1.2 Methodological approaches to understanding protected area dynamics

1.2.1 The World Database on Protected Areas: the backbone of this Atlas

This Atlas is only possible because of the World Database on Protected Areas. This database has grown continuously over the last 65 years to become the most comprehensive source of information on nearly 300 000 protected areas worldwide. As the database compiles information from a variety of sources, data standardisation is not always consistent and it is advised to familiarise with this database, pay attention to its nuances before interpreting findings and drawing strong scientific and policy conclusions.

The World Database on Protected Areas (WDPA)[1] is the most comprehensive source of global information on the geography of protected areas. The database is managed by the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), as a joint product of UNEP and the International Union for Conservation of Nature (IUCN)[2]. The WDPA forms the backbone of this Atlas, which would not have been possible without the decades of development and improvement that, today, represent nearly 300 000 protected areas worldwide. In Africa, the WDPA includes information on more than 8 800 terrestrial, coastal, and marine protected areas that are the focus of the rest of this Atlas.

Appreciating the WDPA means acknowledging that its development is an ongoing process. Instead, the current version is the culmination of 65 years of progress. This progress included decades of evolving political mandates, scientific understanding, and technological advancements. The original list of protected areas was mandated by the 27th Session of the United Nations Economic & Social Council held in 1959, and appeared two years later in 1961[2]. While the list was updated several times over the next 20 years, a digital (non-spatial) version of the list was only released in 1981. This technical breakthrough was followed by the first research paper about the list, which was published a year later[3]. According to the paper, at that time, Botswana (18.16%), Central African Republic (12.04%), Benin (11.9%), Tanzania (11.52%), Zimbabwe (11.29%), Senegal (10.8%), and Rwanda (10.38%) were the only African countries that had protected more than 10% of their territory[3].

As the internet became prominent, the list of protected areas moved online in 1996 with the launch of the website of the World Conservation Monitoring Centre (before its current partnership with the UN Environment Programme, which happened in 2000)[2]. As technology continued progressing, spatial information was added to the list of protected areas, which had to be disseminated on CDs from 2003 onwards. By 2008, the spatial version of the database moved online, where it is still publicly available through the Protected Planet website (http://www.protectedplanet.net/).

The information in the WDPA originates from nearly 500 data providers including[4]:

- National and sub-national government agencies.
- International secretariats, like the Ramsar Convention, World Heritage Convention and the UNESCO Man and Biosphere Programme.
- Regional entities, like the European Environmental Agency.
- Non-government organisations that co-manage protected areas.
- Communities or individuals who co-govern or co-manage protected areas, including indigenous people, local communities, or private actors[4].

After data are provided to UNEP-WCMC, they are verified and formatted according to the WDPA standards. This includes interactions with data providers, internal quality checks and data formatting, and verification by authoritative sources[4]. Although this process is thorough and systematic, it remains imperfect.

Known issues with the World Database on Protected Areas[4].

A comprehensive database compiled from multiple different sources can have known issues. It is important that solutions to these issues are standardised to ensure that different studies are comparable.

Source: UNEP-WCMC (2019). User Manual for the World Database on Protected Areas and world database on other effective area-based conservation measures: 1.6. UNEP-WCMC: Cambridge, UK. http://wcmc.io/WDPA_Manual.

Issue	Description	Recommended solution
Spatial Accuracy	Errors can be introduced when digitising protected area boundaries due to issues of scale, resolution, and alignment with natural or administrative boundaries.	Users should be aware of geographical transformations and projections when using the data before making assumptions about spatial or positional accuracy.
Overlapping protected areas	The same geographical area can be represented by multiple overlapping polygons in the WDPA, differing in their designations or management categories. These polygons will not necessarily align perfectly if they originate from different sources.	Any analysis of spatial coverage should be based on a flattened version of the WDPA, which combines all overlapping geometries into a single layer.
Point data	While there has been considerable progress in replacing locality coordinates with polygon boundaries, some protected areas are still only represented by points.	Points can either be excluded from spatial analyses, or represented as buffered areas corresponding to the reported surface area. Analysis choices should be reported transparently following WDPA guidelines.
Marine delineation	Polygons of protected area boundaries do not necessary align with coastlines, so the WDPA reports whether coastal protected area have partial overlap with both terrestrial and marine territories exceeding 10%.	Intersections with coastlines or similar marine base-layers when distinguishing between marine and terrestrial protection coverage.
Country boundaries	Protected area information includes country attributes, but these territories may be disputed for various reasons.	The base layer of any spatial analysis should be cited clearly and it must be acknowledged that analyses may vary depending on which layers and assumptions were used.
Transboundary sites	Transboundary protected areas overlap more than one country, and the WDPA may report the whole area or each country's portion separately, depending on the data provider.	When calculating national statistics, it is essential to only consider portions of transfrontier protected areas attributable to each country to avoid double-counting.

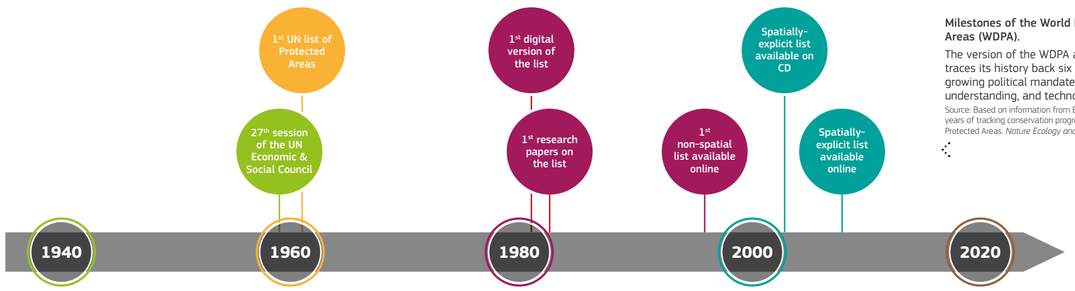
Overlapping protected area designations in the Okavango Delta, Botswana.

When a single geographical area is the focus of multiple different protected area designations, each of these will be presented as sperate protected areas in the WDPA. When the goals is to quantify the area of protection, it is necessary to first flatten the protected areas into a single layer to avoid double-counting.

Source: UNEP-WCMC and IUCN (2024), Protected Planet: The World Database on Protected Areas (WDPA). [On-line], [February/2024], Cambridge, UK: UNEP-WCMC and IUCN. Available at: www.protectedplanet.net

Errors are inevitable whenever information is aggregated from so many different sources. These include subtle mistakes when digitising data or missing information on protected area attributes. For roughly 4% of protected areas globally, spatial information is only available as point coordinates. Nevertheless, this should not detract users from using the database as long as they familiarise themselves with known issues described in the WDPA User Manual[4]. Throughout this Atlas, we follow the guidance of the WDPA User Manual when calculating area statistics or reporting national protected area coverage[5].

The WDPA today is an massive improvement on the same database just 10 years ago, not to mention the earlier lists of protected areas that have existed since the 1960s. Therefore, it rightfully forms the foundation for countless conservation initiatives by a broad array of stakeholders. However, it is almost certain that the current WDPA will be made obsolete by future iterations. The database will continue improving as partnerships with data suppliers grow. Known issues will be resolved, data gaps will be filled, and accuracy will be enhanced. Therefore, conservation scientists and policy officers must make the best use of this excellent resource, while recognising that they are using a living resource that will continue getting better with each new update.



Milestones of the World Database in Protected Areas (WDPA).

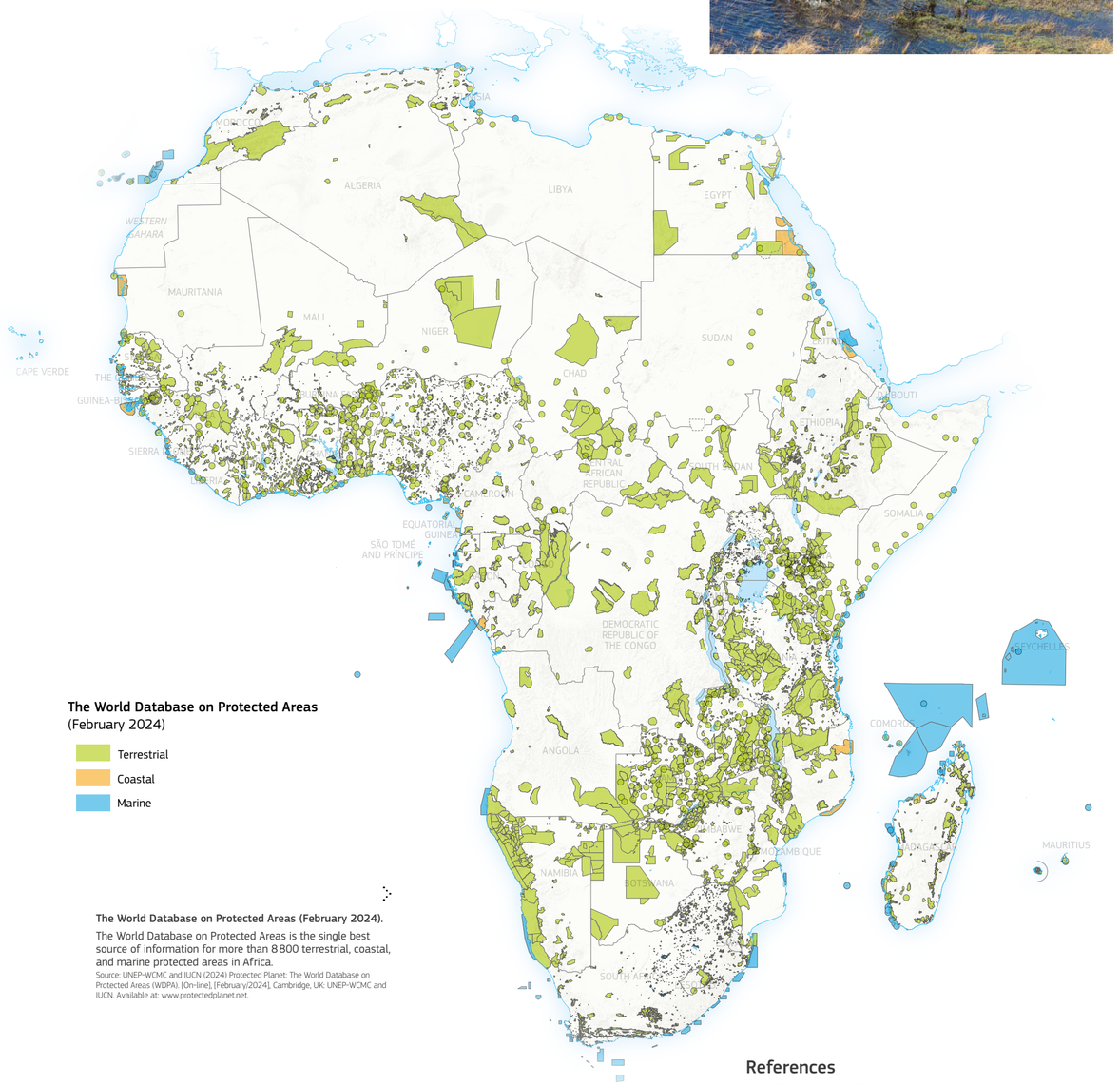
The version of the WDPA available online today traces its history back six decades, representing growing political mandates, scientific understanding, and technological advancement.

Source: Based on information from Bingham, H.C., et al. (2019) Sixty years of tracking conservation progress using the World Database on Protected Areas. *Nature Ecology and Evolution*, 3, 737-743.

Plains zebras (*Equus quagga*) in the Okavango Delta, Botswana.

The unique ecology of Botswana's Okavango Delta has drawn the attention of several conservation stakeholders who recognise the area under various designations. The World Database on Protected Areas records each of these designations even though they overlap the same geographic area.

Source: Diego Delso on Wikimedia Commons CC BY-SA 4.0.



The World Database on Protected Areas (February 2024).

The World Database on Protected Areas is the single best source of information for more than 8 800 terrestrial, coastal, and marine protected areas in Africa.

Source: UNEP-WCMC and IUCN (2024) Protected Planet: The World Database on Protected Areas (WDPA). [On-line], [February/2024], Cambridge, UK: UNEP-WCMC and IUCN. Available at: www.protectedplanet.net.

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[1] UNEP-WCMC and IUCN (2024) Protected Planet: The World Database on Protected Areas (WDPA). [On-line], [February/2024], Cambridge, UK: UNEP-WCMC and IUCN. Available at: www.protectedplanet.net.

[2] Bingham, H.C., et al. (2019) Sixty years of tracking conservation progress using the World Database on Protected Areas. *Nature Ecology and Evolution*, 3, 737-743.

[3] Harrison, J., et al. (1982) The world coverage of protected areas: development goals and environmental needs. *Ambio*, 11, 238-245.

[4] UNEP-WCMC (2019). User Manual for the World Database on Protected Areas and world database on other effective area-based conservation measures: 1.6. UNEP-WCMC: Cambridge, UK. http://wcmc.io/WDPA_Manual

[5] Protected Planet (2021). Webpage: *Calculating protected area and OECM coverage*. https://www.protectedplanet.net/en/resources/calculating-protected-area-coverage

1.2.2 How to measure protected area dynamics

Understanding the dynamics of protected areas is a scientific challenge that is often limited by the quality of data. Depending on data, scientists can track (i) how biodiversity variables change within a protected area, (ii) how they compare to unprotected areas, or (iii) how establishing new protected areas affects these variables. The gold standard for protected area research, however, is a combination of these three approaches in a Before-After-Control-Intervention (BACI) study design. Though such studies are still rare, they should be encouraged by targeted investment for collecting specific data.

Do protected areas conserve biodiversity? As it turns out, this is a difficult question to answer scientifically. The question first needs to clarify the standards against which protected areas are evaluated. Are protected areas effective if biodiversity is in a better state than it was previously? Or is it enough that biodiversity is better within, compared to outside, protected areas? Maybe biodiversity needs to be compared before and after the establishment of a protected area?

Conservation can learn from medical science, which handles these types of questions every day. To understand a treatment's effectiveness, clinical trials make multiple comparisons at the same time. Prior to administering a new treatment, medical researchers take many measurement of a patient's health. They repeat these measurements after the patient receives treatment to monitor its effects. Because sick people sometimes recover on their own, the patient's progress is compared to others who did not receive the same treatment (i.e. those who received no treatment, a conventional treatment, or a placebo). New treatments are only deemed effective when patients recover better than they would from other medical interventions. This is commonly referred to as the Before-After Control-Intervention (BACI) approach because it contrasts the patients recovered before and after treatment (i.e. the intervention), which is compared to a similar patient that received a different treatment (i.e. the control).

The hamerkop, *Scopus umbretta*, a wading bird endemic to sub-Saharan Africa.

A rare assessment using a Before-After Control-Intervention study design found that protected areas had mixed success in conserving waterbird populations. Although 27% of bird populations were better off inside protected areas, 21% were worse off.

Source: Frans Vandewalle on flickr CC BY-NC 2.0.

Before-After-Control-Intervention comparisons

In the context of a protected area, the Before-After Control-Intervention (BACI) approach would compare biodiversity variables before and after establishing the protected area and contrasting this with a comparable unprotected area. While it would be ideal for conservation scientists to follow the same robust approach used in medicine, collecting equally high quality biodiversity data is considerably more difficult. A landmark study published in 2022, compared a high quality global dataset of waterbird counts from 67 species across 864 protected areas using a BACI approach[1]. The researchers found that 27% of all bird populations were positively impacted by protected areas, 21% were negatively impacted, and 48% had no detectable impacts (the remaining 4% were discarded due to statistical model failure). These results suggest that, globally, the effectiveness of protected areas tends to be mixed.

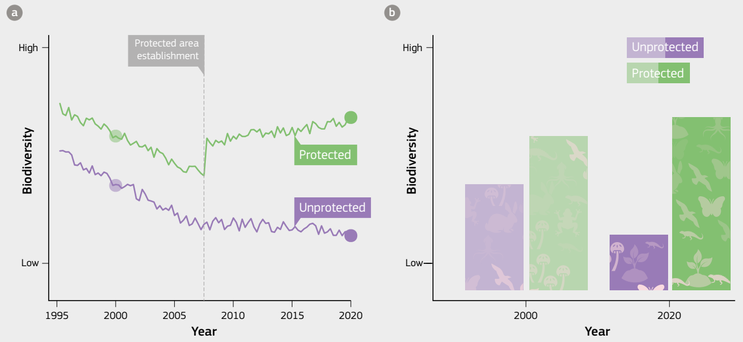
However, less than 1% of the protected and unprotected sites included in this study were in Africa, since high-quality long-term datasets tend to come from Europe and the United States. Due to the shortage of high quality data when studying African protected areas, conservation scientists mostly settle for imperfect approaches that make the best of the limited data available.

A before-after-control-intervention (BACI) approach to evaluating protected areas.

(a) An ideal scientific situation would have access to data on a hypothetical biodiversity variable before and after the establishment of a protected area (vertical grey line), both inside and outside of a protected area. (b) The full BACI study design is the only way to demonstrate conclusively that the designation of a protected area improved the status of biodiversity in the area beyond what would be expected from broad-scale drivers that also affect unprotected areas.

Source: Own conceptual illustration.

The gold standard of protected area research: The Before-After Control-Intervention Approach



Methodological approach	Strengths	Weaknesses
Monitoring within protected areas through time	• Clearly defined geographical boundaries. • Field data can be collected during routine management actions.	• Limited to biodiversity variables measured at least twice. • Overlooks broader positive (e.g. policy changes) and negative (e.g. climate change) drivers that affect protected and unprotected areas alike.
Comparing protected and unprotected areas in geographical space	• Only needs a single measurement in time. • Considers the broader positive (e.g. policy changes) and negative (e.g. climate change) drivers of biodiversity change.	• The buffer surround the protected area may differ fundamentally in ways that may explain differences in biodiversity. • Statistical matching of protected and unprotected areas is complex and may require discarding unmatched data.
Comparing before and after establishing a protected area	• Clearly defined geographical boundaries. • Considers explicitly how protected area establishment and expansion affects biodiversity.	• Limited to biodiversity variables measured at least twice. • Only appropriate for recently established protected areas unless historical data already exist. • May lead to errors if it fails to distinguish between the establishment of a protected area, a change in its designation, or its entry into a database.
Before-After-Control-Intervention comparisons	• The most conclusive approach to evaluating the dynamics and impact of protected areas.	• Suitable data are generally unavailable or too costly to collect. • Cannot be applied retrospectively to long-established protected areas, unless pre-establishment data already exist.

The strengths and weakness of different approaches to evaluating protected area dynamics.

There is no perfect way of evaluating protected area dynamics because more informative approaches have a higher requirement for quality data, which are not always available.

Source: Own summary.

Comparisons within protected areas

This approach tracks the status of a biodiversity variable within the boundaries of a protected area. If the protected area is effective, one expects that biodiversity variables improve with time. In many ways, it is relatively straightforward to collect biodiversity information from within protected areas. Park authorities often collect field data as part of their routine management activities, like wildlife censuses, vegetation surveys, or anti-poaching patrols. These data are useful for tracking trends in the state of biodiversity through time. For data collected remotely using satellite or aerial imagery, it is technically simpler to analyse data within a protect area's clearly distinguishable geographical boundaries.

An example of landscape change can be observed in the southern portion of Virunga National Park, Democratic Republic of the Congo, near the Nyiragongo Volcano. This area has recently been affected by an increased pressure on natural resources due to illegal logging, charcoal production and a complex humanitarian crisis. The scars of deforestation and particularly forest degradation are visible from satellite imagery, showing how closed forest in the area has declined by roughly 30% (equivalent to approximatively 2.000 ha) between July 2022 and July 2023. Only the remnants of the forest's understory remain as open shrublands.

While the value of monitoring within protected areas cannot be overstated, the downside of this approach is that it is only useful for data that have two or more measurements. Relatively static environmental features, like original ecoregion extent, mountains, or rivers, do not change at time-scales relevant to conservation policy. This makes it impossible to track the protection dynamics of these important habitats using this approach.

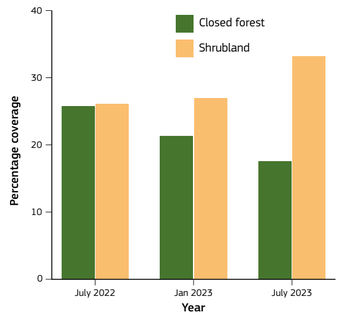
Another limitation is that this approach overlooks broader drivers of biodiversity loss. Negative (e.g. climate change, invasive species, pollution, or pathogens) or positive (e.g. conservation policy or macroeconomics) drivers might affect protected and unprotected areas equally. When this is the case, biodiversity trends inside protected areas may reflect the impacts of these broader drivers, rather than anything attributable to the protected area itself.

Monitoring biodiversity variables within protected areas through time

Monitoring biodiversity within a protected area.

(a) The trajectory of a hypothetical biodiversity variable within a protected area (e.g. the population size of a threatened species, or the extent of an important ecosystem) can be tracked through time. Ideally, data would be collected at regular intervals for a complete time-series, but more often scientists only have brief snapshots of information (represented here as points). (b) Irregular data snapshots can still be used to compare the protected area's biodiversity at different times.

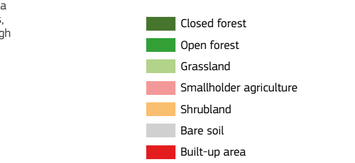
Source: Own conceptual illustration.

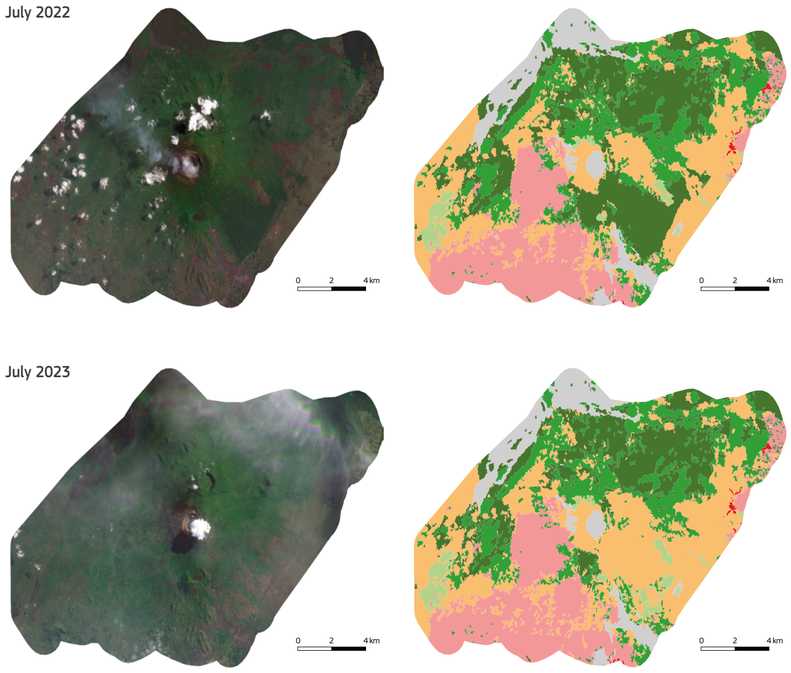


Land cover change within Virunga National Park.

High resolution imagery shows that in the twelve months between July 2022 and 2023, closed forest has declined and been replaced by open shrubland.

Source: Copernicus Land Monitoring Service.





Monitoring within a protected area through time, Virunga National Park.

Since 2022, refugees fleeing conflict zones have aggregated in the southern corner of Virunga National Park, under the Nyiragongo Volcano, in the Democratic Republic of the Congo. Many of these refugees have resorted to cutting down trees for firewood and charcoal. The widespread deforestation can be tracked using satellites and summarised as land cover change, demonstrating the value of regular monitoring within a protected area.

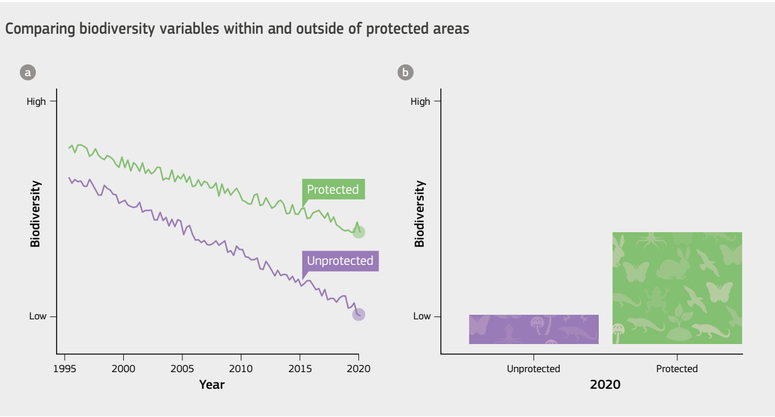
Source: Copernicus Land Monitoring Service.

References

[1] Wauchope, H.S., et al. (2022) Protected areas have a mixed impact on waterbirds, but management helps. *Nature*, 605, 103-107.

1.2.2 How to measure protected area dynamics (continued)

Comparisons inside and outside of protected area



Comparing biodiversity across protected and unprotected areas.
(a) The trajectories of a hypothetical biodiversity variable in protected and unprotected areas. Even when it is not possible to collect multiple measurements, a single measurement from each area (represented here as points) can still be used to evaluate the protected area. (b) The difference between the protected and unprotected areas gives an indication of the effect of the protected area on the biodiversity variable.
Source: Own conceptual illustration.

When data are only available from one moment in time, then it is only possible to evaluate a protected area by comparing it to a comparable unprotected site. The rationale is that, if protected areas are effective, biodiversity variables should be in a worst state in unprotected landscapes.

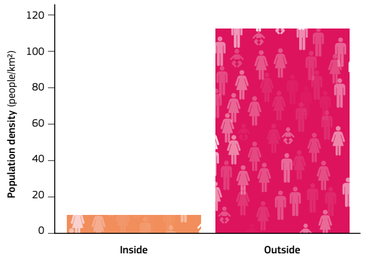
The simplest geographical comparison would be to compare a protected area with its surrounding buffer. This is the most practical approach when collecting field data because it is logistically easier to collect information from unprotected sites that are nearby compared to those that are far away. For remotely collected data, the immediate surroundings are also easy to identify using buffering tools common to most geographical information systems.

An illustrative example of this approach compares the pressures from human population in and around Mount Kenya Reserve. The population density inside the protected area (roughly 10 people per km^2) is an order of magnitude less than the density in the 10 km buffer surrounding the protected area (about 112 people per km^2). This suggest that the protected area is effective at reducing human pressure on nature, especially in the south-east where there is an abrupt change in population density at the protect area's boundary.

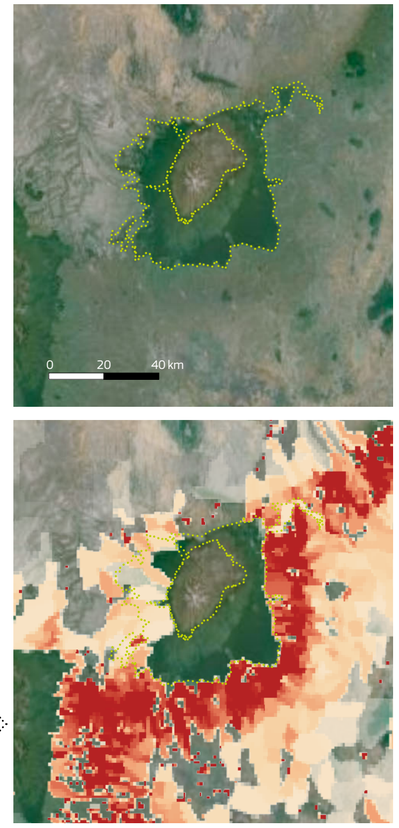
However, Mount Kenya is an extinct volcano with a nearly 4 000 m change in elevation between its foothills and it summit (5 199 metres above sea level). It is just as likely that topography, rather than formal protection, restricts people from settling on the steep slopes within the protected area.

Examples like this one in Mount Kenya where natural environmental differences confound simple proximity analyses, have led conservation scientists to developed statistical matching algorithms. These sophisticated matching approaches use statistical models to identify sites that differ only in their protection status, while being near identical in every other way (e.g., climate, topography, soil, ecoregion, country). The advantage of these models is that they allows researchers to identify the effects of protection, while controlling for unrelated confounding factors. The downside, beyond the technical complexity, is that the model can lead to loss of information if data from within a protected area is discarded when a suitable unprotected analogue cannot be found elsewhere in the landscape. While this loss of information is uncommon, it disproportionately affects the most unique aspects of biodiversity that tend to be uncommon outside of protected areas.

Mount Kenya, seen from the Terek Valley.
Comparing protected areas with their immediate surroundings can be informative, but not when the protected area differs fundamentally from is surroundings. For example, population density around Mount Kenya Forest Reserve is much higher than inside the protected area, but this can be explained by the mountain's steep slopes, rather than differences in protection status.
Source: DavyKirii on Wikimedia Commons CC BY-SA 4.0.



Population density in and around Mount Kenya Forest Reserve.
The average human population density (people per km^2) inside the protected area, compared to the average density in the 10 km buffer around the reserve boundary.
Source: Schiavina M., et al., (2023) GHS-POP R2023A - GHS population grid multitemporal (1975-2030). European Commission, Joint Research Centre (JRC) www.doi.com/10.2905/2FF68A52-5B5B-4A22-8F40-C41DA8332CFE



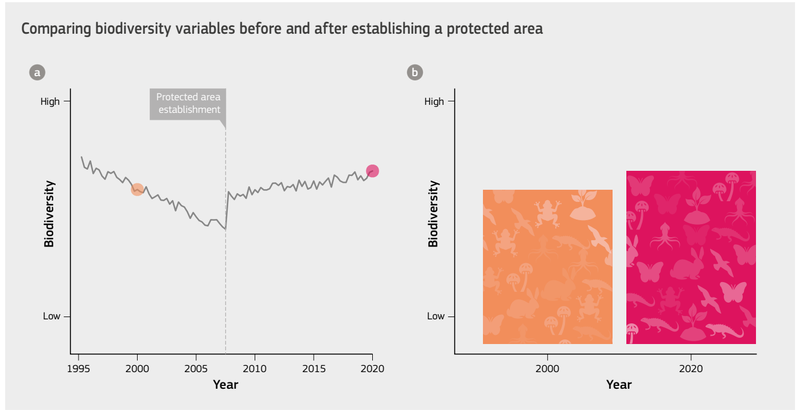
Comparisons inside and outside of protected areas.
Like many African protected areas, Mount Kenya Forest Reserve is surrounded by dense human settlements. The southern and eastern boundaries show a clear demarcation in human population density, which is an indication that pressures on biodiversity within the protected area differ from those the surrounding area.
Source: Schiavina M., et al., (2023) GHS-POP R2023A - GHS population grid multitemporal (1975-2030). European Commission, Joint Research Centre (JRC) www.doi.com/10.2905/2FF68A52-5B5B-4A22-8F40-C41DA8332CFE

Comparisons before and after protected area establishment

Behind global policy goals to increase the coverage of protected areas lies the assumption that establishing new protected areas will be beneficial for biodiversity. A logical way to evaluate this assumption is to compare biodiversity variables before and after establishing new protected areas. Ideally, effective protected areas would lead to recovering biodiversity or, at least, slowed rates of deterioration. For instance, if a protected area reduces poaching, there would be an immediate improvement in the populations of the species being poached, followed by a more sustained recovery in the medium- to long-term.

The potential of this approach can be demonstrated with the recently designated Ise Forest Conservation Area, Nigeria, which received its current designation in 2020. The local state government issued an executive order to establish the reserve believed to be home to about 20 Nigeria-Cameroon chimpanzees. The region faced deforestation and degradation in the decade preceding the latest designation, but little has changed in the first two years of the reserve's existence. Undisturbed forest continues to decline, while degradation and deforestation seem to continue unabated.

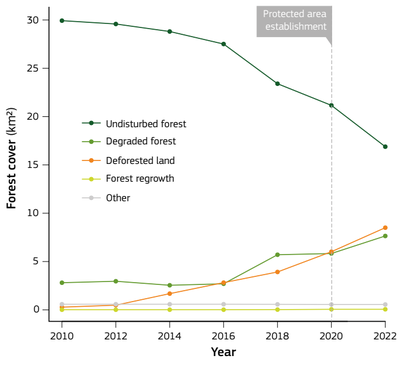
This approach is useful for quantifying the impact of newly declared protected areas, but it is of limited value for older, long-established protected areas without existing historical data. Moreover, this approach can lead to errors if establishment dates are recorded incorrectly. For example, protected area databases may not record the date when a protected area was established, recording instead the date when information on the protected area was added to the database. Similarly, long-established protected areas may change designations, say, from a locally managed area to a nationally managed one, which can introduce errors if the designation date is mistaken for the establishment date.



Comparing biodiversity before and after establishing a protected area.
(a) One expects that establishing a new protected area will change the trajectory of a hypothetical biodiversity variable. In this example, the biodiversity variable immediately improved once the protected area was established in 2007 (vertical grey line), and its previously downward trajectory is reversed in subsequent years. (b) Even without a continuous time-series, it is possible to evaluate the effect of the protected area as long as there is at least one measurement before and after establishing the protected area.
Source: Own conceptual illustration.

Forest rangers in Ise Forest Conservation Area, Nigeria.
Even though Ise Forest Conservation Area was established in 2020, trends in deforestation and forest degradation continue unabated. It may take a few years before any positive impacts of ranger patrols are observable using satellites.
Source: Dorun55 on Wikimedia Commons CC BY-SA 4.0.

Comparing biodiversity before and after establishing a protected area.
Ise Forest Conservation Area, Nigeria, was designated in 2020 as an IUCN Category II protected area. The decade leading up its designation witnessed considerable deforestation and degradation, which seems to have continued into the two years of the protected area's existence. Comparing forest change before and after the establishment of the protected area can be an indicator of its effectiveness.
Source: Vancutsem, C., et al. (2021) Long-term (1990-2019) monitoring of forest cover changes in the humid tropics. Science Advances, 7, eabe1603.



Trends in tropical moist forest coverage before and after establishing Ise Forest Conservation Area, Nigeria.
Despite its establishment in 2020 (vertical dashed line), Ise Forest Reserve has yet to change the downward trajectory of undisturbed forest loss or the increased extent of degradation and deforestation.
Source: Vancutsem, C., et al. (2021) Long-term (1990-2019) monitoring of forest cover changes in the humid tropics. Science Advances, 7, eabe1603.