ECOLOGICAL MONITORING TO SUPPORT CONSERVATION IN KALIMANTAN’S FORESTS: CONCEPTS AND DESIGN

THE ORANGUTAN TROPICAL PEATLAND PROJECT

Position Paper

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Summary

Ecological monitoring is vital for effective conservation management, as it helps steer projects towards implementing management interventions (activities) in such a way to successfully achieve long-term conservation goals. Many different types of ecological monitoring and indicators for monitoring exist, but, to be meaningful and practically feasible, any ecological monitoring programme should be:

1) **Purposeful** with respect to conservation objectives;
2) **Effective** in demonstrating links between the ecological variable(s) of interest and human activities; and
3) **Realistic** within a project’s financial and other constraints.

This is facilitated through matching of monitoring research to specific project conservation goals and gaps in knowledge; careful selection of indicators for monitoring, based on both their utility in detecting meaningful change in the ecosystem and the associated costs of monitoring; establishing baseline reference conditions against which progress towards a more desirable state can be measured; consideration of habitat-specific ecosystem characteristics; and adaptive management and monitoring, wherein management activities and monitoring are continually developed and adapted based on input from the other.

OuTrop’s ecological monitoring programme is being developed to assess the effectiveness of conservation interventions being implemented in our core Sabangau research site; and to establish frameworks, methods and baselines for ecological monitoring studies to support conservation management in other areas of forest in the region. This involves the generation of scientifically-tractable, policy-relevant research questions based around conservation objectives; assessing the utility and cost effectiveness of a variety of indicators at different spatio-temporal levels; establishing baseline reference levels for these indicators; and consideration of how protocols can be simplified to reduce cost, without reducing the quality of data or its utility for informing management decisions. These indicators cover a range of spatio-temporal scales, and include information from flora and fauna surveys, forest cover/area assessments, forest loss and land use change.

Our monitoring programme thus involves intensive research into indicators of forest condition, including forest area, structure and productivity; rapid-response ecological disturbance indicators, such as birds, butterflies and ants; and monitoring of our flagship conservation primate and other mammal species, including felids, sun bears and a variety of smaller mammal species. We anticipate that this knowledge and capacity building will provide important benefits for biodiversity conservation in both Sabangau and other forest areas in Kalimantan.
The Orangutan Tropical Peatland Project is a research and conservation organisation that works in Indonesia in partnership with the Centre for International Cooperation in Sustainable Management of Tropical Peatlands at the University of Palangka Raya. We are supported by the Orangutan Tropical Peatland Trust (Registered UK Charity No.1142870), and linked to the Wildlife Conservation Research Unit (WildCRU) in the Department of Zoology at the University of Oxford, the Wildlife Research Group in the Anatomy School of the University of Cambridge, the College of Life and Environmental Sciences at the University of Exeter, and the Department of Geography at the University of Leicester.

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# Contents

**Summary** iii

**Acknowledgements** iv

**Contents** v

**Introduction** 1

- What is ecological monitoring and why is it important? 1
- Who uses ecological monitoring? 1

**Essential elements for ecological monitoring** 2

**Types of ecological monitoring** 3

- Implementation monitoring 3
- Effectiveness (or trend) monitoring 3
- Validation monitoring 3

**Biological indicators** 4

- Forest structure (or habitat) indicators 4
- Environmental indicators 4
- Biodiversity indicators (surrogate species) 4
- Focal species 5
- Threatened species and flagship conservation species 5
- Ecological disturbance indicators 5

**Baseline levels and controls** 6

- Establishing baselines and reference levels 6
- Use of control sites 6

**Ensuring cost efficiency and feasibility of monitoring** 7

- Identifying cost-efficient indicators 7
- Simplifying methods to reduce salary costs 7

**The need for adaptive monitoring and management** 8

**Habitat-specific considerations and peat-swamp forests** 9

**OuTrop’s ecological monitoring programme** 11

- Programme goals and design 11
Introduction

What is ecological monitoring and why is it important?

Ecological monitoring is vital for effective conservation management, as it helps steer projects towards implementing management interventions (activities) in such a way to successfully achieve long-term conservation goals. In other words, it helps ensure that projects “do what they say on the tin”. Ecological monitoring involves the repeated measurement of ecological and other variables, to detect changes in the environment over time. This can be as simple as illustrating that, for example, the total area of peat-swamp forest in Central Kalimantan has changed over time. Such an approach is limited in its utility, however, as it only tells us that a change has occurred, without telling us why that change occurred or how conservation managers might be able to act upon this change.

A well-designed ecological monitoring programme provides feedback on the impacts of human activities – both positive (management interventions) and negative (e.g., logging, hunting, fire) – on biodiversity. This helps conservation managers assess whether their management interventions are helping them to achieve their stated conservation aims. Combined with information on the cost of intervention implementation, this helps managers to consider whether they should continue with their existing intervention programme, adapt it in any way and/or consider introducing new management interventions. In this way, ecological monitoring helps ensure that the management interventions being implemented are effective and cost efficient, thereby enabling conservation projects to achieve maximum impact at minimum cost.

Who uses ecological monitoring?

The answer to this question is simple: any area manager/s with biodiversity conservation as a project objective should employ an ecological monitoring programme, to ensure that their management programme is effective and cost efficient. Users of ecological monitoring may therefore include national park authorities, managers in charge of other types of protected areas for biodiversity conservation, Reduced Emissions from Deforestation and Degradation (REDD+) projects, and businesses that may have an influence on biodiversity and are adopting good Corporate Social Responsibility (CSR) standards to maintain High Conservation Value Forest (HCVF) areas. Such businesses may include oil-palm, mining, or logging companies; food agriculture; fisheries; and even tourism operators. Projects may be obliged to adopt ecological monitoring by law, or to achieve authentication to voluntary industry standards to demonstrate that the project is doing all it can to help conserve biodiversity (helping them to sell their product). For example, ecological monitoring is a key element of the Climate, Community and Biodiversity Alliance Project Design Standards for REDD+ [1].
Essential elements for ecological monitoring

To be meaningful and practically feasible, any ecological monitoring should be [2, 3]:

1) **Purposeful** with respect to conservation objectives;
2) **Effective** in demonstrating links between the ecological variable(s) of interest and human activities; and
3) **Realistic** within a project’s financial and other constraints.

Unawareness of, and/or inability to meet, these criteria has led to a frequent lack of implementation of (suitable) ecological programmes by conservation projects, with the result that the considerable benefits of ecological monitoring are often not obtained [2, 4]. This is unfortunate, as it means that much conservation funding will have been squandered on ineffective management interventions and, hence, that many biodiversity conservation opportunities will not have been claimed.

Meeting the first of these criteria is only possible if clear conservation goals exist against which progress can be assessed. Conservation goals will vary from project to project, depending on the underlying aims of the project (e.g., ecosystem services vs. single species conservation), ecology of the area (e.g., which species are present), the past history of disturbance (i.e., the starting point), previous conservation experience in the area and the resources available. Consequently, ecological monitoring programmes should also vary from project to project, being tailored to the specific goals of that project.

Clearly, this requires effective dialogue between conservation managers and the scientific staff/consultants conducting ecological monitoring research. This is not only important in ensuring that the monitoring programme is purposeful with respect to conservation goals, but also to facilitate adaptive management, in which the results of ecological monitoring research feed back into the management process, leading to improvements in the management intervention regime.

The next six sections of this report deal with how to design an ecological monitoring programme to meet the criteria of effectiveness and realism.
Ecological monitoring programmes come in all shapes and sizes, depending on the aims of the project, management interventions being implemented, financial and other resources available for monitoring, and the area’s underlying ecology and disturbance history. In essence, there are three main types of monitoring that are relevant to managed forests: implementation, effectiveness and validation monitoring [2, 5, 6].

**Implementation monitoring**

This consists of simply monitoring the management interventions implemented (e.g., number of illegal logging patrols conducted) to assess whether minimum standards have been met. Because this does not include monitoring of biodiversity, it can say nothing about whether these interventions have had the desired impact(s) on biodiversity. Indeed, it is possible that the interventions employed might be entirely unsuccessful in achieving the anticipated biodiversity impact.

**Effectiveness (or trend) monitoring**

This involves the monitoring of ecological variables within the ecosystem. Many ecological monitoring programmes are of this nature; however, this only questions if a change has occurred, without attempting to assess why the change has occurred (change can happen for reasons entirely unrelated to management). Such an approach is therefore also of limited utility, because without understanding why a change has occurred, it is impossible to effectively manage the direction and pace of this change, say which of the management interventions deployed are effective and which are not, predict intervention performance in other areas, or identify opportunities for improvement.

**Validation monitoring**

This type of monitoring is most useful, as it enables changes in management interventions to be linked to changes in the ecological variables of interest, and consequent assessment of whether management is having the desired impact. Effective management interventions can be identified and potentially increased to improve results, and ineffective interventions can be identified and improved or discontinued, enabling streamlining of management to achieve maximum results with minimum resources. Central to this is the use of testable, scientifically-tractable and policy-relevant hypotheses regarding the impact of management interventions on biodiversity, and well-designed sampling regimes to help identify causal relationships.
Biological indicators

Borneo’s forests are among the most biodiverse terrestrial ecosystems on earth [7]. Consequently, it is impossible to monitor every aspect of them, necessitating the identification of appropriate “indicators” through which changes in the ecosystem components of interest can be assessed [8]. Careful indicator selection is crucial if the impacts of human activities on the ecosystem are to be identified accurately. Certain indicators may also serve as an early-warning signal, providing early indications of ecosystem changes that are likely to have a large impact on biodiversity [8, 9].

A huge variety of different potential biological indicators exists, and the indicators chosen for use in a project will depend on the conservation goals, ecology of the area and biodiversity present, and resources available for monitoring. All indicators must, however, satisfy two essential criteria [2]:

1) They accurately reflect something that cannot be measured directly, while also providing more information than that relating only to themselves; and
2) Their field measurement is logistically and financially feasible.

A typology of different indicator types is given below (see also [2]).

Forest structure (or habitat) indicators

Monitoring forest structure provides a link between management interventions and biodiversity impacts, which is essential for validation monitoring. Put simply, management influences the forest, which influences biodiversity. For example, a reduction in forest area would be expected to lead to a negative impact on populations of forest-dependent species, such as orangutans or gibbons. Habitat condition is generally monitored at either a landscape (e.g., measures of forest extent derived from remote images) and/or a stand level (e.g., tree height, canopy and ground vegetation cover).

Environmental indicators

Environmental indicators provide a mechanism through which a physical/non-biological characteristic of the environment that is otherwise difficult to measure can be assessed; e.g., pollution levels in a stream. This type of indicator may be useful for monitoring in mining areas.

Biodiversity indicators (surrogate species)

Biodiversity indicators are ‘surrogates’ of biodiversity; i.e., differences in their abundance and/or distribution provide an indication of the level of diversity of other taxa. This concept actually receives relatively weak theoretical and empirical support [10].
Focal species

These species effectively represent partial surrogates for biodiversity. They are characterised as species that have specific ecological requirements, the protection of which may help ensure the conservation of other species. Focal species are used to identify specific threats and the minimum acceptable level of that threat is then identified using the species most susceptible to that threat. This incorporates the concepts of area-limited, dispersal-limited, resource-limited, process-limited, umbrella and keystone species [11, 12]. The main disadvantage of this approach is that we currently lack adequate knowledge on species characteristics to implement such an approach in most situations, leading to frequently subjective choices of focal species.

Threatened species and flagship conservation species

Conservation of threatened ‘flagship’ species frequently represents the main goal of biodiversity conservation projects and, consequently, such species commonly feature in ecological monitoring programmes. Monitoring threatened species alone will rarely be adequate, however, as this approach fails to consider the underlying integrity of the ecosystem, upon which all species in the ecosystem rely. Thus, increases in populations of threatened species could be accompanied by undesirable decreases in populations of other species. Many threatened species are also threatened by species-specific stressors, such as hunting or disease, and/or have very specific resource requirements, to the extent that trends in populations of these species are unlikely to reflect changes in the wider biological community.

Ecological disturbance indicators

This is potentially the most useful type of indicator, as changes in their populations illustrate the links between management interventions and underlying “ecological integrity” [2, 13-15]; i.e., “the quality of an ecosystem in which its constituent species and natural ecosystem processes are sustained” [16]. In essence, this refers to ‘natural’ forests, with the tacit assumption that conserving this naturalness will protect the species found within the forest and its ecosystem services. Ecological disturbance indicators are identified through field tests, comparing species or groups of species between sites of differing disturbance levels. Multi-taxa comparisons are needed to assess which indicators are the optimum performers [8, 15].
Baseline levels and controls

In assessing the impacts of human activities on an ecosystem and its biodiversity, it is important to establish: (i) that any change in the ecosystem is indeed a ‘true’ change and lies outside of natural levels of variation; (ii) whether any confirmed changes in the ecosystem represent a change towards a desired natural/less disturbed state; and (iii) that any change is, in fact, a result of the management interventions and would not have occurred in their absence. This is achieved through establishing baseline levels for the variable(s) of interest, particularly in minimally disturbed forests, and establishing control sites not subjected to the management intervention/s under investigation.

Establishing baselines and reference levels

Spatio-temporal variations will naturally occur in any variable measured in any ecosystem. If a change detected through ecological monitoring lies within natural variability levels, we cannot be confident that it represents a real effect of human activities. Furthermore, in the absence of data collected from areas of no or minimal disturbance, it is impossible to objectively assess whether any confirmed changes resulting from management interventions are occurring in the desired direction; i.e., if the forest is approaching a more ‘natural state’. To maintain scientific integrity, this natural state should be defined using objective field measurements. Thus, ecosystem changes and management impact are evaluated against established baselines and reference points, which indicate the average condition of the indicator and the variability around this [2, 8, 17, 18].

Use of control sites

Scientists use a combination of experimental and control conditions to assess the impact of experimental procedures on the variable/s under investigation. In the case of a managed forest, the experimental condition would be the managed area of forest and the control would be an ecologically-similar area not subjected to management. While this may not always be feasible, it is desirable to increase the confidence in assertions regarding the impacts of management interventions in the forest of interest. It is important to select control sites carefully, so that they mirror as closely as possible the characteristics of the managed forest and have a similar probability of being disturbed in the absence of forest management (e.g., forests in very remote/rugged areas are likely to be at relatively low risk of disturbance, even in the absence of protection). This is achieved through the use of “matching techniques”, which control for factors influencing the likelihood of disturbance in the absence of protection, thereby matching like forests to like [19, 20].
Ensuring cost efficiency and feasibility of monitoring

Given the highly restricted funding of most conservation projects, it is clearly crucial to ensure that ecological monitoring is cost effective and, ideally, enables refinement of management intervention regimes to reduce overall project costs. Two key approaches to achieve this are highlighted below.

**Identifying cost-efficient indicators**

The aim here is to acquire the required amount of indicator information to conduct the necessary assessments of management intervention effectiveness at the minimum cost. Surprisingly few examples of such research exist. The best available example of such an indicator assessment is that of Gardner et al. [15], who adopted the following four-stage approach:

1) Assess the relative usefulness of each potential indicator in documenting the response of interest, as discussed above.
2) Conduct a detailed audit of the cost of collecting, analysing and interpreting data for each indicator, including salary costs at the minimum level of expertise required to obtain results.
3) Standardise survey costs, based on differences in sample effort between different taxa, to enable direct comparisons.
4) Compare the information gained/unit cost across taxa, to identify “high-performance” indicators (i.e., those that yield high amounts of information at low cost).

**Simplifying methods to reduce salary costs**

Opportunities exist to reduce the cost of ecological monitoring if the level of expertise needed to reliably collect, analyse and interpret data can be reduced. Frequently, the chief obstacle faced will be the identification skills needed to accurately conduct surveys of some taxa, such as birds and invertebrates. Potential ways in which this obstacle can be overcome include training of local villagers, students and scientists; reducing the depth of identification conducted (e.g., from species, to genus or family); focusing on only a restricted sub-set of easily identifiable species; using morpho-species, as opposed to formal taxonomic identifications [21]; or, better still, eliminating the need for specialist identification skills through focusing on assessment of “functional traits” in target indicator groups, such as body or wing length [22]. When considering such an approach, it is essential to compare the utility of any such methodological simplification for informing management with results from in-depth taxonomic analyses.
**The need for adaptive monitoring and management**

Our knowledge of the natural world, and the impacts of human threats and management on this, is very incomplete. Consequently, any rigid management programme unable to adjust in light of new knowledge will never be capable of meeting its true potential for biodiversity conservation. Similarly, any ecological monitoring programme that is unable to evolve as new scientific information emerges and research questions change (due to changes in the ecosystem, threats faced, management interventions implemented or project aims) will also be of very limited use to management. Thus, to ensure effective management and useful, relevant ecological monitoring, it is essential that both management and monitoring can adapt based on input from the other [2, 23, 24].

Adaptive management and monitoring is more than just simple trial and error, or a willingness to be flexible. It involves a continuous, integrated cycle of design, management and monitoring, to test key assumptions regarding the impacts of human activities and reduce our uncertainty surrounding these, which, in turn, enables both sides to adapt and learn [3, 24].

Important criteria of effective adaptive monitoring include [23]:

1) That monitoring is driven by scientifically-tractable, policy-relevant questions/hypotheses regarding the impacts of management interventions on the ecosystem. Thus, if these questions change, monitoring will likely also need to change in reflection of this.

2) That a conceptual model of the present understanding of how the ecosystem in question functions, and the impacts of human activities on this, is developed and continually updated. This provides the framework around which the above questions are constructed.

3) That rigorous statistical design is established at the outset.

4) That developing and refining questions occurs through a partnership between scientists carrying out the monitoring, statisticians, policy makers and conservation managers. Institutional and political barriers can make this criterion difficult to achieve.

5) That the integrity of long-term datasets on core ecological variables of high relevance is not breached or compromised by the introduction of new sampling or analytical methods (e.g., by ‘improving’ the method half way through, so that a higher proportion of individuals in the population are detected in one half of the data set than the other).
Habitat-specific considerations and peat-swamp forests

Different forests can vary enormously in their species composition, ecology, specific threats faced and appropriate management solutions to mitigate these threats. Consequently, no single management or ecological monitoring programme will be applicable for use in all forests [25].

For example, although South-east Asia’s peat-swamp forests have received relatively little scientific attention compared to dryland forests in the region, it is clear that there are important ecological differences between these forests that must be taken into account by both conservation managers and ecologists. Most important among these is near-permanent water-logging in peat-swamp forests, where the water level may be at or above the surface for much of the year [26]. This results in (i) a very important role of water in nutrient cycling in peat-swamp forests, e.g., [27]; (ii) habitat-specific threats, most notably the construction of drainage channels for timber extraction by illegal loggers and agricultural conversion, leading to lowering of water tables, peat degradation and increased risk of fire [26]; and (iii) habitat-specific management solutions to these threats, such as the construction of dams to block these channels and restore natural hydrology [28].

Such habitat-specific considerations have clear relevance when considering the research questions to be investigated and, hence, the indicators and methods needed to answer these questions. Bearing this in mind, and considering the importance of sound conceptual models of how forests might work for developing research questions for adaptive monitoring (see previous section), we have developed a habitat-specific conceptual model of peat-swamp forest ecosystem function, adapted from previous models developed for dryland forests [29-31]. This model is presented in Figure 1 and discussed in detail elsewhere [32].
Figure 1. A conceptual model of peat-swamp forest ecosystem processes and functions. Management interventions (dashed line) can be targeted towards mitigating anthropogenic disturbances (stochastic factors, red circle) to maintain ecosystem function and services.
OuTrop’s ecological monitoring programme

Programme goals and design

Our ecological monitoring programme is being developed in collaboration with the Centre for the International Cooperation in Sustainable Management of Tropical Peatlands (CIMTROP) to achieve two main goals:

1) To evaluate and improve the effectiveness of CIMTROP’s management interventions for conservation of ecological integrity and threatened flagship species in the Natural Laboratory of Peat-Swamp Forest (NLPSF) and Kalampangan Research Stations, in Sabangau, Central Kalimantan, Indonesia; and
2) To establish frameworks, methods and baselines for ecological monitoring studies in other areas of forest, and particularly peat-swamp forest, in the region.

In light of these goals, our ecological monitoring programme is purposeful in relation to CIMTROP’s management goals, validatory and has a broad focus. It includes conceptual model and research question generation, and assessing the effectiveness and feasibility of a variety of types of indicator at different spatio-temporal levels. This process of conceptual model and research question generation is ongoing, such that research questions and methods can be adapted in light of improvements in our knowledge, or changes in threat status, conservation aims and/or management interventions.

As described in the following sub-section, we are collecting and analysing data on forest structure/habitat condition, a variety of potentially useful ecological disturbance indicator taxa and the area’s threatened flagship conservation species. Collection of data on forest structure/habitat condition will facilitate interpretation of the links between human disturbance and changes in biodiversity. Data are being collected from relatively pristine, highly-degraded and burnt areas of forest in Sabangau, to (i) establish natural spatio-temporal variations in indicators, including seasonal variations in abundance that may confound assessments; (ii) establish baseline reference levels for minimally disturbed forests; and (iii) assess the responses of different potential indicators to human disturbance. In this way, we aim to ensure that our monitoring programme is effective in documenting ecological changes with respect to differences in human disturbance.

This data collection will be supplemented by an analysis of associated costs, to assess the cost-effectiveness of the different indicators and identify “high-performance” indicators. Furthermore, our data collection protocols are being developed with the future potential for method simplification in mind. That is, data are being collected in as much (taxonomic) depth as possible initially and includes documentation of functional traits that are simple to measure, so that, upon analysis, the simplest level of data collection (and, hence, observer expertise) necessary to retain the utility of the indicator for assessing ecological disturbance can be identified. In this way, we aim to minimise the financial resources needed for effective ecological monitoring in peat-swamp forests, helping to ensure the feasibility of the programme.
Ecological variables monitored

A brief overview of the different indicators that we are studying in our monitoring programme is given below. Detailed descriptions of methods and results will be provided in subsequent OuTrop reports and/or can be found in the References section.

Forest Structure – Habitat Condition

Habitat condition is monitored through (i) assessments of forest area and loss; (ii) vegetation plots to detect changes in forest structure (e.g., tree size) and tree recruitment/mortality; and (iii) assessments of forest productivity through litter-fall surveys and monitoring of primate fruit/flower/leaf flush availability in tree plots.

Ecological Disturbance Indicators

We are evaluating the utility of a number of potential indicators of ecological disturbance, and establishing monitoring protocols and baseline reference levels for these. Faunal indicators that have shown high promise in trials and are currently the topic of detailed investigation include birds, frugivorous butterflies and ants.
Primates – Flagship Species

We conduct detailed long-term population assessments and behavioural studies on three of the flagship primate species in this habitat: orangutans (*Pongo pygmaeus wurmbii*), gibbons (*Hylobates albibarbis*) and red langurs (*Presbytis rubicunda*).

Felids – Flagship Species

We conduct monitoring of cats and their prey using camera traps to obtain population density estimates. Focal species include the clouded leopard (*Neofelis diardi*), marbled cat (*Pardofelis marmorata*) and flat-headed cat (*Prionailurus planiceps*).

All photos: OuTrop/WildCRU, University of Oxford
References


32. Harrison (submitted) Using conceptual models to understand ecosystem function and impacts of human activities in tropical peat-swamp forests.
Further Reading

The following articles by OuTrop scientists provide further background and information relevant to this report:


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