Title

How is the effectiveness of terrestrial protected areas to conserve biodiversity measured? A systematic map

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Abstract

Protected areas (PAs) are fundamental in preserving ecological diversity, supporting ecosystem services, and mitigating human impacts in today's world. However, the mere designation of PAs is insufficient for achieving conservation goals. It needs to be ensured through employment of robust management practices and the deployment of scientifically sound monitoring methodologies.

This systematic map aims to collate and synthesize global evidence on the methods and metrics used to assess the effectiveness of terrestrial PAs in biodiversity conservation. By doing so, we seek to identify the consistency of monitoring schemes across different geographies and determine how well standardized monitoring methods have been adopted. This broad evidence base will not only inform the management and evaluation of PAs within Europe but also contribute to the global discourse on biodiversity conservation, facilitating the exchange of knowledge and best practices.

Keywords

Biodiversity conservation, monitoring and evaluation, impact evaluation, protected area effectiveness, evidence synthesis, evidence mapping

Background

In the context of global biodiversity conservation, protected areas (PAs) are considered foundational to preserving ecological diversity, supporting ecosystem services, and mitigating human impacts (Watson et al. 2014). The strategic establishment and management of PAs are guided by international and regional policy frameworks, such as the Kunming-Montreal Global Biodiversity Framework (CBD 2022) and the European Union's biodiversity strategy for 2030 (European Commission 2023). These frameworks set quantitative goals for PA coverage and underscore the necessity for effective and equitable management practices that are ecologically representative and well-connected (Adams et al. 2023).

However, the mere designation of PAs is insufficient for achieving conservation goals. The efficacy of these areas in biodiversity conservation is contingent upon robust management practices, the deployment of scientifically sound monitoring methodologies, and the adaptation of conservation strategies to address emergent issues (Mascia et al. 2014). The challenge of evaluating PA effectiveness toward biodiversity conservation lies in measuring direct impacts amidst complex ecological dynamics, the variability of conservation goals, and the scarcity of baseline data and long-term monitoring efforts (Geldmann et al. 2019). This endeavour is further complicated by the wide range of indicators and metrics used to gauge effectiveness, pointing to a critical need for systematic consolidation of this information (Rodrigues & Cazalis 2020).

In the context of this study, we define effectiveness as the degree to which PAs contribute towards meeting global biodiversity targets, encompassing a wide spectrum of goals, from averting species extinction to preserving threatened ecosystems (Maxwell et al. 2020). However, it is important to note that while the focus of this research is on biodiversity outcomes, PAs also play a crucial role in addressing social dimensions, such as supporting local communities, safeguarding indigenous rights, and contributing to ecological development (Boris et al. 2013). Nonetheless, while critically important, these social aspects fall outside the primary scope of this study.

This systematic map aims to collate and synthesize global evidence on the methods and metrics used to assess the effectiveness of terrestrial PAs in biodiversity conservation. By doing so, we seek to identify the consistency of monitoring schemes across different geographies and determine how well standardized monitoring methods have been adopted. This broad evidence base will not only inform the management and evaluation of PAs within Europe but also contribute to the global discourse on biodiversity conservation, facilitating the exchange of knowledge and best practices.

Objectives

The objective of this evidence synthesis is to collate and describe the evidence base relating to terrestrial protected areas and biodiversity measurement. The systematic map's primary question is:

How is the effectiveness of terrestrial protected areas to conserve biodiversity measured?

Secondary questions include:

- Which protected area effectiveness methods and metrics have been well used, and which are under-represented or absent from the evidence base or particular contexts?
- What is the level of consistency in monitoring schemes across geographical areas, protected area designations, and managing and researching institutions?

- What standardised monitoring methods have been developed in the literature and how well have they been adopted?

This question can be broken down into the following key elements:

Population: Terrestrial systems globally
Intervention: Protected area establishment/presence
Comparator: Outside protected areas, before establishment of protection, or in the absence of a protected area
Outcome: Methods for measuring terrestrial protected area conservation effectiveness using direct or indirect biodiversity metrics

Methods

Search strategy overview

We will search for evidence across a range of sources, including bibliographic databases, a web-based academic search engine, organisational websites, and using citation chasing. This range of sources aims to cover a diversity of terminological descriptions of the topic, publication platforms, traditional academic and grey literature, and citation networks of related works that might otherwise evade other search methods. The search string used in bibliographic databases is based on several previously published systematic reviews on related topics and the team's expertise in this field. The string has been tested for functionality and compared against a benchmark list to ensure a relevant set of primary studies are returned within the search results.

Bibliographic database search string

The search string adapted to Scopus is as follows:

(("protected area" OR "national park*" OR "conservation area*" OR "wilderness area*" OR "natural monument*" OR "natural park*" OR "natural feature*" OR "protected landscape*" OR "nature park*" OR "nature reserv*" OR "biosphere reserv*" OR "world heritage site*" OR "natura 2000" OR "ramsar")*
W/15
(effect OR affect* OR impact* OR effic* OR mitig* OR perform* OR success* OR indicator* OR evaluat* OR assess* OR fail* OR analy*))*
AND
(biodiversity OR ecosystem OR species OR habitat* OR communit* OR "biological diversity" OR conservation)*

Pilot testing results

We have tried out the above search in Scopus, yielding 20,070 hits on March 11th 2024.

Bibliographic databases

We will search across a suite of different bibliographic databases using the tried-and-tested search string above. The search string will be adapted to the syntax of each individual resource.

Table 1. Bibliographic databases that will be searched for relevant literature.

Database	Access/subscription notes
Scopus	University of Tasmania
Web of Science Core Collection	University of Helsinki

CAB Abstracts through Ovid	University of Helsinki
ProQuest (Dissertations and Theses)	University of Helsinki

Benchmark testing

We assembled a set of 9 articles of known relevance (Annex 1) that we used as a benchmark list to test the functioning of the search string in Scopus. During testing, minor modifications were necessary to the search to retrieve all benchmark records, reflected in the final string provided above. We therefore consider this string sufficiently comprehensive.

Other search methods

Call for grey literature

We will distribute a call for relevant grey literature via social media (LinkedIn, Twitter/X, and ResearchGate), email (Biodiversa+ partners, Conservation International, IUCN, WWF, ZSL, BirdLife International), and the mailing lists of existing networks (the Collaboration for Environmental Evidence, Mongabay, the Society for Conservation Biology).

Organisational websites

We will search a range of websites of relevant organisations in search of evidence, particularly grey literature (see Table 2). We will manually scan the websites for publications pages and relevant literature before using built-in search facilities where available, and Google site search (searching in Google using "site:xxx.com [search terms]") where there is no built-in search facility. We will use the following basic search terms across all websites:

"biodiversity protected area national park nature reserve"

Table 2. Organisational websites that will be searched for relevant literature.

Organisation	**URL**
The World Bank Publications	https://www.worldbank.org/en/research
Conservation International	https://www.conservation.org/home
The UN Environment Programme World Conservation Monitoring Centre	https://resources.unep-wcmc.org/
International Union for Conservation of Nature	https://www.iucn.org/resources
Global Environment Facility Publications	https://www.thegef.org/newsroom/publications
International Institute for Environmental Development	https://www.iied.org/
European Commission's Joint Research Centre	https://publications.jrc.ec.europa.eu/repository/

Since search results cannot readily be exported, records are not in RIS format, and records typically lack abstracts, we will screen the search results for relevance *in situ* (i.e. during searching), retaining only relevant records to be screened at full text along with the results of abstract screening from other sources. We will record the number of search results and relevant records from all website searching.

Web-based search engine

We will search Google Scholar for additional records, which has been shown to be useful as an additional resource in obtaining grey literature as well as unindexed academic research (Haddaway et al. 2015). Because of the limitation in search functionality of Google Scholar, we will use the following basic Boolean search across a variety of relevant languages:

English: *Biodiversity effectiveness "protected area" OR "national park" OR "nature reserve" -marine*
French: *Biodiversité efficacité "aire protégée" OR "parc national" OR "réserve naturelle" -marine*
Spanish: *Biodiversidad efectividad "área protegida" OR "parque nacional" OR "reserva natural" -marina*
Portuguese: *Biodiversidade eficácia, "área protegida" OR "parque nacional" OR "reserva natural" - marinha*
German: *Biodiversität Wirksamkeit "Schutzgebiet" OR "Nationalpark" OR "Naturreservat" -marine"*
Finnish: *"Luonnon monimuotoisuus" vaikuttavuus luonnonsuojelualue OR kansallispuisto OR luonnonpuisto OR erämaa-alue*
Swedish: *Biologisk mångfald effektivitet "skyddat område" OR nationalparker OR "naturreservat"*

We will use "Publish or Perish" software (https://harzing.com/resources/publish-or-perish) to export the first 1,000 records displayed in Google Scholar. (Although, typically, only 980 records are exportable in this way because of technical restrictions in web scraping). Results will be exported as RIS files that will be subjected to a DOI lookup using the freely interrogable resource OpenAlex to repair partial and missing abstracts (https://estech.shinyapps.io/repairRIS/), before being combined with the results of bibliographic database searching prior to deduplication and screening.

Citation chasing

We will undertake forwards and backwards citation chasing, using a starting set of records of known relevance (the benchmark list of 9 articles described above) to obtain lists of research cited by and citing these records. We will then deduplicate relative to bibliographic search results to remove records already screened, and then screen the remaining records for relevance. We will then repeat the citation chasing process with the remaining relevant records. We will make use of citationchaser (Haddaway et al. 2022) to perform citation chasing, which uses the lens.org database.

Article screening and study eligibility criteria

We will screen potentially relevant records from all sources using a set of *a priori* inclusion criteria, outlined below. We will screen records at two levels: title and abstract (together), and then full text. Before commencing title and abstract screening in full, a subset of 200 records will be screened independently by all members of the review team who will conduct the screening and at least 2 authors. Screening decisions will then be compared, and all discrepancies discussed in detail, with the inclusion criteria refined and clarified where necessary. A kappa statistic (Cohen 1960) will be calculated, and where the score is lower than 0.6, indicating a less-than-moderate agreement, a second set of 200 records will be screened and again discussed. This will proceed until the agreement score is greater than 0.6. From here on, the remaining records will be shared across the team and each record will be screened by one reviewer.

Full texts will be retrieved using the subscription access of the combined team. Records that cannot be identified or retrieved at full text will be recorded and reported in the final review.

At full text screening level, a subset of 20 full texts will be screened independently by all reviewers who will undertake screening. Any disagreements will be discussed in full, and a kappa score once again calculated. The inclusion criteria will be clarified and refined where necessary before proceeding. If the kappa score is less than 0.6, a second set of 20 full texts will be screened. Where necessary, a third review team member will be consulted on disagreements that are not immediately clarified. The results of these consistency checking practices will be reported in the final review in accordance with best practices (CEE 2018). Full texts will then be shared and screened amongst the team, with each record screened by one reviewer.

All screening activities will be conducted in the review management software Rayyan.ai.

Eligibility criteria:
The inclusion criteria for study eligibility screening are described below.

Population: Any documented research study conducted in a primarily terrestrial biome (i.e. a greater surface area than 50% must be terrestrial)
Intervention: Any officially designated protected area
Comparator: A comparison with the absence of a protected area, either prior to protection implementation, outside of the established protected area, or in a matched area lacking protection
Outcome: Any method used to measure protected area conservation effectiveness using indirect or direct quantification of terrestrial biodiversity (e.g., deforestation as a proxy indicator for biodiversity loss)
Study type: Any empirical study including primary data collection

Data coding and presentation of results
The final set of included studies will be coded and meta-data extraction will be performed. Meta-data include descriptive information about the location, protected area, local context, and research methods used. The data schema is described in Table 3. We will design the database in long format, i.e. independent methods-outcomes data, in order to facilitate visualisation and analysis (Haddaway et al. 2021).

Prior to commencing data extraction, reviewers will independently perform a pilot extraction on a set of 5 studies. They will then discuss all discrepancies between reviewers and clarify the item descriptions to ensure consistent implementation of the data schema. Where necessary, a second set of 5 studies will be independently extracted and discussed before moving on. After the review team is satisfied that the level of agreement is high between reviewers, ideally with no further disagreements, the remaining full texts will be shared between reviewers and extracted, with each full text extracted by one reviewer. The results of consistency checking will be reported in full in the final report. We will use sysrev.com for data extraction.

Table 3. Data schema for meta-data extraction and coding

Item	Description
Study country	Standardised country name
Study location	Free-text protected area name/description
Study biome	Free-text description of the biome as described by authors
Study biogeographic sub-region	Free-text description of the sub-region as described by authors
Study ecosystem	Free-text description of the ecosystem as described by authors
Latitude	Provided or estimated study latitude
Longitude	Provided or estimated study longitude
Protected area name	Provided name of the protected area
Protection type	Provided protected area designation
Starting study year	Year study began
Study timescale	Period of time (in months) over which data were collected
Study objectives	Free-text description of the study objectives
Subject studied	Provided description of the group or taxon/taxa measured
Class studied	For animals, plants and fungi, provided description of the class studied in the protected area
Broad methodological category	Categorical list of methods
Survey method (outcome measurement)	Provided description of survey method (outcome measurement) used
Area/transects surveyed	Provided description of extent of the area surveyed.
Metric(s) used for monitoring	Provided description of the metric(s) used for monitoring (e.g., species richness, abundance, community composition), following the Essential Biodiversity Variables framework.
Experimental design	Free-text description of experimental design (e.g. BACI)
Study type	Experimental/observational
Comparator	Free-text description of study comparator
Funding source	Funding statements

We will summarise the evidence base in a narrative synthesis that describes patterns in the studies across settings, protected area categorisations, countries, biodiversity measurement methods, and the studied subject (e.g., species/taxa). We will do this using a combination of visualisations and tables of varying complexity. Heat maps will be used to present the number of studies in the evidence base categorised over 2 to 3 categorical variables (for example, methods used, study countries, and protected area categories in a 'bubble heat map', where each bubble size represents the volume of evidence). We will also present the evidence base cartographically, producing an interactive visualisation displaying each study location, with descriptive information about each study in pop-ups (also known as an 'evidence atlas', Haddaway et al. 2018).

Using these tables and visualisations, we will be able to identify knowledge clusters (topics where sufficient evidence exists to allow meaningful meta-analysis), but primarily also knowledge gaps (areas that are un-/ or under- represented with fewer studies than might be needed/hoped/expected). By visualising methods used over various other variables (including time, geography, protected area type, taxa, etc.) we will be able to identify combinations for which there are relatively fewer studies than expected. Heat maps facilitate this process by displaying the number of studies as colour graded tiles, with lighter shades indicating potential knowledge gaps and darker shades suggestion clusters. In all cases, the suitability of these topics will be discussed relative to their importance conceptually as well as numerically (i.e. are they meaningful gaps).

Author contribution

All authors contributed equally to this work.

Conflict of interest

The authors declare no conflict of interests regarding this work.

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Annex 1. A list of articles to test comprehensiveness of the search string

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