used to encourage appropriate management.



South island, Inishkea Islands SPA, Ireland, looking down to the now abandoned former village. The wind-swept natural grasslands provide crucial grazing for Ireland's largest population of Greenland Barnacle Geese (*Branta leucopsis*). Limited generic Conservation Objectives are published for the site that do little more than state the broad legislative requirements. There is no management plan for the site, nor Conservation Measures to deliver objectives. © David Cabot

Respondents considered that management plan implementation was good overall at only 21 sites with some form of management plan (medium at 51, poor at 27 sites).

Implementation of CMs for qualifying species was sufficient at only two SPAs, compared to 12 where it was wholly insufficient. For the remaining 86 SPAs it was only partly sufficient.

At all sites assessed, at least some bird species had no, insufficient or inappropriate implementation of CMs. In almost half (48), respondents considered implemented measures insufficient for a significant proportion of qualifying species (over half the species – Figure 3).

Management capacity and financing

Almost 40 per cent of respondents (Table 2) indicated insufficient or low capacity and/or financial resources of the organisation responsible for CM implementation.

Regular funding for CMs and monitoring was often lacking, with site conservation frequently only achievable through time-limited external funds (LIFE, other EU funds such as Common Agricultural Policy, national or regional funds) meaning long-term financial continuity was insecure.

Governance

The ten MS showed a wide variety of models for SPA governance. Management was often the responsibility of a conservation authority which, in most cases, was a national or a regional statutory body.

Table 2. Assessment from 180 respondent questionnaires of capacity (defined as availability of adequately trained staff), and financial (and other technical) resources for CM implementation at 96 SPAs.

Assessment of capacity and resources	1 Completely insufficient	2	3	4	5 Completely sufficient
Overall capacity for SPA management and for CM implementation	14%	26%	33%	20%	7%
Financial resources for site management and CM implementation	23%	37%	23%	15%	2%

In some MS such as Italy, management approaches were determined by the site manager for example encouraging agreements with farmers to carry out specific conservation measures defined collaboratively and paid under the Rural Development Programme. The participatory and collective approach there, and increased sensitivity of farmers involved, resulted in no conflicts with agricultural uses and activities generating beneficial grassland management.

At ten SPAs in Latvia, Slovakia and Romania, management was undertaken by a local organisation (either non-government or a public institution) with a further six managed by NGOs or through partnerships.

Stakeholders were usually involved in preparing and adopting management plans at 88 sites where plans exist. Stakeholders typically were involved in initial development of objectives and measures, yet their continuing active engagement in implementation measures was uncommon. Only 39 sites reported adequate stakeholder engagement, and only 27 had processes to address management conflicts.

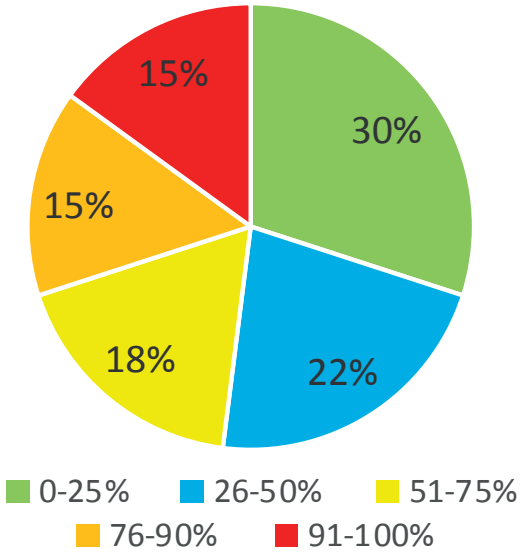
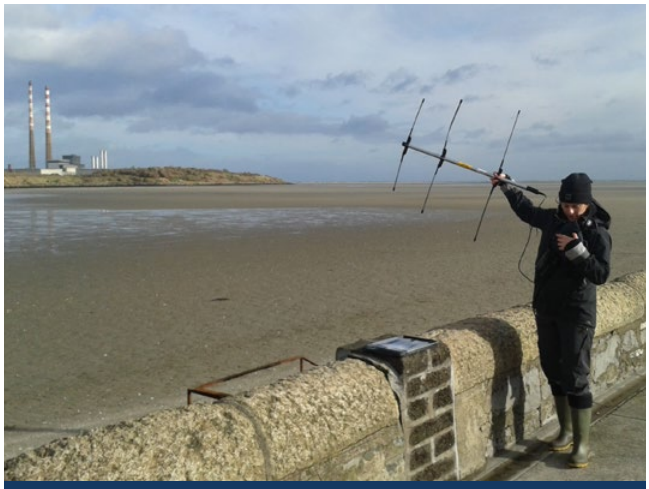


Figure 3. Proportion of species for which the SPA was classified for which conservation measures implemented were insufficient. Thus, in 15 SPAs conservation measures were insufficient for 91-100 per cent of qualifying species.



Radio-tracking non-breeding waders at Dublin Bay, SPA, a heavily industrialised estuary. The fine-grained data on areas used and movements has the potential to be used for advising on development proposals, although the study found no management plan for the site nor evidence of use of these, or other survey and monitoring data. © Niall Tierney

Monitoring

Monitoring provision was widely variable (Table 3). At some SPAs, management plans included a monitoring programme to assess implementation and CM outcomes. Other plans however did not include monitoring, or it occurred at basic levels with few implementation indicators. Almost all management plans analysed recognised the need to monitor CM implementation – even if this did not occur.

Monitoring populations of *all* qualifying species was carried out regularly at only 40 SPAs. For nearly 50 sites, there was only partial or incomplete monitoring. Where undertaken, monitoring results were publicly available for half the sites. At only 21 sites was the quality of monitoring good (41 medium and 38 poor). In some MS where monitoring occurred, it was not used by authorities to direct or review management adaptively. Most respondents highlighted the need to reinforce monitoring at all SPAs, with insufficient funding reported as the main limitation.

In many MS, principal data sources were through personal communications (e.g. 72 per cent of Latvian sources). Other sources there were technical publications

Table 3. Assessment from 180 respondent questionnaires of monitoring effectiveness at 96 SPAs.

Monitoring in assessed SPAs	Yes	Partly	No	N/A
Are protected bird populations regularly monitored?	38%	48%	9%	5%
Are monitoring results publicly available?	43%	26%	26%	5%
Is there a regular evaluation of CM efficacy?	16%	39%	40%	5%

(16 per cent), scientific publications (8 per cent) and citizen science databases (4 per cent).

Task 6 assessed CM effectiveness. Nearly a quarter of questionnaire respondents, mainly site managers, considered the potential benefit of CMs for qualifying species to be limited – measures benefited all or most species in only 34 of the 100 SPAs. At 42 sites, measures benefited a significant proportion (over 75 per cent) of qualifying species present but at 24 others, less than 25 per cent of species.

At most SPAs, there was limited evidence that implemented measures had improved species status since classification. At only half the SPAs was it possible to verify that populations of at least some qualifying species had increased (or at least not declined) since classification. Conversely, there were decreases from classification baselines at 53 SPAs. Where improvement in status of qualifying species could reasonably be attributed to CM implementation, this was attributed to the regulation of activities demonstrated by adequate surveillance. However, there was no monitoring of outcomes at 43 sites.

Land-use changes

Changes in land uses or human activities since classification benefited qualifying species at 40 SPAs, but no beneficial changes were reported at over 50 sites. Most beneficial changes were linked to adaptation of agriculture and forestry practices, and to regulation of activities such as hunting, extractive activities, tourism and recreational activity. In contrast, more than half of respondents reported changes in land uses and human activities which had harmed qualifying species during the last decade. These were mainly changed/intensified agricultural practices, tourism and/or recreation.

Conflicts of interest between CM implementation and other human activities (including farming, forestry, fishing and hunting, tourism and use of sensitive areas) were reported by 76 per cent of respondents. At some sites with both SAC and SPA classifications, conflicts of interests occurred between habitat COs (under HD) and bird needs (under BD), including conflicting grazing/grass management regimes and needs for scrub management (for birds).

Table 4 presents a summary of results in relation to the main stages in SPA management across the ten MS using several key questions as performance indicators. It shows highly variable results both between MS for a single issue and overall between the different issues. No single SPA demonstrated all elements of good/required good practice concerning legal certainty; establishment of COs; establishment and implementation of CMs; comprehensive monitoring and review processes; and stakeholder engagement. However, many sites showed some, or indeed many, of these elements.

DISCUSSION

Methodological issues

This study is the first wide-scale survey of practical implementation of EU SPA requirements. Resources and logistics did not allow for use of protected areas protocols such as WWF's Management Effectiveness Tracking Tool (Stolton et al., 2021). Consequently, there was no model capable of achieving wide-scale assessment with the depth needed to capture both positive and negative outcomes. Supplementary Online Material 3, Annex 4 provides a critical assessment of our methodology aimed at improving any future surveys of the N2K network.

We note the non-random nature of site sampling designed by the EC to enable exploration of extant management processes. In terms of outcomes, however, this may skew statistical results to be more positive than a truly random sample, but whether this occurred is unknown (Supplementary Online Material 1, Task 2).

Legal certainty

Correct statutory establishment of SPAs is critical to establish the legal framework for delivery of SPA management and provide 'legal certainty' in the event of third-party challenge. This need was established by European Court of Justice case-law (in C-293/07 and C-415/01) which, *inter alia*, establishes that "the identification of species of importance which have warranted classification of that SPA must satisfy the same requirement" of clarity. Such wide disparity of practice is concerning as it renders a site's legal

Table 4. Overall progress results (as %) using a simple indicator system. Information drawn from 180 questionnaire respondents and other data sources. Darker colour indicates higher implementation score. Source: Olmeda et al. (2022) giving detailed national breakdown.

Member State	Croatia	Finland	France	Italy	Ireland	Latvia	Poland	Romania	Slovakia	Spain	Average
Planning	73	65	69	53	16	48	61	53	88	71	59
CM implementation	52	40	58	37	5	65	40	20	58	52	41
Site management	55	23	56	49	1	53	46	64	64	51	44
Monitoring	52	70	58	33	27	53	47	17	55	46	44
Conservation outcomes	44	71	52	39	28	54	35	25	49	47	43

protection and management regime less effective. In particular, confusion about which species are legal 'qualifiers' has significant consequences for SPA protection and management through the scope of Environmental Impact Assessments and Appropriate Assessments.

Management plan establishment

There were significant shortcomings in the establishment of good quality site-specific COs and CMs. This negatively impacts implementation and effectiveness of CMs and ultimately protected species status – likely being one of the main reasons why the status of qualifying species at many sites has not improved over time. Establishment of COs and CMs mainly occurred in management plans. Whilst some plans have legal status, others were essentially non-statutory 'wish-lists'. In Ireland, there were no management plans. There was variable involvement of stakeholders in the development of COs and CMs. Whilst some MS, such as France, Poland and Finland, are inclusive in the involvement of stakeholders in CO/CM development, others (such as Ireland) are not.

Management plan implementation

Lack of CM delivery is driven by inadequate management plan implementation despite the need for such conservation actions being well understood. Sometimes, CMs known to be effective, such as prohibiting hunting or raising water levels, were not implemented due to landowner/hunter resistance or perceived negative impacts on surrounding land use. Several respondents indicated that apparently, site managers/authorities avoid these measures for fear of stimulating negative responses towards nature conservation.

Governance

In sites where land is mainly privately owned/farmed there appear to be greater challenges to implement CMs compared to state-owned SPAs, and established nature conservation/wilderness areas where default non-intervention management is the main CM.

A frequent problem in achieving COs relates to land uses and other influences *outside* the SPA. For example, in Finland, mire restoration within the SPA/SAC can typically be impossible or at least be very difficult to initiate if it has unwanted impacts on surrounding areas (most often privately-owned land). Other negative influences, such as atmospheric pollution, are beyond site managers' control.

Lack of stakeholder engagement is a cross-cutting issue. It seemed that even if stakeholders had been involved in management plan development, they seemed rarely involved in CM implementation – a major shortcoming given the internationally acknowledged importance of such engagement. Concerningly, we further found that many otherwise knowledgeable individuals consulted had limited understanding of the processes that should be occurring on 'their' SPA.

Resources

Lack of adequate, consistent long-term resources is the main constraint on SPA effectiveness. Many sites are dependent on ad hoc funding: at some, CM implementation commenced through LIFE projects but after these concluded so did site management – sometimes even for the original objectives of the LIFE project. This led to the loss of benefits, at least partly, of the original funded actions. For agricultural measures, this is despite strong recognition of agri-environment scheme importance, published evidence of its efficacy, and ready availability of best practice models (e.g. through the EC's Birds@Farmland initiative).

Our findings reinforce earlier conclusions of the Fitness Check that widespread poor management of N2K sites results from lack of financing leading to inadequate staffing, coupled with low stakeholder engagement in site management (EC, 2016).



Delta Neretve SPA, Croatia, is an estuarine and coastal site of importance for waterbirds. There is no management plan and as at many other sites, COs do not contain quantified attributes for the area and structure of habitats; do not address threats recorded in the SPA's Standard Data Form and are not clearly linked to the ecological requirements of individual species. The timeframe and resources needed for achievement of COs have not been defined. © Jasminka Radovic

Monitoring

Regular, complete and systematic bird monitoring was lacking at most sites – being only present at 15 SPAs. Where conducted, monitoring often lacked standardised protocols, varying both between SPAs within individual MS and between MS. Thus, it was not feasible to quantitatively analyse trends for qualifying species at sites. The consequence of such deficiencies was that important changes were not detected, and management measures were accordingly poorly adapted to conservation needs. Lack of funding seemed the primary constraint on adequate monitoring.

Lack of management plan 'adaptive' review resulting from monitoring failure is a shortcoming in nearly all MS (other than on the Finnish mainland where there is systematic monitoring implementation and periodic review of SPA management plan effectiveness).

Effectiveness of Conservation Measures

We found limited evidence that CMs had widely improved population status of qualifying species (only at a third of sites). This finding contrasts with previous studies that demonstrated positive influences on populations linked to Annex I status (e.g. Sanderson et al., 2015) based on wide-scale, correlative methods. Probable reasons for the lack of strong positive effects (and indeed, significant declines at over half the sites) relate to lack of positive directed management. At others, CMs are either inadequately framed, or even if drafted correctly, inadequately implemented (if at all).

Ultimate reasons for most implementation problems relate to lack of financing limiting human capacity to implement CMs/monitoring. Frequently SPAs lacked sufficient staff for management, personnel for monitoring and guarding, and expert advice.

Population changes within SPAs were directly influenced by land uses that were adverse to COs. Where such conflicts existed, there was typically limited evidence of systematic measures taken to address those. Sometimes (given above) needed measures were not implemented for fear of negative public reactions. Such management deficits are critical and constrain ability to deliver legal requirements to ensure non-deterioration at SPAs.

Where populations increased on sites this often mirrored national scale increases unrelated to SPA condition. In contrast, some qualifying species showed declines or stability contrasting with wider scale increases – implying SPA habitat degradation. We conclude that many implemented CMs have prevented population declines to some extent, but at most of the assessed sites further implementation measures with adequate monitoring are clearly, and urgently, needed.

Overall, results show SPA management frequently has been unable to prevent or limit changes in land uses or human activities detrimental to birds. We found CMs were insufficient to reduce negative land-use impacts which is likely why some species are still declining in SPAs. Widespread structural support for other crucial land uses, such as sustainable traditional agriculture was generally lacking.

Whilst there were some excellent examples of good practice, there was overall poor implementation of legal requirements and compliance with policy guidance on SPA management.

Major constraints to delivering favourable site conditions

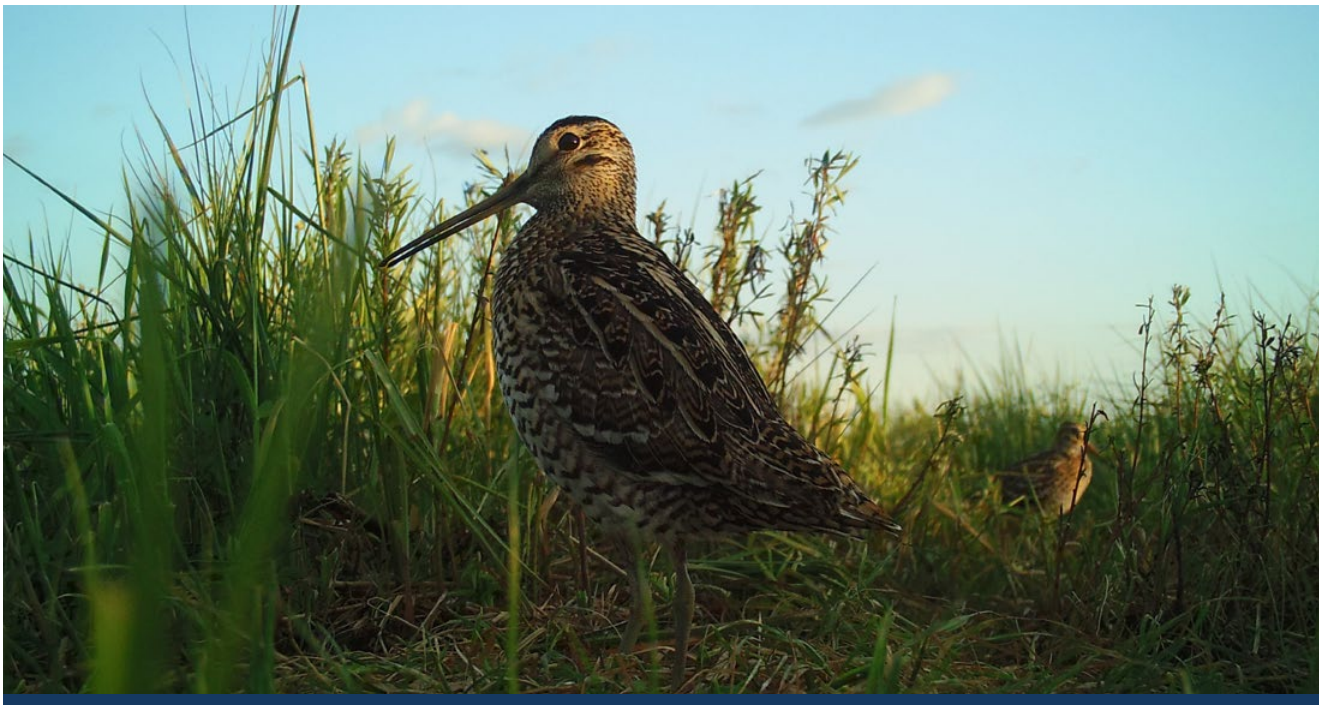
We identified two major issues as significant constraints on effective SPA management. Of greatest, and fundamental, importance is the lack of adequate funding for all aspects of the SPA adaptive management cycle. Whilst the EC has provided much guidance on what *needs* to happen (EC, 2012a,b,c), there has never been adequate regional, national or EU resources for delivery. Reliance on short-term funding initiatives, such as LIFE or time-limited agri-environment schemes, is inadequate for long-term management needs. Such financing is limited either to few sites and/or to those agriculturally managed.

We found frequent lack of active stakeholder engagement in CM development and implementation and consider this a major constraint on delivering long-term, effective site management.

Low-cost solutions?

Whilst system-wide financial deficits with multiple implications is a major constraint, we suggest the following low-cost actions as means to improve the situation:

- As first priority, establish COs for each SPA since other needs (monitoring, conservation measures) depend on these.
- EU funding bodies (e.g. Horizon and the LIFE Programme), as well as national research bodies, should require publication of site-related data on SPAs by funded projects. Too much relevant data quickly becomes unavailable once project funding ceases.
- Promote more systematic engagement with active researchers and 'citizen scientists' at sites as they are likely to be already 'invested' in its conservation. Such individuals typically are productive sources of monitoring data past and present and should be proactively encouraged by state authorities.
- Create site-level committees including researchers, landowners and other users to provide a discussion forum. Such fora can provide information on SPA pressures and facilitate cost-effective solutions/conservation measures.



Great Snipe (*Gallinago media*) at Kuja SPA, Latvia. In recent decades this species has been focus of significant conservation measures, including restoration of floodplain grasslands, leading to population stabilisation, if not increase. Novel technologies such as trail cams offer new monitoring possibilities. © Otars Opermannis



Heronry at South Alessandro Lake within Risaie della Lomellina SPA, Italy. SPAs embedded in intensively used landscapes often face competing demands from farming, hunting and water management, highlighting the need for governance frameworks capable of reconciling conservation priorities with broader socio economic interests. Improving conservation in such complex agricultural landscapes requires timely ecological information. Emerging tools such as drone based surveys offer practical opportunities to address monitoring gaps and support more adaptive management. © Mauro Fasola.

- Raise general awareness by state authorities at multiple scales, as well as with stakeholders, regarding the legal and other implications of SPA status. Bizarrely, this basic knowledge is poor in many MS – decades after BD adoption.
- Publish (by MS) summary information on the issues addressed in this study, perhaps as a national 'dashboard'. Such transparency will generate public/political pressure for resource allocation to improve site condition.
- Make full use of LIFE funded projects to kick-start more coherent national approaches to SPA conservation management where needed.
- Consider how to integrate the current study's outcomes into reporting under BD Article 12 to monitor progress.
- Revise publicly-funded national monitoring schemes which purport to provide monitoring data, but in practise, fail to do so, to ensure their effectiveness.

Global contexts

The Kunming-Montreal Global Biodiversity Framework (Convention on Biological Diversity, 2022) Target 3 includes both an area sub-target and, crucially, also a sub-target for management: that such areas should be "… effectively conserved and managed …".

For the EU, this requirement is delivered through the Biodiversity Strategy (EC, 2020) key commitments which relate not just to the extent of protected areas, but also to the need to "effectively manage all protected areas, defining clear conservation objectives and measures, and monitoring them appropriately". This survey indicates significant good practice but also a wide range of problematic issues that MS need to address urgently to ensure the SPA network is fit for purpose and effectively managed. Highly relevant is the 2024 Nature Restoration Regulation establishing restoration targets, especially for N2K sites as priority, as well as targets for bird species' habitats.

We urge that attention be given by MS to the survey's conclusions which identified multiple issues where (significant) improvements are necessary, including:

- Enhancing completeness/quality of SPA classification acts to give legal certainty;
- Establishing explicit COs for all SPAs;
- Drafting and implementing SPA management plans (or equivalent mechanisms) at all sites (containing clear statements of CMs to deliver necessary management), and at all stages involving NGO stakeholders;
- Regular, complete and systematic bird monitoring of qualifying species at all SPAs supported by sustained long-term funding, with results

transparently and systematically reported; and
- Relevant national-funding streams to routinely require publication of data collected at SPAs.

Since this study was undertaken, and in part in response to its findings, the Commission have launched a LIFE-funded PAME (Protected Area Management Effectiveness) project to develop a European framework complementing existing PAME systems. In early 2026, the involvement of 47 pilot sites from 26 MS, and ten more from five non-EU countries has been confirmed. The project provides staff training on identified deficiencies such as stakeholder engagement and governance. A pilot programme report is expected in early 2027.

ACKNOWLEDGEMENTS

The study was funded by the EC (Contract No. 07.0202/2020/8366633/ENV.D3). We acknowledge guidance and inputs from Iva Obretenova, Micheal O'Briain, Anna Cheilari, Andras Bartal, Laszlo Becsy, Jérémie Crespin, Beatriz Molina, Vedran Nikolić, Sophie Ouzet, Christina Pantazi, Luisa Samarelli and Frank Vassen. Views expressed here do not necessarily represent those of the EC.

Our thanks especially to the very many contacts and stakeholders in the ten MS who provided information, opinions and the benefit of their often deep knowledge. We also thank Jonas Geldmann and two referees for their helpful comments on earlier drafts.

SUPPLEMENTARY ONLINE MATERIAL

1. Methods/results for Task 1 (selection of ten MS), and Task 2 (selection of ten SPAs within MS)
2. Methods for Tasks 3, 4, 5 and 6
3. Supplementary data Annexes:
   - Annex 1. Details of the 100 SPAs selected
   - Annex 2. Main strengths and weaknesses in setting COs in each MS
   - Annex 3. Examples of procedures for establishment of COs and CMs
   - Annex 4. Summary of methodological issues and recommendations

ABOUT THE AUTHORS

Concha Olmeda is project manager and conservation expert at ATECMA, Spain. https://orcid.org/0009-0007-1599-1459.

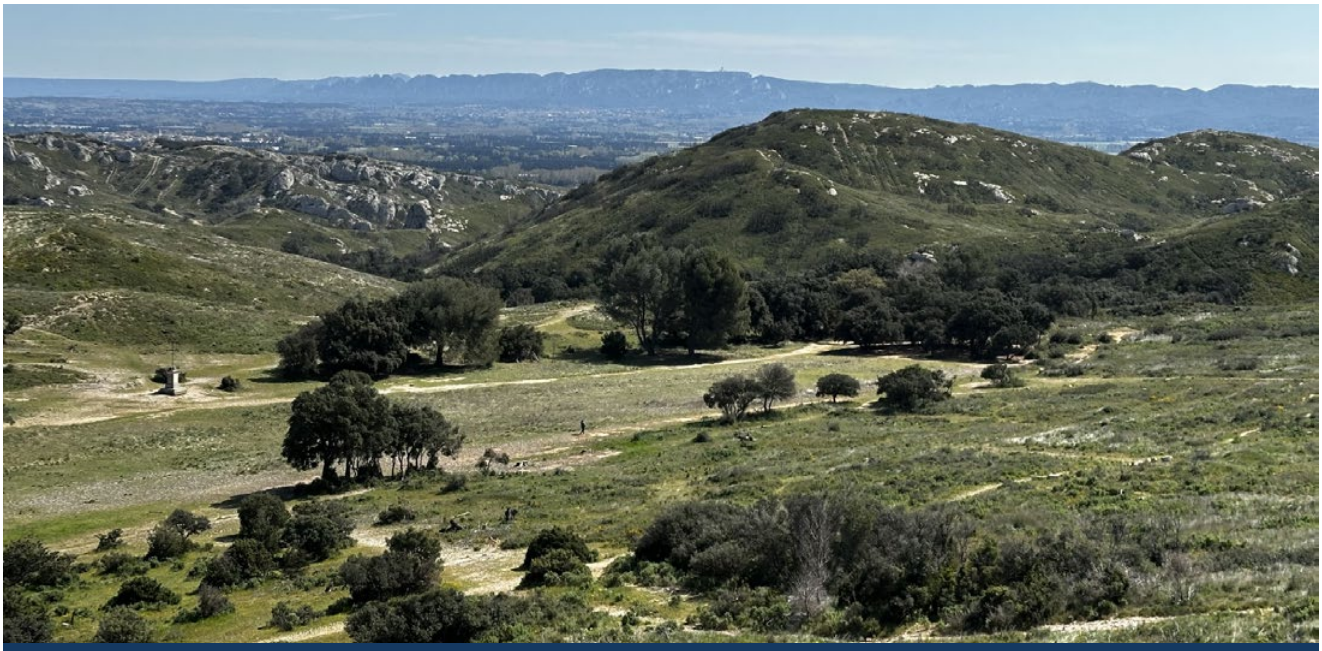
Viera Šefferová Stanová Deputy Director of DAPHNE – Institute of Applied Ecology, Slovakia.

Kerstin Sundseth Ecosystems Ltd, Brussels, Belgium.

Lucia Millán Agudo former environmental consultant at ATECMA and current research technician at the Marine Sciences Institute, Barcelona. https://orcid.org/0000-0001-5940-784X.

Marita Arvela former senior N2K Group expert and currently senior coordinator at Finnish Environment Institute.

Barbara Calaciura biodiversity expert at Comunità Ambiente srl., Rome.



Les Alpilles SPA, France. An extensive Mediterranean site holding a diversity of habitats, including pseudo-steppes, grassland, scrub, forests, wetlands, rocky outcrops and dunes and is important for steppe-loving birds such as European Roller (*Coracias garrulus*) and Stone Curlew (*Burhinus oedicnemus*). Good quality and prioritised Conservation Measures, based on well-drafted Conservation Objectives are published for the SPA in a publicly accessible site management plan. © Ludovic Lejour.

Alvaro Garcia Herrero marine environment technician at ATECMA, Spain. https://orcid.org/0000-0002-7331-2529.

Otars Opermanis independent Latvian consultant, specialising in protected area networks, reporting and biodiversity data.

Pawel Pawlaczyk conservation officer in Naturalists Club, Poland and nature conservation consultant. https://orcid.org/0000-0002-5593-9555.

Claire Pirat conservation specialist at Ecosphère, France.

Mihai Proca independent Romanian consultant.

Jasminka Radovic former senior adviser at Croatian government conservation service and consultant for Sjajno Ltd in Zagreb.

Angela Ruiz conservation and environmental technician at ATECMA, Madrid, Spain.

David Stroud independent consultant. https://orcid.org/0000-0002-2967-0046.

Marc Thauront conservation specialist at Ecosphère, France.

REFERENCES

Cashman, L. & Miron, N. C. (2023). *European Union Case Law on the Birds and Habitats Directives.* Kluwer Law International, Netherlands.

Convention on Biological Diversity (2022). *Kunming-Montreal Global Biodiversity Framework.* CBD/COP/15/L.25.

EC (2012a). *Commission note on setting conservation objectives for Natura 2000 sites.* http://tinyurl.com/4m64w2cy

EC (2012b). *Commission note on establishing conservation measures for Natura 2000 sites.* http://tinyurl.com/2efc4t5z

EC (2012c). *Commission note on the designation of Special Areas of Conservation (SACs).* http://tinyurl.com/3yz25sfx

EC (2013). *Guidelines on climate change and Natura 2000. Dealing with the impact of climate change on the management of the Natura 2000 Network of areas of high biodiversity value.* European Union. https://www.natura2000.fr/sites/default/files/references_bibliographiques/guidance_document.pdf

EC (2016).*Commission Staff Working Document. Fitness Check of the EU Nature Legislation (Birds and Habitats Directives) Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds and Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.* Brussels, 16.12.2016 SWD(2016) 472 final. https://tinyurl.com/bp6jyfmv

EC (2017). *An Action Plan for nature, people and the economy. The EU Habitats and Birds Directives.* Brussels: EU Publications Office. https://tinyurl.com/37hbjspr

EC (2019). *Managing Natura 2000 sites – The provisions of Article 6 of the 'Habitats' Directive 92/43/EEC.* Commission Notice C(2018) 7621 final, Brussels, 21.11.2018. https://tinyurl.com/4nf3685f

EC (2020). *EU Biodiversity Strategy for 2030.* Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of Regions. Brussels 20.5.2020. Com(2020) 380 final.

Olmeda, C., Stanová, V., Sundseth, K., Arvela, M., Bellisari, L., Calaciura, B., Herrero, A. G., Šeffer, J., Millan, L., ... Zaghi, D. (2022). *Assessment of the measures established in Special Protection Areas and their effectiveness.* Final report from N2K Group to EC. https://data.europa.eu/doi/10.2779/488430

Sanderson, F. J., Pople, R. G., Ieronymidou, C., Burfield, I. J., Gregory, R. D., Willis, S. G., Howard, C., Stephens, P. A., Beresford, A. E. & Donald, P. F. (2015). Assessing the performance of EU Nature Legislation in protecting target bird species in an era of climate change. *Conservation Letters,* 9(3), 172–80.

Stolton, S., Dudley, N. & Hockings, M. (2021). *METT Handbook: A guide to using the Management Effectiveness Tracking Tool (METT). Second edition guidance for using METT-4.* Switzerland: WWF, Gland.

Tucker, G., Hart, K., Farmer, A., Dunn, E. & Baldock, D. (2023). Nature conservation policy, legislation and funding in the EU. In G. Tucker (Ed.) *Nature conservation in Europe: approaches and lessons* (pp. 59–105). UK, Cambridge: CUP.

RESUMEN

Este estudio de dos años de duración (2020-22) sobre 100 Zonas de Especial Protección para las Aves (ZEPA) de la UE, designadas por diez Estados miembros, ha revisado diferentes aspectos de su gestión. Si bien se encontraron buenas prácticas, hubo diferencias importantes en la eficacia de la gestión tanto dentro como entre los Estados miembros, con un amplio margen de mejora en todos los aspectos analizados. La falta de una financiación adecuada y de la participación de las partes interesadas se identificaron como limitaciones significativas. Se necesita un esfuerzo organizado y urgente de todos los Estados miembros para que la UE pueda lograr el Objetivo 1 de la Estrategia de Biodiversidad para 2030, que consiste en «gestionar eficazmente todas las áreas protegidas, definiendo objetivos y medidas de conservación claros y supervisándolos adecuadamente».

RÉSUMÉ

Une étude menée pendant deux ans (2020-22) sur 100 aires protégées relevant de la Directive Oiseaux de l'UE, désignées par dix États membres, a permis d'analyser de multiples aspects de leur gestion adaptative. Si des bonnes pratiques ont été constatées, d'importantes disparités subsistent quant à l'efficacité de la gestion, tant au sein des États membres qu'entre eux, laissant une marge d'amélioration considérable à tous les niveaux du processus. Le manque de financement adéquat et d'implication des parties prenantes constitue un frein majeur. Un effort concerté et urgent de la part de tous les États membres est indispensable pour permettre à l'UE d'atteindre l'objectif 1 de sa stratégie en matière de biodiversité à l'horizon 2030, à savoir « gérer efficacement toutes les aires protégées, en définissant des objectifs et des mesures de conservation clairs et en y assurant un suivi approprié ».



JERUSALEM WILDERNESS AND DEAD SEA: CONSERVATION SIGNIFICANCE OF TWO NEWLY DESIGNATED PROTECTED AREAS IN PALESTINE

Sara G. Khair[1], Nina Lütkehermöller[1, 2], Johann G. Gedeon[1], Conrad Schittko[2], Banan Al-Sheikh[1], Saed Shomaly[1] and Mazin B. Qumsiyeh[1]*

* Corresponding author: mazinq@bethlehem.edu

[1] Palestine Institute for Biodiversity and Sustainability, Bethlehem University, Mar Andrea Building, Al Karkafeh Street , Bethlehem, State of Palestine

[2] Technische Universität Berlin, Charlottenburg, Germany

ABSTRACT

A newly established Protected Areas Network (PAN) of Palestine marks a substantial advancement in national conservation frameworks and significantly reshapes earlier management approaches. Within this framework, two protected areas have been designated along the eastern slopes of the West Bank: the Jerusalem Wilderness Protected Area (JWPA) and the Dead Sea Protected Area (DSPA). This study examined the faunal and floral composition, habitat characteristics, and major threats in both areas, while addressing management challenges within the context of ecosystem services and the region's complex socio-political conditions. Despite geographical proximity, the two areas exhibit markedly distinct ecological assemblages. Only four rare plant species are shared between JWPA and DSPA, whereas 19 rare species occur exclusively in JWPA and 34 in DSPA. Although all bird species recorded in JWPA were also documented in DSPA, an additional 34 species, along with several mammalian taxa, were restricted to DSPA. Threats and management challenges were assessed against international conservation standards, and potential habitats for rare plant species were modelled using MaxEnt. The most critical threats identified include desertification, drought and habitat fragmentation. Based on zonation analysis, the study recommends strict protection of the natural oasis of Ain Fashkha in DSPA, a grazing management plan in JWPA, and the development of sustainable ecotourism initiatives.

Key words: Biodiversity, desertification, habitat fragmentation, ecosystem services, management plan

INTRODUCTION

Palestine[1] possesses a unique and rich biodiversity, due to its location at the crossroads of continents and its diverse topography shaped by geological history, ranging from the lowest point on Earth to high mountain ranges. These features gave rise to multiple climatic zones and a distinct assemblage of phytogeographical and zoogeographical regions, including Mediterranean, Irano-Turanian, Saharo-Arabian, Coastal, and Ethiopian-Sudanese zones (Atallah, 1977; Soto-Berelov et al., 2015; Whyte, 1950). Palestine has remarkable biodiversity, including numerous endemic and near-endemic plant and animal species. This biological richness facilitated early domestication of plants and animals approximately 12,000 years ago as part of the Fertile Crescent (Zeder, 2008), contributing to the characterisation of the Eastern Mediterranean as the "Cradle of Civilization" (Lopes & Almeida, 2017).

The Sixth National Report of the State of Palestine to the Convention on Biological Diversity identified critical gaps in biodiversity conservation that mirror global challenges in achieving sustainability objectives (EQA, 2021). The Kunming-Montreal Global Biodiversity Framework (GBF) emphasises not only the expansion of protected area coverage but also improved protection efficiency through active local engagement. In response, the State of Palestine has established a Protected Areas Network (PAN), integrated into national spatial plans (Qumsiyeh, Hussein et al., 2023). The PAN designates areas based on IUCN criteria, increasing protected land from 9 to 9.98

1 Palestine here and throughout the text is used as a geographic name of the the land situated on the Eastern Mediterranean coast between Lebanon and Sinai known as such for 3,500 years and not a political designation.

percent of Palestinian territory. Its 28 protected areas represent all major vegetation types and phytogeographical zones (Qumsiyeh, Hussein et al., 2023); however, only five currently have management plans, highlighting the need for baseline assessment, monitoring and planning for remaining sites (Qumsiyeh & Al-Sheikh, 2023; Qumsiyeh, Hussein et al., 2023). The National Biodiversity Strategy and Action Plan (NBSAP) further emphasises systematic studies and development of management plans for newly designated protected areas (EQA, 2022).

This study aims to advance biodiversity knowledge for two newly designated protected areas, including one located at the lowest land point on Earth. The selected areas – the Jerusalem Wilderness Protected Area (JWPA) and the Dead Sea Protected Area (DSPA) – were identified through a Marxan analysis optimising biodiversity conservation while accounting for socio-economic factors (Qumsiyeh et al., 2023a). Both areas are recognised as Important Bird Areas by BirdLife International (2023b, 2024), and the DSPA is designated as an Important Plant Area (Radford et al., 2011). We provide the first baseline assessment of these areas, addressing habitat characteristics, species composition, and conservation challenges. Like other protected areas, JWPA and DSPA face pressures from climate change, habitat degradation, pollution, invasive species, and overexploitation (Qumsiyeh & Abusarhan, 2021). Nevertheless, opportunities exist for conservation and restoration through management approaches that actively involve local communities (Qumsiyeh et al., 2024). This paper evaluates environmental threats and proposes management strategies informed by ecosystem services and geopolitical context.

METHODOLOGY

Study areas

The Dead Sea Protected Area (DSPA) and the Jerusalem Wilderness Protected Area (JWPA) are located along the eastern slopes of the West Bank (Figure 1; Qumsiyeh, Bassous-Ghattas et al., 2023). The DSPA (https://www.protectedplanet.net/555757282) encompasses an area of 235 km² and is classified under IUCN Category IV, while the JWPA (https://www.protectedplanet.net/555757283) covers 52.8 km² and is designated as IUCN Category Ib. The climate along the eastern slopes of the West Bank ranges from mild mountainous conditions, with annual precipitation of approximately 450 mm, to extremely arid conditions near the Dead Sea, receiving less than 50 mm of rainfall (UNEP, 2020). Portions of the DSPA overlap with Israeli military firing zones, where activities restrict civilian access and have resulted in habitat disturbance, vegetation damage, and limitations on biodiversity monitoring and conservation management. Although the DSPA is formally designated as an IUCN Category Ib protected area, ongoing military use creates a management contradiction that affects ecosystem integrity and community interactions with the landscape.

The Dead Sea Basin, situated at approximately 430 m below sea level, is shrinking due to hydrological and climatic changes. The Lower Jordan Valley site of DSPA is characterised by extreme salinity and minimal rainfall, with most flora and fauna concentrated in oasis-like habitats such as Ain Fashkha and Ain Gedi. The basin has functioned as a sediment trap since tectonic subsidence in the Miocene, preserving thick sedimentary sequences. Intense solar radiation, low precipitation and high evaporation – amplified by its position east of the Palestinian mountain range – shape its conditions. Dominant soils in the Jordan Valley include bare rock, Desert Lithosols, Brown Lithosols and Loessial Serozems, which are prone to erosion due to the land structure. The region's geological history and biogeographical links to Africa and Asia have contributed to richness in flora and fauna, including several endemic species (Qumsiyeh & Amr, 2025).

The geological and topographic diversity of the valleys provides a wide range of habitats and elevations, resulting in the representation of three major biogeographic zones within the two protected areas: the Irano-Turanian, Saharo-Sindian and Ethiopian zones. According to the IUCN Global Ecosystem Typology, the ecosystems in both areas are classified as semi-desert steppes, characterised by "suffrutescent (i.e., woody-based) or sub-succulent (semi-fleshy) perennial shrubs and tussock grasses" (Keith et al., 2020, p. 62).

The protected areas contain numerous historical and archaeological sites, including monasteries, shrines, and Byzantine and Roman settlements. Notable sites include the 5th-century Saint Saba Monastery (Mar Saba) (Photo 1), founded in 484 AD and hosting annual pilgrimages (Al-Natsheh, 2024). These sites have coexisted with local communities and nature for centuries (Hay, 1996; Norris, 1950) and can support eco-friendly tourism initiatives (ARIJ, 2010; VanderKam & Flint, 2005).

Gathering data on biodiversity and habitats and discussion with locals

Biodiversity assessments were based on a combined literature review and forty field surveys that were conducted between 2014 and 2024. Thirty field trips preceded the areas' protected designation within the National Protected Areas Network (PAN) (Qumsiyeh et al., 2023a). Published sources included peer-reviewed

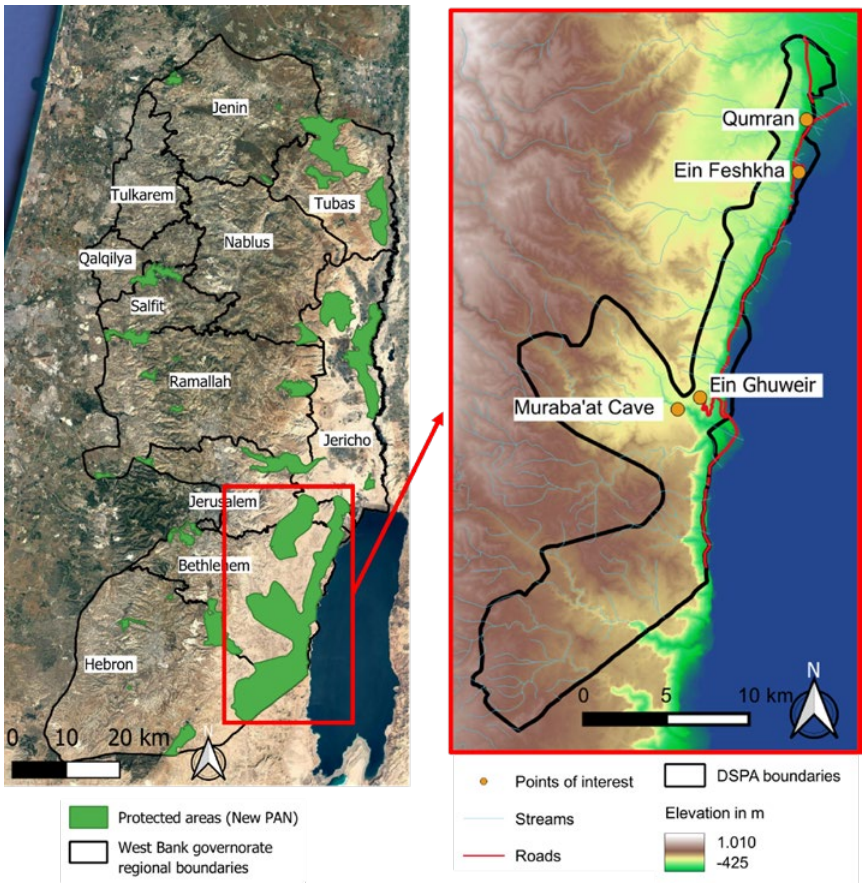


Figure 1. Left: Boundaries of the protected areas according to the new Protected Areas Network in the West Bank. The Dead Sea Protected Area (DSPA) is the one at the bottom and right and the Jerusalem Wilderness Protected Area (JWPA) is to its left. The names of the governorates are written on a white background; right: Study area (DSPA and JWPA) with Digital Elevation Model (white and brown show high altitudes whereas blue and green show low altitudes), main points of interest for tourism (orange), streams (blue), and road network (red). The borders of the protected areas are outlined in black.

literature, governmental and international reports, and biodiversity databases (e.g. BioGIS, iNaturalist). All biodiversity records were collected as presence-only data. Quantitative abundance measures (e.g. density or cover) were not systematically recorded across the study area. Instead, plant species were assigned to relative abundance and rarity categories: rare (11–30 sites), very rare (4–10 sites), extremely rare (1–3 sites) (Al-Sheikh, 2019; Al-Sheikh & Qumsiyeh, 2021). Vertebrate data were collected through field observations, small mammal trapping (Sherman traps, seven trapping nights – three in DSPA and four in JWPA with 40 traps each), camera trapping (3 cameras over 12 nights), and echolocation recordings for bats (ten recording nights, June–August 2023). Birds were surveyed during breeding (February to June) and migration seasons (peaks March/April and September/October), and reptiles through active searches for tracks and individuals. Species data were systematically recorded following IUCN criteria (https://www.iucnredlist.org/en). Invertebrates were sampled using standard zoological techniques: butterflies with nets, moths via light traps, arthropods from substrates and plants, and scorpions, spiders and molluscs from under rocks and crevices. Specimens were identified and preserved using taxonomic standards, with selected samples deposited at the Palestine Museum of Natural History (PMNH) and voucher specimens maintained in the herbarium.

Field data were collected at discrete survey sites, defined as locations visited during field campaigns. These survey sites served as the primary units for data collection and documentation of species presence. Environmental, social and economic factors and threats to the DSPA were analysed through literature and field assessments (April–May 2023). Data were interpreted using the Open Standards for the Practice of Conservation (Conservation Measures Partnership, 2025), identifying conservation and human well-being targets, threats, and ecosystem services. For conservation targets, one representative plant from each phytogeographic region in the DSPA was selected based on conservation status and regional abundance (Al-Sheikh & Qumsiyeh, 2021). Threats were ranked using the WWF Absolute System (WWF, 2007) by scope, severity, and irreversibility. Plant species distribution modelling was performed using MaxEnt (Phillips et al., 2006) for 55 rare species (*sensu* Al-Sheikh, 2019) recorded during 2023 surveys and PAN data. Environmental grids for the West Bank were obtained from https://www.worldclim.org/, https://unbiodiversitylab.org/en/ and https://geomolg.ps/, and harmonised using R and QGIS (https://docs.qgis.org/3.44/en/docs/training_manual/processing/r_intro.html). MaxEnt models (logistic output, 10 replicates) incorporated a gridded bias file to correct for sampling effort (cf. Kramer-Schadt et al., 2013). Habitat suitability

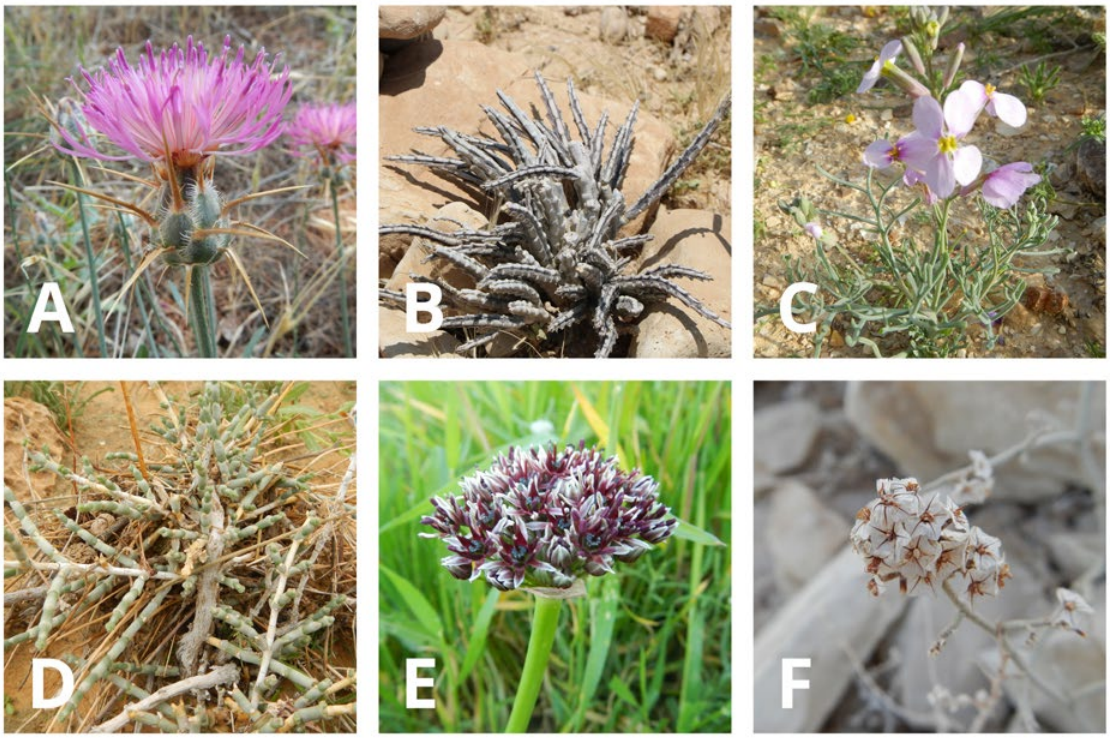


Figure 2. Notable plants: A: Eryngio Star Thistle (*Centaurea eryngioides* Lam); B: Dead-sea Caralluma (*Caralluma sinaica* (Decne) A.Berger); C: *Pseuderucaria clavata* (Boiss. & Reut.) O.E.Schulz; D: *Anabasis oropediorum* Maire; E*:* Roth's Garlic (*Allium rothii* Zucc); F: Frosty Sea-lavender (*Limonium pruinosum* (L.) Chaz). Photos by B. Al-Sheikh.

maps were generated and aggregated to highlight areas of special conservation interest (Babich Morrow, 2019).

Finally, we also engaged the local communities near those two areas. This included primarily the town of Ubaidiya and the Bedouin communities of Jahhalin around the Dead Sea area. Semi-structured interviews with groups of 5–10 locals were held over a period of four years (minimum 15 meetings). We especially asked about their relationship with nature and threats they see to their livelihood (mostly pastoralism) and to nature.

RESULTS

Across the two protected areas – the JWPA and DSPA – a total of 241 plant species were recorded (Table 1.2 Supplementary Online Material) . Of these, 26 species occur in both areas, 137 species are unique to JWPA, and 130 species are unique to DSPA. Nine invasive species were documented, with only one shared between the two sites. Five species are endemic or near-endemic: four occur exclusively in JWPA and one in DSPA, with no overlap. Sixteen species are classified as extremely rare (O-status, 1–3 sites only). Fifteen occur in DSPA (including one sub-endemic), while only one is recorded in JWPA, with no O-status species shared. Twenty-three species are classified as very rare (RR). Three occur in JWPA (one endemic), whereas twenty occur in DSPA (one endemic), with no overlap. Twenty-two species are classified as rare (R). Six occur in JWPA (including one endemic) and sixteen in DSPA, with no overlap. The lack of overlap among endemic, rare, very rare and O-status species underscores the complementary conservation value of both protected areas.

Among the notable species are the locally endangered and very rare Leafless Bean Tree (*Moringa peregrina* (Forssk.) Fiori) and the rare Umbrella Thorn Acacia (*Acacia tortilis* (Forssk.) Hayne), both xerophytic species. Other significant plants include the locally endangered and very rare Hoary Abutilon (*Abutilon hirtum* (Lam.) Sweet) and the Irano-Turanian *Anabasis oropediorum* Maire (Figure 2D), restricted to semi-arid shrub-steppes, and Desert Savory (*Satureja thymbrifolia* Hedge & Feinbrun) (Figure 3B), an endemic and very rare species belonging to the Irano-Turanian–Saharo-Arabian chorotype. In addition, Samwa (*Cleome droserifolia* (Forssk.) Delile) and Hogweed (*Commicarpus helenae* (J.A.Schult.) Meikle) are very rare species restricted to the Sudanian chorotype. Notably, only one of the 55 rare species recorded was found in both the DSPA and JWPA (Table 1.1 Supplementary Online Material), underscoring the conservation importance of both areas.

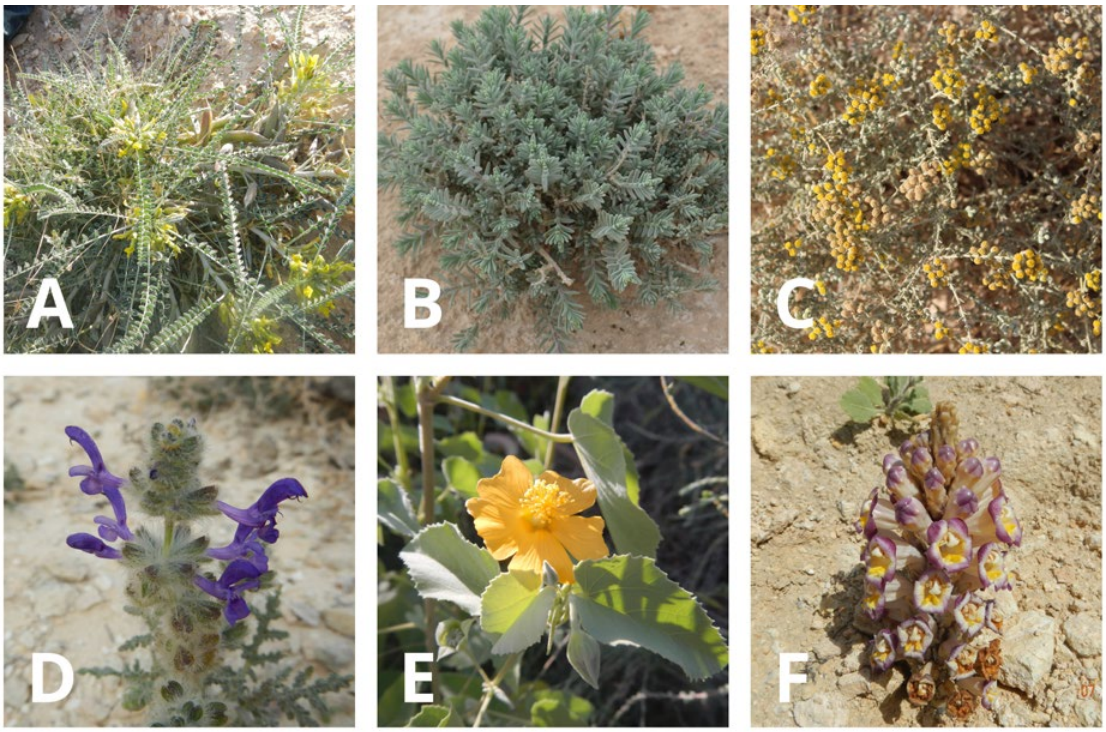


Figure 3. Other notable plants. A: Dagger's Milk-vetch (*Astragalus dactylocarpus* Boiss); B: Desert Savory (*Satureja thymbrifolia* Hedge & Feinbrun); C: Fragrant Lavender Cotton (*Achillea fragrantissima (Forssk) Sch.Bip.*); D: Wrinkle-leaved Sage (*Salvia lanigera* Poir); E: Texas Indian Mallow (*Abutilon fruticosum* Guill. & Perr.); F*: Cistanche salsa* (C.A.Mey) G.Beck. Photos by B. Al-Sheikh.

Among the rare plant species, 49 yielded an area under the receiver–operator curve (AUC; Bland et al., 2015) value above 0.7 in the species distribution models. Figure 4 displays the number of rare and invasive species per grid cell, assuming that "the 10% of occurrence records in the least suitable habitat aren't occurring in regions representative of the species' overall habitat" (Babich Morrow, 2019). The majority of rare species occur in the eastern part of the DSPA bordering the Dead Sea, with up to ten species per grid cell. Invasive species per grid cell range from 0 to 4 in the DSPA, without a clear spatial concentration. Missing data along the western border of the DSPA result from the coarse resolution of the environmental layers. Habitat and soil type were the main contributing variables to rare species distribution (Sayre et al., 2020). Nine invasive plant species were recorded: Golden Wreath Wattle (*Acacia saligna* (Labill.) Wendl.f.), Purple Amaranth (*Amaranthus blitum* L), Careless Weed (*Amaranthus palmeri* S.Watson), Pop Slatbush (*Atriplex holocarpa* F.Muell.), Downy Thorn-apple (*Datura innoxia* Mill.), Matted Sandmat (*Euphorbia serpens* Kunth), Malabar Sprangletop (*Leptochloa fusca* (L.) Kunth), Tree Tobacco (*Nicotiana glauca* Graham) and Castor-oil Plant (*Ricinus communis* L.).

Fauna

We recorded 37 mammalian species and 166 bird species across the two areas (Tables 3–4, Supplementary Online Material). Of the 166 bird species, 132 occur in both protected areas, while 34 were recorded in the DSPA but not in the JWPA; no species were documented exclusively in the JWPA. One species present in both areas is globally Endangered (EN): the Egyptian Vulture (*Neophron percnopterus*). Although classified as Least Concern (LC) globally by the IUCN, several birds are rare and endangered locally (See this https://redlist.parks.org.il/en/aves/aves_report/ and we have unpublished data based on declining populations and distributions using IUCN criteria for local and regional listing; Bubb et al., 2009): Trumpeter Finch (*Bucanetes githagineus*), Sinai Rosefinch (*Carpodacus synoicus*), Striolated Bunting (*Emberiza striolata*), Peregrine Falcon (*Falco peregrinus*), Eurasian Scops Owl (*Otus scops*) and Desert Finch (*Rhodopechys obsoletus*). The Pallid Scops Owl (*Otus brucei*) is endangered regionally, and Syrian Serin (*Serinus syriacus*) is globally Vulnerable (VU) but endangered locally. Three species present in both areas are regionally Near Threatened (NT) – Golden Eagle (*Aquila chrysaetos*, LC globally), Steppe Eagle (*Aquila nipalensis*, globally EN), and Eurasian Griffon Vulture (*Gyps fulvus*, LC globally) (Figure 5B). A total of 120 species in both areas are Least Concern, while 34 species have unknown local status.

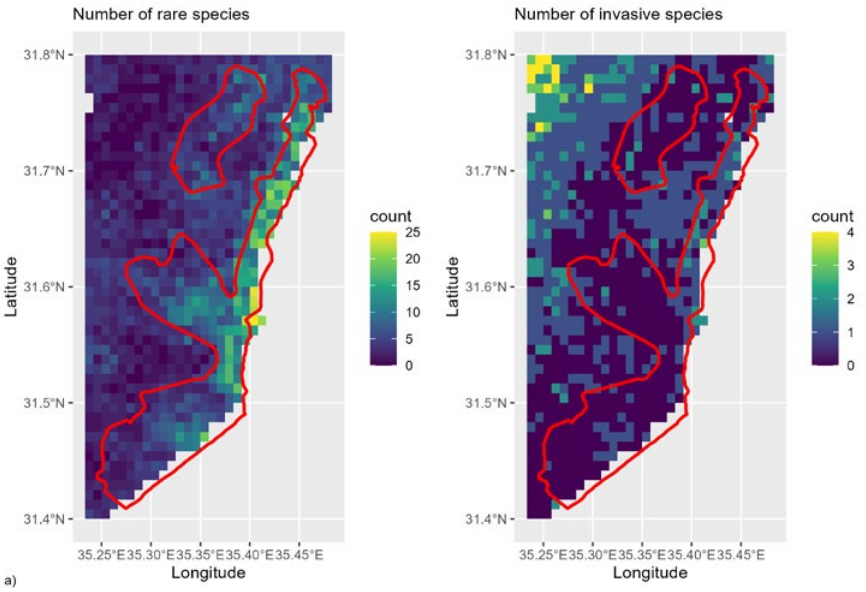


Figure 4. Distribution of MaxEnt-modelled (a) rare species and (b) invasive plant species per grid cell in the Dead Sea Protected Area (DSPA) and Jerusalem Wilderness Protected Area (JWPA). Higher species numbers are shown in yellow shades, while lower numbers appear in dark blue. The boundaries of the DSPA (right) and JWPA (top-left) are delineated in red.

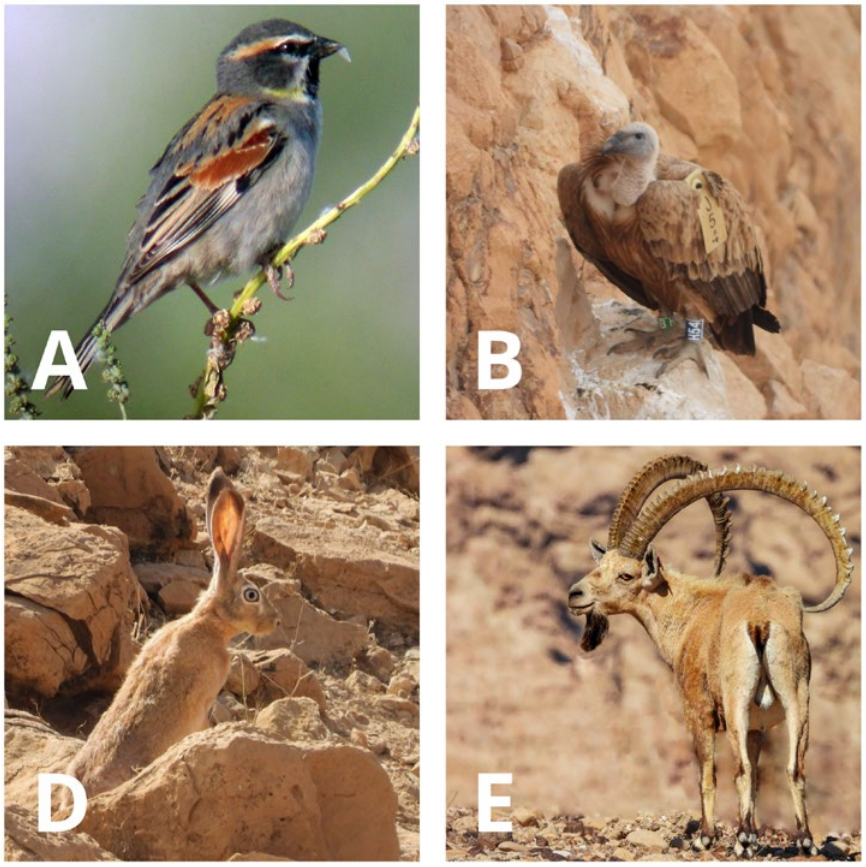


Figure 5. Selected animals: (A) Dead Sea Sparrow (*Passer moabiticus*) (photo by Saed Shomali), (B) Eurasian griffon vulture (*Gyps fulvus)* (photo by Saed Shomali), (C) Desert cottontail (*Sylvilagus audubonii*) (photo by Waseem Dawwas), (D) Nubian Ibex *(Capra nubiana)* (photo by Waseem Dawwas).

The type locality of Tristram's Starling (*Onychognathus tristramii*) lies within the JWPA (near Mar Saba Monastery). Species requiring particular conservation attention include the Greater Spotted Eagle (*Clanga clanga*, VU globally), Eurasian Griffon Vulture (*Gyps fulvus*, LC globally but threatened locally), Steppe Eagle (*Aquila nipalensis*, globally EN) and Syrian Serin (*Serinus syriacus*, globally VU).

Among mammals, all species larger than the rock hyrax (*Procavia capensis*) and all bats can be considered locally threatened in both areas (Mendelssohn & Yom-Tov, 1999; Qumsiyeh, 1996). Of particular concern are the Nubian ibex (*Capra nubiana*) (Figure 5D) and the Afghan fox (*Vulpes cana*). Gazelles (*Gazella gazella*) were previously recorded but have not been observed during the past 20 years; with appropriate grazing management and ecosystem restoration, reintroduction may be possible.



Convent of Mar Saba © PIBS, Bethlehem University

A total of 31 species of reptiles were noted in the targeted areas but 19 of them occur in one protected area but not the other (Table 2, Supplementary Online Material).

A rich assemblage of invertebrates was noted. We worked more intensively for this survey on two classes, butterflies and land snails (Tables 5–6, Supplementary Online Material). *Buliminus alepensis* and *Buliminus lamprostatus* are distinctive endemic land snails of the Dead Sea region and eastern slopes (Amr et al., 2018; our data).

Threats and challenges

JWPA and DSPA, like many protected areas in Palestine, face significant threats, including climate change, habitat loss, overexploitation of resources, pollution, invasive species and occupation-related pressures (Qumsiyeh & Abusarhan, 2021). Desertification, including climate change, was identified as the primary threat to fauna and flora. Some threats were site-specific, such as overgrazing recorded only in JWPA and the decline in the Dead Sea level altering habitats, for example for birds (Haran et al., 2023), including by creating sinkholes (Popperl, 2018).

Invasive plants represent the second largest threat to native biodiversity after habitat destruction (Pyšek et al., 2020). Nine invasive plant species were documented. Lacking natural enemies, these species reduce availability of habitats for and crowd out native species, with *Datura innoxia* having the most pronounced impact (Powell et al., 2011).

Untreated sewage from East Jerusalem neighbourhoods and Palestinian communities flows into Wadi Nar, worsening wastewater management issues. Central collection in East Jerusalem remains partial, with about 40 per cent of Palestinian household wastewater stored in cesspits and septic tanks (ARIJ, 2016; Isaac & Hosh, 1997). Technical failures cause wastewater losses that, along with runoff, drain into Wadi Nar, affecting urban and rural areas, including JWPA. Some wastewater is partially treated near JWPA and used for settler plantations in the Jericho area.

Large portions of the study areas have been designated closed military zones or 'nature reserves', often excluding only Palestinians without ecological justification (Allombert & Qumsiyeh, 2024; Brophy & Isaac, 2009). Exclusion structures such as fences and walls impose major environmental and humanitarian impacts (Braverman, 2023; Husein & Qumsiyeh, 2022).

The Dead Sea, a hypersaline inland lake, supports only extremophile taxa such as Archaea, Bacteria and fungi (Georges et al., 2021; Perl et al., 2017). However, its surface area declined by 11.27 per cent between 1985 and 2019 (Al-Mashagbah et al., 2021), driven by Jordan River water extraction, high evaporation rates, and over-pumping of brine for mineral extraction in Palestine, Jordan and Israel. Sinkholes along its shores increased due to deterioration of the freshwater–saltwater interface in recent decades (Arkin & Gilat, 2000; Popperl, 2018).

DISCUSSION

The results demonstrate that JWPA and DSPA harbour diverse fauna and flora, with many species unique to each area, thereby justifying their designation as separate protected areas along the Eastern Slopes of Palestine. For example, a majority of rare plants are unique to each site, with 54 of the 55 locally rare species recorded in only one area (Table 1.1 in Supplementary Online Material). MaxEnt species-distribution models show a concentration of rare species near the Dead Sea, explained by the distinct valley habitats and the presence of springs such as Ain Fashkha compared to the eastern slopes. Model performance could be improved by removing low-contribution predictors (Low et al., 2021), using finer-resolution spatial layers – especially along the western DSPA border – and reducing highly correlated climate variables, except temperature seasonality and precipitation of the warmest quarter.

Key threats to both protected areas (Qumsiyeh et al., 2014; Qumsiyeh & Abusarhan, 2021) include overgrazing; illegal hunting and wildlife poisoning; pollution – especially sewage inflow through Wadi Nar; settlement expansion; invasive species; habitat fragmentation (notably fencing around Ain Fashkha); and desertification and climate change effects. There is also a risk of expanding the segregation wall being built throughout the Israeli occupied West Bank to the two protected areas which would have a direct and negative impact on biodiversity (Husein & Qumsiyeh, 2022).

Conservation of both the JWPA and DSPA is essential to safeguard biodiversity and unique ecosystems. As demonstrated in this study, many species are not shared between the two areas; for example, only 11 per cent of plant species occur in both. Mammalian assemblages are only found in DSPA, whereas iconic bird species overlap more substantially, with both areas supporting endangered raptors. To address the threats identified, discussions with local communities and stakeholders highlight the following priorities:

Habitat conservation and restoration: We recommend merging the JWPA and DSPA into a single, larger protected area, as the JWPA's habitat closely resembles parts of the DSPA and the two sites are geographically adjacent. Exploring listing areas on both the eastern and western sides of the Dead Sea as IUCN Red List Ecosystems, recognising the region's uniqueness; this will require cross-border collaboration. Targeting degraded areas affected by overgrazing and illegal land use through reforestation and protection of critical ecological zones;

Species protection: Strengthening anti-poaching measures, mitigating human–wildlife conflict, revoking military firing zones, and safeguarding important habitats, including breeding sites for migratory birds. Due to the shrinking Dead Sea that is now creating many sink holes on its coastal areas, we need to develop species management strategies especially along the Dead Sea shoreline highway while also promoting ecotourism;

Community engagement: Working with Bedouin and local residents through eco-tourism initiatives, sustainable agricultural and pastoral practices, and youth-focused environmental education;

Sustainable land management in a biocultural landscape: Promoting eco-friendly farming, regulating livestock grazing, and enforcing legal mechanisms against unauthorised land use, drawing on successful examples from other newly established PAs (Qumsiyeh, Bassous-Ghattas et al., 2023; Qumsiyeh et al. 2024);

Local management rights: Both areas lie in one of the three administrative divisions of the West Bank established under the 1995 Oslo II Interim Agreement (Area C; Anziska, 2018). Area C comprises approximately 60 per cent of the West Bank and remains under Israeli civil and military control, including authority over land use, planning, security, and natural resource management. Area C contains most of the West Bank's open landscapes, agricultural land, water resources, and areas of high ecological and biodiversity value. For Palestinians, managing their own nature reserves in Area C would require the transfer of legal and administrative authority over land and environmental governance. This would enable Palestinian institutions to designate and manage protected areas, implement sustainable land-use practices, conduct scientific research, and conserve native biodiversity in line with national legislation and international standards.

Wetlands such as Ain Fashkha are critical conservation targets (Grenfell et al., 2022). Although they provide major ecosystem services in drylands, they are also highly vulnerable to climate change, agricultural pressures, hydrological alterations, and occupation-related restrictions. Ain Fashkha, managed by the Israel Nature and Parks Authority (INPA), includes fenced zones that restrict wildlife movement and Palestinian access – reflecting a broader pattern in which springs are designated as reserves while excluding the Indigenous population (Braverman, 2023).

Bedouin communities in JWPA – and to a lesser extent DSPA – face marginalisation and restricted access to traditional resources (B'Tselem, 2011; UNDP, 2013). In

DSPA, the remaining population consists exclusively of settlers, despite the prohibition of settlement construction under Article 49 of the Fourth Geneva Convention (Hareuveni, 2011). This contradicts international conservation norms, which advocate management by or with Indigenous Peoples (Phillips, 2000).

Both protected areas have high ecotourism potential. Palestine is among the world's less visited regions (UNWTO, 2020), yet JWPA and DSPA offer exceptional wilderness scenery, springs, canyons, valleys, rock formations, caves, and views overlooking the lowest point on Earth (Santarém et al., 2020; Teff-Seker & Orenstein, 2019). The Egyptian vulture serves as a powerful conservation target due to its cultural symbolism of freedom of movement (BirdLife International, 2023a). Additional management options include enhancing Nubian ibex (*Capra nubiana*) populations and exploring reintroduction of the recently extirpated leopard. Plant conservation should take into account local foraging traditions instead of blanket restrictions on wild plant foraging (Braverman, 2023). Despite these pressures, threat ratings for plant species were generally low to medium.

FUNDING

This work was supported by the Critical Ecosystem Partnership Fund (CEPF), under grant number CEPF-114345, and was implemented through BirdLife International in 2023.

ACKNOWLEDGEMENTS

The authors express their sincere gratitude to all individuals and institutions that contributed to the success of this study.

ABOUT THE AUTHORS

Sara G. Khair is an education specialist, biologist and fauna curator at the Palestine Institute of Biodiversity and Sustainability–Bethlehem University. https://orcid.org/0009-0004-5569-9389

Nina Lütkehermöller is a University of Göttingen student. https://orcid.org/0009-0007-3188-3562

Conrad Schittko is a Visiting Professor of Ecosystem Science and Plant Ecology at Technische Universität Berlin. https://orcid.org/0000-0002-2200-8762

Johann G. Gedeon is a botanist, medicinal flora and invasive plant species expert, researcher, and herbalist at the Palestine Institute for Biodiversity and Sustainability–Bethlehem University. https://orcid.org/0009-0009-3065-8069

Banan Al-Sheikh is an independent researcher with more than 25 years of experience in plant survey and documentation. https://orcid.org/0000-0003-4948-4686

Saed Shomaly is an independent researcher with 25 years of expertise in bird taxonomy. He specialises in identifying and documenting avian species. https://orcid.org/0009-0007-9478-4326

Mazin B. Qumsiyeh is a professor at Bethlehem University and founder of the Palestine Institute for Biodiversity and Sustainability. A biologist, educator and activist, he leads research and community programmes focused on conservation and environmental justice. https://orcid.org/0000-0003-2002-3026

REFERENCES

Al-Mashagbah, A. F., Ibrahim, M., & Al-Fugara, A. (2021). Estimation of changes in the Dead Sea surface water area through multiple water index algorithms and geospatial techniques. *Global NEST Journal*, 23, 565–571. https://doi.org/10.30955/gnj.004018

Al-Natsheh, Y. (2024). *Maqam of Nabi Musa. Discover Islamic Art – Museum With No Frontiers*. https://islamicart.museumwnf.org/database_item.php

Al-Sheikh, B. (2019) Checklist and Ecological Data Base of Wild plants of the West Bank – Palestine. National Agricultural Research Center, Palestine,

Al-Sheikh, B., & Qumsiyeh, M. B. (2021). Imperiled ecosystems in Palestine: Rare plants as Indicators. In: D. DiPaolo & J. Villella *Imperiled: The Encyclopedia of Conservation*, Reference Module in Earth Systems and Environmental Sciences, Elsevier, 1–7. https://doi.org/10.1016/B978-0-12-821139-7.00076-3

Allombert, C., & Qumsiyeh, M. B. (2024). Israel's designation of "nature reserves": A tool of colonization. *International Review of Contemporary Law*, 6(4), 9–14. https://iadllaw.org/newsite/wp-content/uploads/2024/11/IADL-Review-Nov-2024.pdf

Amr, Z. S., Najajreh, M. H., Zawahrah, M., Neubert, E., Handal, E. N., Abu Baker, M. A., & Qumsiyeh, M. B. (2018). Diversity and ecology of the land snails of the Palestinian Territories of the West Bank. *Zoology and Ecology*, *28*(1), 25–35. https://doi.org/10.1080/21658005.2017.1419107

Anziska, S. (2018). *Preventing Palestine: a political history from Camp David to Oslo*. Princeton University Press.

Applied Research Institute – Jerusalem (ARIJ) (2010). *Al 'Ubeidiya town profile*. http://vprofile.arij.org/bethlehem/pdfs/VP/Al%20'Ubeidiya_tp_en.pdf

Applied Research Institute – Jerusalem (ARIJ) (2016). *The status of environment in the State of Palestine: State of Environment Report 2015*. https://www.arij.org/wp-content/uploads/2016/06/Final_SOER_2015_opt_r.pdf

Arkin, Y., & Gilat, A. (2000). Dead Sea sinkholes–an ever-developing hazard. *Environmental Geology*, 39(7), 711–722. https://doi.org/10.1007/s002540050485

Atallah, S. I. (1977). *Mammals of the Eastern Mediterranean Region; their ecology, systematics and zoogeographical relationships*. Zeitschrift fur Saugetierkunde 25:241-320.

B'Tselem. (2011). *Dispossession and exploitation: Israel's policy in the Jordan Valley and northern Dead Sea*. B'Tselem. https://www.btselem.org/publications/summaries/dispossession-and-exploitation-israels-policy-jordan-valley-northern-dead-sea

Babich Morrow, C. (2019). *Thresholding species distribution models*. Cecina Babich Morrow. https://babichmorrowc.github.io/post/2019-04-12-sdm-threshold/

BirdLife International (2023a). *Species factsheet: Neophron percnopterus*. http://www.birdlife.org

BirdLife International (2023b). *Important Bird Area factsheet: Ein Al-Fashkha*. http://datazone.birdlife.org/site/factsheet/ein-al-fashkha-iba-palestine

BirdLife International (2024). *Jerusalem Wilderness IBA. BirdLife Data Zone*. https://datazone.birdlife.org/site/factsheet/jerusalem-wilderness-iba-palestine/text

Bland, L. M., Collen, B. E. N., Orme, C. D. L., & Bielby, J. O. N. (2015). Predicting the conservation status of data-deficient species. *Conservation Biology*, *29*(1), 250–259.

Braverman, I. (2023). *Settling nature: The conservation regime in Palestine-Israel*.

Brophy, Z., & Isaac, J. (2009). *The environmental impact of Israeli military activities in the occupied Palestinian territory.* Applied Research Institute–Jerusalem. https://www.arij.org/wp-content/uploads/2014/01/The-environmental-impact-of-Israeli-military.pdf

Bubb, P., Butchart, S., Collen, B., Dublin, H., Kapos, V., Pollock, C., Stuart, S. & Vié, J.C. (2009). *IUCN Red List index: Guidance for national and regional use.* Version 1.1. IUCN.

Conservation Measures Partnership (2025). *Open Standards for the Practice of Conservation.* Version 5. https://www.conservationstandards.org/wp-content/uploads/2026/03/CMP-Open-Standards-Report-v5.0-FINAL-v.-2026-03-25.pdf

Dudley, N. (2008). *Guidelines for applying protected area management categories*. IUCN. https://doi.org/10.2305/IUCN.CH.2008.PAPS.2.en

Environmental Quality Authority (2020). *IUCN Global Ecosystem Typology 2.0: Descriptive profiles for biomes and ecosystem functional groups*. IUCN. https://doi.org/10.2305/IUCN.CH.2020.13.en

Environment Quality Authority (2021). *State of Palestine—Sixth national report to the Convention on Biological Diversity*. https://www.cbd.int/doc/nr/nr-06/ps-nr-06-en.pdf https://chm.cbd.int/database/record?documentID=257520

Environmental Quality Authority (2022). *State of Palestine—National Biodiversity Strategy and Action Plan (NBSAP)*. https://ps.chm-cbd.net/sites/ps/files/2024-08/NBSAP%202022.pdf

Georges, O., Fernandez, S., Martinez, J. L., & Garcia-Vazquez, E. (2021). DNA metabarcoding illustrates biological pollution threats of Red Sea-Dead Sea water conveyance to Dead Sea biodiversity. *Marine Pollution Bulletin*, 168, 112451. https://doi.org/10.1016/j.marpolbul.2021.112451

Grenfell, S., Grenfell, M., Tooth, S., Mehl, A., O'Gorman, E., Ralph, T., & Ellery, W. (2022). Wetlands in drylands: diverse perspectives for dynamic landscapes. *Wetlands Ecology and Management*, 30(4), 607–622. https://doi.org/10.1007/s11273-022-09887-z

Haran, R., Troupin, D. & Izhaki, I. (2023). Dead Sea level decline pushed a sensitive ecosystem out of equilibrium, causing the relocation of a colonial bird breeding site. *Bird Study*, *70*(1–2), 1–12.

Hareuveni, E. (2011). *Dispossession and exploitation: Israel's policy in the Jordan Valley and northern Dead Sea*. B'tselem. https://doi.org/10.1163/2210-7975_HRD-2338-0219

Hay, K. (1996). Impact of St Sabas: The legacy of Palestinian monasticism. *Byzantina Australiensia*, 10, 118–125. https://doi.org/10.1163/9789004344709_012

Husein, D., & Qumsiyeh, M. B. (2022). Impact of Israeli segregation and annexation wall on Palestinian Biodiversity. *Africana Studia*, 1(37). https://ojs.letras.up.pt/index.php/AfricanaStudia/article/view/11964

Isaac, J., & Hosh, L. (1997). Political conflict and environmental degradation in Jerusalem. Jerusalem. In N. Ateek, C. Duyabis & M. Shrader (Eds.), *What makes for peace*. Melisende. https://www.arij.org/wp-content/uploads/2014/01/1997-Political-conflict-and-environmental-degradation-in-Jerusalem.pdf

Keith, D. A., Rodríguez, J. P., Brooks, T. M., Burgman, M. A., Barrow, E. G., Bland, L., Comer, P. J., Franklin, J., Link, J. ... & Spalding, M. D. (2015). The IUCN Red List of Ecosystems: Motivations, challenges, and applications. *Conservation Letters*, 8(3), 214–226. https://doi.org/10.1111/conl.12167

Keith, D. A., Ferrer-Paris, J. R., Nicholson, E., & Kingsford, R. T. (eds.). (2020). *The IUCN Global Ecosystem Typology 2.0: Descriptive profiles for biomes and ecosystem functional groups*. Gland, Switzerland: International Union for Conservation of Nature (IUCN). https://doi.org/10.2305/IUCN.CH.2020.13.en

Kramer-Schadt, S., Niedballa, J., Pilgrim, J. D., Schröder, B., Lindenborn, J., Reinfelder, V., & Wilting, A. (2013). The importance of correcting for sampling bias in MaxEnt species distribution models. *Diversity and Distributions*, 19(11), 1366–1379. https://doi.org/10.1111/ddi.12096

Lopes, H. T., & Almeida, I. (2017). The Mediterranean: The Asian and African roots of the cradle of civilization. In B. Fuerst-Bjelis (Ed.), *Mediterranean Identities-Environment, Society, Culture*. IntechOpen. https://doi.org/10.5772/intechopen.69363

Low, B. W., Zeng, Y., Tan, H. H., & Yeo, D. C. (2021). Predictor complexity and feature selection affect Maxent model transferability: Evidence from global freshwater invasive species. *Diversity and Distributions*, 27(3), 497–511. https://doi.org/10.1111/ddi.13211

Mendelssohn, H. & Yom-Tov, Y. (1999). *Mammalia of Israel*. The Israel Academy of Sciences and Humanities.

Norris, H. T. (1950). Mediaeval monasteries of eastern Palestine. *Palestine Exploration Quarterly*, 82(1), 31–39. https://doi.org/10.1179/peq.1950.82.1.31

Perl, T., Kis-Papo, T., & Nevo, E. (2017). Fungal biodiversity in the hypersaline Dead Sea: extinction and evolution. *Biological Journal of the Linnean Society*, 121(1), 122–132. https://doi.org/10.1093/biolinnean/blw025

Phillips, A. (2000). Indigenous and traditional peoples and protected areas: principles, guidelines and case studies (Vol. 4). J. Beltrán (Ed.). IUCN. https://doi.org/10.5962/bhl.title.44953

Phillips, S. J., Anderson, R. P., & Schapire, R. E. (2006). Maximum entropy modeling of species geographic distributions. *Ecological Modelling*, 190(3–4), 231–259. https://doi.org/10.1016/j.ecolmodel.2005.03.026

Popperl, S. (2018). Geologies of erasure: Sinkholes, science, and settler colonialism at the Dead Sea. *International Journal of Middle East Studies*, 50(3), 427–448. https://doi.org/10.1017/S002074381800082X

Powell, K. I., Chase, J. M., & Knight, T. M. (2011). A synthesis of plant invasion effects on biodiversity across spatial scales. *American Journal of Botany*, 98(3), 539–548. https://doi.org/10.3732/ajb.1000402

Pyšek, P., Hulme, P. E., Simberloff, D., Bacher, S., Blackburn, T. M., Carlton, J. T., Dawson, W., Essl, F., Foxcroft, L. C. ... & Richardson, D. M. (2020). Scientists' warning on invasive alien species. *Biological Reviews*, 95(6), 1511–1534. https://doi.org/10.1111/brv.12627

Qumsiyeh, M., & Amr, Z. (2025). Northern Great Rift Valley: Deserts and other biomes. In *Terrestrial biomes* (pp. 23–34). Academic Press. https://doi.org/10.1016/B978-0-443-36569-0.00002-1

Qumsiyeh, M., Zavala, S. & Amr, Z. (2014). Decline in vertebrate biodiversity in Bethlehem, Palestine. *Jordan Journal of Biological Sciences*, 7(2), 101–107.

Qumsiyeh, M.B. (1996). *Mammals of the Holy Land*. Texas TechPress.

Qumsiyeh, M. B., & Abusarhan, M. A. (2021). Biodiversity and environmental conservation in Palestine. In *Biodiversity, conservation and sustainability in Asia: volume 1: prospects and challenges in West Asia and Caucasus* (pp. 1–22). Springer. https://doi.org/10.1007/978-3-030-59928-7_1

Qumsiyeh, M. B., & Al-Sheikh, B. (2023). Flora and conservation issues in two protected areas in Palestine: Wadi Al-Zarqa Al-Ulwi and Wadi Qana. *Diversity*, 15(2), 142. https://doi.org/10.3390/d15020142

Qumsiyeh, M. B., Bassous-Ghattas, R., Handal, E. N., Abusarhan, M., Najajreh, M. H., & Albaradeyiyah, I. (2023). Biodiversity Conservation of a new protected area 'Al-Arqoub', South Jerusalem Hills, Palestine. Parks Journal, 29(29.1), 33–42.

Qumsiyeh, M. B., Hussein, D., Boulad, N., Albaradeiya, I. M., Mahasnah, M., Abusarhan, M., Najajreh, M. H., Al-Shaikh, B., Handal, E. N., & Amr, Z. S. (2023). Updating and enhancing the protected areas network of Palestine: A step towards biodiversity conservation. *PARKS*, 29, 73–84. https://doi.org/10.2305/UBEA6691

Qumsiyeh, M. B., McHugh, C., Shaheen, S., & Najajrah, M. H. (2024). Bio-cultural landscape and eco-friendly agriculture in Al-Arqoub, South Jerusalem, Palestine. *Agroecology and Sustainable Food Systems*, 48(10), 1489–1513. https://doi.org/10.1080/21683565.2024.2392652

Radford, E. A., Catullo, G., & de Montmollin, B. (Eds.) (2011). *Important plant areas of the south and east Mediterranean region: priority sites for conservation*. IUCN. https://portals.iucn.org/library/efiles/documents/2011-014.pdf

Santarém, F., Saarinen, J., & Brito, J. C. (2020). Mapping and analysing cultural ecosystem services in conflict areas. *Ecological Indicators*, 110, 105943. https://doi.org/10.1016/j.ecolind.2019.105943

Sayre, R., Karagulle, D., Frye, C., Boucher, T., Wolff, N. H., Breyer, S., Wright, D., Martin, M., Butler, K., ... & Possingham, H. (2020). An assessment of the representation of ecosystems in global protected areas using new maps of World Climate Regions and World Ecosystems. *Global Ecology and Conservation*, 21, e00860. https://doi.org/10.1016/j.gecco.2019.e00860

Soto-Berelov, M., Fall, P. L., Falconer, S. E., & Ridder, E. (2015). Modeling vegetation dynamics in the Southern Levant through the Bronze Age. *Journal of Archaeological Science*, 53, 94–109. https://doi.org/10.1016/j.jas.2014.09.015

Teff-Seker, Y., & Orenstein, D. E. (2019). The 'desert experience': Evaluating the cultural ecosystem services of drylands through walking and focusing. *People and Nature*, 1(2), 234–248. https://doi.org/10.1002/pan3.28

UNWTO (UN World Tourism Organization). (2020). *Compendium of Tourism Statistics, Data 2014–2018, 2020 Edition*. Madrid: World Tourism Organization. https://doi.org/10.18111/9789284421459

United Nations Development Programme (2013). *In focus: Bedouins in the occupied Palestinian territory (Internal Resilience Series)*. UNDP – Palestinian Programme of Assistance to the Palestinian People https://unispal.un.org/pdfs/UNDP_BedouinsRep.pdf

United Nations Environment Programme (2020). *State of environment and outlook report for the occupied Palestinian territory*. https://ceobs.org/wp-content/uploads/2020/06/SEORP.pdf

VanderKam, J., & Flint, P. (2005). *The meaning of the Dead Sea scrolls: their significance for understanding the Bible, Judaism, Jesus, and Christianity*. A&C Black.

Whyte, R. O. (1950). The phytogeographical zones of Palestine. *Geographical Review*, 40(4), 600–614. https://doi.org/10.2307/211105

World Wide Fund for Nature (2007). *Resources for implementing the WWF project & programme standards: WWF Step 1.4 Threat Ranking*. WWF.https://www.conservationstandards.org/wp-content/uploads/sites/3/2020/10/WWF-1_4_threat_ranking___july_13__2007.pdf

Zeder, M. A. (2008). Domestication and early agriculture in the Mediterranean Basin: Origins, diffusion, and impact. *Proceedings of the National Academy of Sciences*, 105(33), 11597–11604. https://doi.org/10.1073/pnas.0801317105

RÉSUMÉ

La mise en place récente d'un réseau d'aires protégées (PAN) en Palestine marque une avancée considérable dans les cadres nationaux de conservation et redéfinit de manière significative les approches de gestion antérieures. Dans ce cadre, deux zones protégées ont été désignées le long des versants orientaux de la Cisjordanie : la zone protégée de la nature sauvage de Jérusalem (JWPA) et la zone protégée de la mer Morte (DSPA). Cette étude a examiné la composition de la faune et de la flore, les caractéristiques des habitats et les principales menaces dans ces deux zones, tout en abordant les défis de gestion dans le contexte des services écosystémiques et des conditions sociopolitiques complexes de la région. Malgré leur proximité géographique, les deux zones présentent des assemblages écologiques nettement distincts. Seules quatre espèces végétales rares sont communes à la JWPA et à la DSPA, tandis que 19 espèces rares sont présentes exclusivement dans la JWPA et 34 dans la DSPA. Bien que toutes les espèces d'oiseaux recensées dans la JWPA aient également été observées dans la DSPA, 34 espèces supplémentaires, ainsi que plusieurs taxons de mammifères, étaient propres à la DSPA. Les menaces et les défis de gestion ont été évalués au regard des normes internationales de conservation, et les habitats potentiels des espèces végétales rares ont été modélisés à l'aide de MaxEnt. Parmi les menaces les plus critiques identifiées figurent la désertification, la sécheresse et la fragmentation des habitats. Sur la base d'une analyse de zonage, l'étude recommande une protection stricte de l'oasis naturelle d'Ain Fashkha dans la DSPA, un plan de gestion des pâturages dans la JWPA et le développement d'initiatives d'écotourisme durable.

RESUMEN

La recién creada Red de Áreas Protegidas (PAN) de Palestina supone un avance sustancial en los marcos nacionales de conservación y reconfigura de manera significativa los enfoques de gestión anteriores. En este marco, se han designado dos áreas protegidas a lo largo de las laderas orientales de Cisjordania: el Área Protegida de la Naturaleza Salvaje de Jerusalén (JWPA) y el Área Protegida del Mar Muerto (DSPA). Este estudio ha examinado la composición de la fauna y la flora, las características de los hábitats y las principales amenazas en ambas áreas, al tiempo que ha abordado los retos de gestión en el contexto de los servicios ecosistémicos y las complejas condiciones sociopolíticas de la región. A pesar de su proximidad geográfica, las dos áreas presentan comunidades ecológicas marcadamente distintas. Solo cuatro especies vegetales raras son comunes a la JWPA y la DSPA, mientras que 19 especies raras se dan exclusivamente en la JWPA y 34 en la DSPA. Aunque todas las especies de aves registradas en la JWPA también se documentaron en la DSPA, otras 34 especies, junto con varios taxones de mamíferos, se limitaban a la DSPA. Las amenazas y los retos de gestión se evaluaron con arreglo a las normas internacionales de conservación, y se modelizaron los hábitats potenciales para las especies vegetales raras utilizando MaxEnt. Entre las amenazas más graves identificadas figuran la desertificación, la sequía y la fragmentación del hábitat. Basándose en el análisis de zonificación, el estudio recomienda la protección estricta del oasis natural de Ain Fashkha en la DSPA, un plan de gestión del pastoreo en la JWPA y el desarrollo de iniciativas de ecoturismo sostenible.



BOOK REVIEWS

Meanings that matter: A review of Jon Kohl's Interpretive Theme Writer's Field Guide

Jon Kohl. Published by Bloomsbury 2026

Reviewed by Kelley Anderson, PhD, Sr. Research Associate, Virginia Tech, Department of Forest Resources and Environmental Conservation, College of Natural Resources and Environment

Drawing the map that Florida (and the world) followed

Regional Landscape Conservation Planning: Wildlife, Connectivity, and the Florida Model. Edited by Reed F. Noss and Thomas S. Hoctor. University of Florida Press, 2026

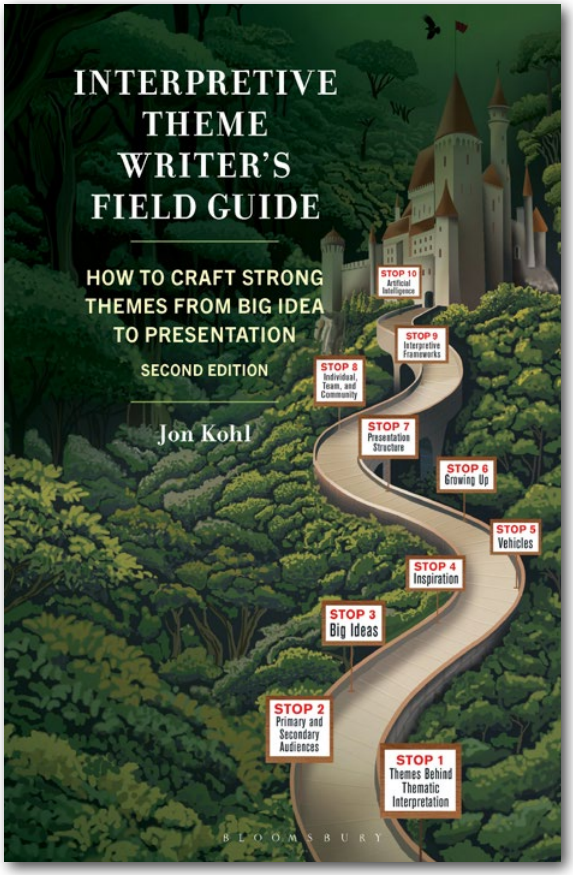
Reviewed by Eric Dinerstein, PhD, Chief Scientist, Landseed

Meanings that matter: A review of Jon Kohl's Interpretive Theme Writer's Field Guide

Dr. Kelley C. Anderson is a Sr. Research Associate in the Department of Forest Resources and Environmental Conservation at Virginia Tech. Her research focuses on environmental education and interpretation, program evaluation, and adaptive management. She works closely with mission-driven organizations to implement evidence-based practices and improve their services.

Interpretation in protected areas is often expected to do much more than convey information and provide visitors with an enjoyable experience. Its true potential lies in helping visitors make meaning, revealing the extraordinary in the familiar, fostering connections to place, nature and culture, and inspiring reflection and transformation in service of the greater good. This is a hefty task for both the novice and experienced interpreter alike. Jon Kohl's *Interpretive Theme Writer's Field Guide*, now in its second edition, builds on Sam Ham's thematic interpretation tradition while expanding and modernising the 2018 *Field Guide*. Kohl's greatest contribution is not simply providing practitioners with a recipe and tools for writing better themes, but treating theme development as a deliberate process of discovery, creativity, self-reflection and collaboration.

The *Field Guide* organises the main text as a journey through ten 'stops', a guided experience that should feel familiar to any interpreter. Through these chapters, readers are directed to consider thematic interpretation and its distinguishing features; opine on 'Big Ideas' and develop vehicles to operationalise them; lead with curiosity and practise creativity; consider audiences' needs; structure experiences intentionally; and



effectively collaborate with both teams and technology. Kohl envisions themes as more than a product or takeaway message, and rather as practical tools and design decisions that guide interpreters in crafting transformative experiences. For protected areas to endure, we must do more than pass knowledge and culture from one generation to the next; we must create opportunities for visitors to encounter and grapple with Big, meaningful, messy Ideas that change how we interact with, govern and protect these sacred sites. To

https://doi.org/10.2305/WOCK2949

riff off Kohl's analogy, interpretation is precisely the arrow for this target, and themes set its trajectory.

The publication is aptly titled a *Field Guide* as its strengths lie in making abstract concepts concrete. The book features clear guidelines, numerous real-world examples, exercises and worksheets, a theme inventory, and even AI prompts. In reviewing this book, I had the luxury to get lost in poetic prose, learn from the diverse perspectives within the *Voices from the Field* callouts, examine the *Theme Spotlights*, and contemplate how my own experience and training aligns with or diverts from this *Field Guide*. And while I encourage all readers to do the same, this publication can just as easily be thumbed through on a 15-minute lunch break for quick guidance or a tangible exercise before an imminent presentation. As the field of interpretation has grown and modernised in an ever-changing world, themes have remained somewhat elusive. Nearly all interpreters would say theme development is critical to their success, while few would confidently admit they have mastered the craft. This *Field Guide* moves us from the elusive towards the practical. By laying out a deliberate process and clearly explaining key components without overexplaining them, Kohl makes the hard-to-teach far more approachable.

The *Field Guide* covers much of what one might expect, from ideation to mechanics to implementation. I focus here on the more unique contributions that address present and future societal challenges. Much of Kohl's writing emphasises that interpretive theme writing is a deeply personal endeavour, requiring interpreters to conduct research from a position of curiosity, reflect on their development processes, and recognise their interests, perspectives and biases. Yet modern interpretation also demands co-creation as society grapples with questions such as: Who gets to decide what the Big Idea is? What happens when a protected area has multiple narratives informed by diverse lived experiences? Can thematic interpretation accommodate contested meanings? Kohl recognises this tension and contributes meaningfully to the conversation by providing structures and processes for developing 'Theme Teams' and 'Interpretive Frameworks' that leverage community voices, power and perspectives. He also provides critical questions for practitioners considering theme writing as a community-building process. The *Voices from the Field* callout in Stop 2 (Dr Kylie Christian and Leanne Redpath) offers a glimpse of the realities of such a process, even with highly trained facilitators. While co-creation may offer a valuable approach to theme development, practitioners should ensure they have the resources, expertise and necessary reflexivity to engage in the process effectively.

This second edition also considers the rise of AI and its potential use in interpretive theme writing. The central question is: if interpretation is fundamentally about developing meaningful Big Ideas and connecting people and place, what part of theme development should remain human? Generative AI may be able to produce grammatically sound themes, but it cannot determine what deserves attention, whose perspectives matter most, what relationship ideas and meaning have to a place, or what interpretive experience we create for visitors. Kohl establishes his own relationship with AI as collaborative, an idea that can be carried over to his concept of a Theme Team. Each member brings different strengths and perspectives. AI's strength lies in its ability to quickly generate a variety of themes that follow established guidelines. Does AI have perspectives, however? While that might be up for debate, Kohl's hope (and mine) is that the Big Ideas at the foundation of any theme remain distinctly human. For practitioners who wish to collaborate with AI, Kohl provides guidance for training AI based on the *Field Guide* and prompts to support the theme-writing process.

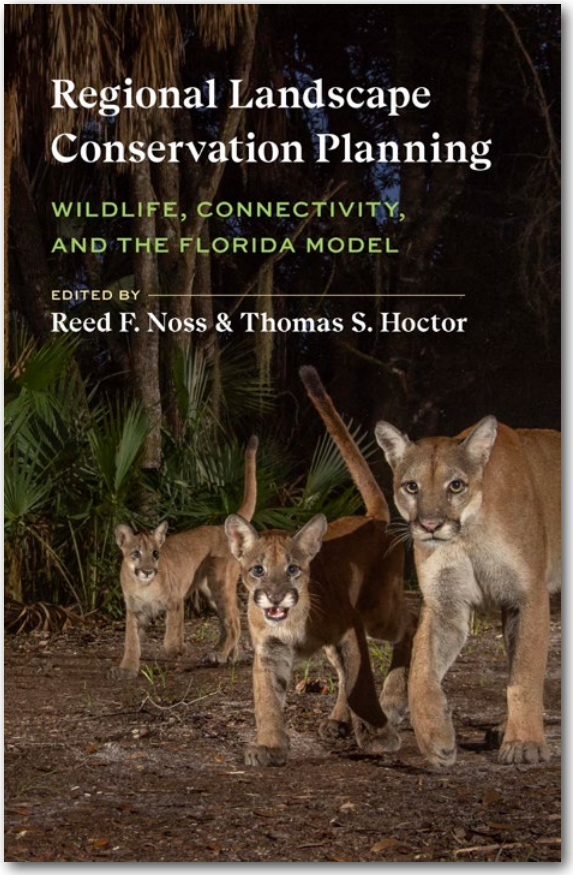
There is one question I believe remains unanswered and debated in the broader field: Can a theme take the form of an interrogative question? Kohl states that themes must be declarative, not interrogative: "A theme statement should not be a question because a theme is precisely the answer to a question" (p. 53). Current interpretive training in the US National Park Service diverges from this standpoint. Upon a close review of the guidelines presented in this *Field Guide*, one could plausibly follow all but one and arrive at a meaningful theme question. Could this theme question provoke thought, reveal meaning, relate to the audience, and serve as an organising structure? There has yet to be any empirical evidence supporting or refuting one approach over the other, so a hard line stance may be premature. The choice likely depends on the mission of the organisation, the desired outcomes, and the experience and preference of the interpreter. Kohl does make an important distinction that themes should be declarative rather than imperative, leaving room for multiple meanings. But if audiences are provoked to create their own meaning, does this leave room for more open-ended themes? While Kohl has a firm stance, this question may remain open to debate.

This debate illustrates the usefulness and limits of a prescriptive approach to thematic interpretation. Kohl provides a clear and practical framework for developing themes, but underlying questions about what, and who, themes are for, and how much meaning interpreters should leave open to audiences, remain unsettled. These

questions matter because protected areas are not simply collections of biodiversity facts. They are places that hold and preserve ideas, meanings, and legacies. The *Field Guide* is best understood not merely as a manual for writing better interpretive sentences, but as a guide for more intentional decisions about meaning, audience and experience. Its value for protected-area practitioners lies in translating the principles of thematic interpretation into a practical process while beginning to address increasingly important questions of collaborative authorship, cultural perspectives and AI.

One potentially overlooked contribution of the *Field Guide* is its application to interpreter training. Its exercises and examples will undoubtably help interpreters write more powerful themes. Yet Kohl's writing points to two characteristics that interpreters must develop and for which I fear we provide little time. First, interpreters must be curious. "The goal isn't to become a content expert necessarily, rather as your research progresses you may expose yourself to provocative new perspectives about your topic" (p. 38). Research without curiosity and the latitude to explore surprising connections can lead interpreters down a narrow path towards lacklustre themes. Second, interpreters must become conscious of their own development and continually practise self-awareness and self-reflection. This process allows interpreters to grapple with and refine Big Ideas and hone their craft of meaningful and transformative interpretation.

I ask the field: do we allow time for and prioritise these essential skills? While Kohl's book is first and foremost a practical guide, it leaves space for philosophical musings. Let's keep the conversation alive, sharpen these essential skills, and continue to reflect on what it means to be an interpreter of a protected area.



Drawing the map that Florida (and the world) followed

Most naturalists can name the sighting of an intriguing species that set them on a lifetime of studying nature. For conservation biologists, the epiphany can take other forms. Mine was a map: the first proposed Florida Wildlife Corridor network (reproduced as Figure 2.2 on p. 37 of this book). Reed Noss's drawing showed core areas, buffers and corridors stitched together across an entire state of interconnected human-dominated landscapes. It told me what conservation planning at scale had to achieve if we were to be serious about saving life on Earth, and it has informed my career more than any other image I have seen.

This edited volume tells the story behind that map and how Floridians put it to good use. The volume has a bit of everything. It is a comprehensive guide to large-scale landscape planning, starting appropriately by looking back at what was there in order to decide what must be conserved or restored. It covers terrestrial, freshwater and coastal realms, connectivity, climate refugia, road ecology, and the role of land trusts. The editors state their aim plainly: to give engaged citizens accessible explanations of why landscape-scale conservation matters, and of the opportunities and obstacles in carrying out ambitious plans.

Noss and Hoctor open with the science–implementation gap. Two-thirds of published conservation assessments never lead to action, mostly because researchers never plan for implementation. Florida is the counterexample, by necessity. More than 1,000 new residents arrive each day, and the state has the highest rate of habitat loss in the Southeast. Even more critical is the observation that Florida anchors the North American Coastal Plain, the 36th global biodiversity hotspot, and holds hundreds of endemic plants, most of them in fire-dependent pine savannas and scrub.

What makes this hotspot remarkable is its depth in time. A recent phylogenetic analysis shows that Florida, more than California, holds a rich mix of both ancient lineages (paleoendemics) and recently evolved species (neoendemics). Florida has been an evolutionary museum, where old species survived for millions of years in a climate buffered by the sea, and an evolutionary cradle, where new ones arose. Many of the young species evolved on ridges that were islands when sea levels stood higher, between the mid-Miocene and the Pleistocene. Others live only in the Keys, which were cut off from the mainland just 6,000 years ago. The editors frame the case for their protection through irreplaceability and vulnerability, the touchstones of conservation planning for decades.

The first chapter contains a passage I did not expect. Noss, who as much as anyone made protecting large intact landscapes the gospel of conservation biology, concedes that the movement he helped start nearly abandoned small, isolated sites. Botanists criticised the early corridor plans because much of what makes Florida a hotspot is its wealth of narrow-range endemic plants, many of them on isolated fragments too small to matter in mapping large blocks of Florida panther habitat. Looking back, Noss and Hoctor reveal that the right answer was always both: large connected landscapes for area-sensitive species such as the Florida panther and black bear, and many small sites for the endemics.

The science explains why. Plant communities in the longleaf pine savannas are dominated by turnover: small sites hold species that larger sites lack. Beta-diversity, the change in species composition with distance or along environmental gradients, is the variable that conservation planning most often ignores, because measuring it requires species lists and turnover rates across many sites. Yet it is among the most important variables to consider. Ecologist Jim Quinn of UC Davis once offered the most accurate and succinct, one-line definition of conservation biology and planning: "Pay attention to landscapes and beta-diversity." This book shows what that means in practice.

https://doi.org/10.2305/EPJU1499

Chapter 2 also sets out what survived of island biogeography in reserve design. The rule that one large reserve is always more valuable than several small ones of equal total area has not held up, because habitat quality and species turnover along environmental gradients vary too much. Two rules do persist: Other things being equal, big blocks of habitat retain more species than small ones, and connected patches persist better than isolated fragments.

The book's greatest lesson for conservationists is that what is first dismissed as radical can become the status quo within a few years. When Noss's statewide corridor map appeared in the mid-1980s, mainstream environmental groups ignored it, some ecologists opposed corridors outright, and agricultural groups fought it. It lay fallow for nearly a decade. Noss's inspirational map came back as the Florida Ecological Greenways Network in 1997, and in 2021 the legislature passed the Florida Wildlife Corridor Act unanimously. Today about 30 per cent of Florida is in conservation areas, already meeting the 2030 global target known as 30x30. The Corridor's conserved and opportunity lands cover nearly half the state. A Noss-ism: Be ambitious, and stay with a sound idea: doing less may be the bigger risk.

The bipartisanship documented here should encourage practitioners everywhere. Through governors and legislatures of both parties, Florida has paid for land conservation since committing US$3 billion through the 1990 land acquisition programme, Preservation 2000. The state also made its land buying accountable. Florida Forever, the successor programme, set nine goals and 38 performance measures, and proposed purchases are scored against statewide data in a site-selection analysis rerun each year.

It is worth turning from Figure 2.2 to the later statewide maps in Chapters 3 and 7. It is like moving from a diagram of the body's main arteries to one that shows the smaller vessels and finally the capillaries: where each corridor should run, what it must connect and how wide it must be. That progression depended on the birth and application of a game-changing technology. Geographic information systems made components of the plan spatially explicit and shortened the time needed to make important decisions. Advances in conservation sometimes wait on hardware and software.

In the American West, much of the land is federal, and conservation can advance through changes in agency policy. In the Southeast, most rare elements of biodiversity occur on private land. The chapters on acquisition priorities and on land trusts show how Florida has dealt with that directly, with easements that keep ranches going while removing the threat of development. Florida is larger than many countries and, in places, as densely settled as small crowded nations. Its methods for planning amid rapid growth should transfer well.

One ally will surprise many readers: the US military. Florida has 42 military facilities, several among the nation's largest and biologically richest. Through several Department of Defense Environmental Protection programmes and landscapes partnerships, the military pays for land and easements around its bases to keep development away from training ranges. In northeast Florida, Army and Navy funding helped launch the Ocala-to-Osceola corridor. The bases matter for habitat management as well as protection. Eglin Air Force Base in the Panhandle holds the largest remaining tract of old-growth longleaf pine savannas in the world. Munitions testing sparks fires there, and the base burns regularly to keep fuels down. Many of Florida's rare species need periodic fire to persist, and fire is hard to apply in a fragmented heavily populated landscape.

The road ecology chapter deserves attention. Vehicle collisions are a major cause of death for panthers and bears, and for deer, the panther's main prey. According to Noss and Hoctor, Florida now has 223 wildlife crossing structures, and dozens more are planned. We have the means to make such engineering the rule rather than the exception. The US Army Corps of Engineers already runs an Engineering with Nature initiative; I would like to see a much larger part of the Corps given over to green infrastructure. A new administration in Tallahassee or Washington could put many people to work retrofitting our major transportation corridors so that wildlife can cross them safely.

I found the growth-modelling chapter among the most useful. Teams have modelled Florida's future again and again, under business-as-usual, sprawl, and conservation scenarios. The Florida 2070 study (2016) reached a finding relevant to planners: even modest increases in development density save large areas of natural and agricultural land. Florida's planners show how looking 50 years ahead is essential, not an academic exercise.

Climate change sharpens the problems facing the state. Florida is nearly flat, and sea level is projected to rise about 0.9 m by 2070 in recent scenarios, potentially displacing an estimated 900,000 people inland and converting natural land. The climate chapter, however, also offers a surprise. Flat terrain is usually assumed to leave species nowhere to go. But the sea surrounds Florida on three sides and buffers temperature extremes, and during Pleistocene cold periods Florida was actually warmer. Florida has been a climate refugium for

millions of years, which helps explain its treasure chest of endemics. Freshwater springs, which hold a near-constant temperature, serve as microrefugia; manatees now depend on them in winter, though degraded vegetation, heavy recreation, and dams have reduced their value.

The chapter's conclusion is, to me, the most important passage in the book. Many of Florida's key refugia, including springs, caves, sinkholes, ravines and the remnant ridges that will stand above a rising sea, are small and isolated. They do not fit inside broad corridors designed for panthers. Protecting them requires the same small-site strategy that Chapter 1 calls essential for the rarest endemics. The book comes full circle, recommending large cores and corridors, plus small sites, for both biodiversity and climate adaptation.

Conservation planning grew up terrestrial. For a peninsula with this much coastline, freshwater and marine systems came late to the mix. The chapter on aquatic and coastal conservation now gives them their rightful place. The final chapter, on Florida's influence from Yellowstone-to-Yukon to Bhutan, feels tacked on rather than integral, and the shifts between co-authors' voices interrupt the flow. A few other quibbles: the Seminole Tribe appears only as a source of gaming revenue for land acquisition, and other tribal lands are barely mentioned at all. Their role in the conservation landscape deserves a chapter in the next edition.

A question I would put to the editors: when planning began in the 1980s, who foresaw what invasive species would do to the native biota? Burmese pythons have nearly removed the mesopredators of the Everglades, and some of the herbivores with them. Neither pythons nor climate change shaped the original plans. Again, a topic for the next edition.

This book is a tremendous accomplishment and, in many ways, the culmination of Reed Noss's extraordinary career as one of the founders of modern conservation biology. It is a large part of his legacy, and it should be read wherever people are trying to conserve nature at scale.