A SOURCEBOOK

BIODIVERSITY MONITORING FOR REDD+

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BIODIVERSITY MONITORING FOR REDD+

2014

EXECUTIVE SUMMARY

Biodiversity is complex. REDD+ is complex. Monitoring biodiversity as part of REDD+ could therefore add a complexity and cost to REDD+ that stymies rather than promotes progress. A large range of approaches is available to both project- and national-level REDD+ stakeholders in designing purposeful, effective and realistic monitoring systems. To bring clarity to the options, this sourcebook adopts a simple four-stage monitoring framework:

- Defining objectives: Why monitor biodiversity for REDD+?
- Selecting indicators: What to monitor for REDD+?
- Implementation of monitoring: How to monitor for REDD+?
- Informing relevant audiences: Sharing and using the information generated

Across this framework, the key considerations for REDD+ can be summarised under three criteria for meaningful monitoring:

- Purposeful: having clearly stated goals and objectives;
- Effective: being able to attribute changes in biodiversity to its causes;
- Realistic: being able to achieve this given real-world resource constraints.

Objectives

Defining the monitoring objective is the first critical step in developing a purposeful monitoring system. REDD+ presents both opportunities and risks for biodiversity, with the former recognised by the CBD and the latter by the UNFCCC, in its Cancún Safeguards. Biodiversity information generated through monitoring has the potential to address not only Cancún Safeguards and CBD Targets, but also funding agencies' safeguards and requirements, and project standards. Thus, monitoring biodiversity for REDD+ can provide a link between Conventions, helping to achieve international climate and biodiversity targets more cost- effectively. In addition, biodiversity monitoring can be important for compliance with the safeguards and standards required by donor agencies and investors in REDD+.

Indicators

Decades of biodiversity monitoring experience have shown that it is vital to choose indicators that are based on an adaptive management approach to achieving effective biodiversity conservation. Therefore, the ideal monitoring system would include indicators of the Pressures impacting biodiversity, the State of biodiversity, the Benefits humans derive from biodiversity, and the management Responses being adopted. Reflecting the need to provide readers with practical and focused information, this sourcebook focuses on indicators of the state of biodiversity.

Implementation

Monitoring methods can be broadly split into field-based and remote sensing methods. Each method has its strengths and weaknesses, but the primary selection criterion is how realistic they are given limited resources. A phased approach is likely to be needed in many situations, starting with existing monitoring systems and available databases and gradually introducing more detailed methods when possible. Also, a streamlined approach linking existing REDD+ carbon monitoring to scalable biodiversity monitoring tools such as remote sensing and camera trapping is likely to be cost-effective and realistic.

Informing

Procedures for informing will vary depending on the monitoring objective. However standardised processes for information collection and sharing are emphasised to enable information to be scaled up, and used to infer wider trends in biodiversity at national to international levels.

Framework scenarios

To conclude, five real-world examples of both national, sub-national and project scale biodiversity monitoring initiatives across the globe are used to illustrate the sourcebook framework. These scenarios emphasise the range of approaches and methods used when monitoring biodiversity for natural resource management and REDD+. Despite these varied approaches, each project consistently identifies the advantages of stakeholder-engagement and incorporation of existing knowledge in their design, highlighting their importance for meaningful monitoring for REDD+.

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THE IMPORTANCE OF FORESTS: BIODIVERSITY, CARBON AND REDD+

Forests are among the most biodiverse terrestrial ecosystems on Earth, home to complex communities of plants, animals and microorganisms. Tropical forests, in particular, harbour over half of global terrestrial biodiversity[1,2] and also contain the majority of the world's biodiversity hotspots[3]. This biodiversity underpins the important ecosystem services that forests provide, such as carbon sequestration and watershed protection[4,5]. Compared with monoculture plantations or heavily modified natural forests, biodiverse forests have a greater capacity to withstand external pressures and recover from disturbances, thereby maintaining ecosystem services such as carbon storage[5].

Since many forest ecosystem services are 'public goods', they tend to be unrecognised and undervalued and the private profits obtained from their conversion to alternative land uses, such as agriculture, have encouraged large-scale deforestation[6]. Deforestation is one of the greatest threats to global biodiversity[4,7] and despite a decline in recent years, globally the rate of deforestation remains alarmingly high[8].

Land use change, mostly deforestation, contributes approximately 10% of anthropogenic greenhouse gas emissions (GHGs)[9]. Given this, and the costs of losing forests[6,10], the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) are developing policy approaches and positive incentives on issues relating to Reducing Emissions from Deforestation and forest Degradation (REDD+) in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries. REDD+ provides developing countries with an economic incentive to change current land use practices by recognising the value of forest carbon – making tropical forests 'worth more alive than dead'[11].

REDD+ covers five main activities:
(1) reducing emissions from deforestation,
(2) reducing emissions from forest degradation,
(3) conservation of forest carbon stocks,
(4) sustainable management of forests and
(5) enhancement of forest carbon stocks[12].

These REDD+ activities will be comprised of a set of policy and management responses aimed at conserving/restoring/managing forests in developing countries. Although REDD+ is focused on carbon, the fact that forests, in particular tropical forests, are highly biodiverse means that REDD+ may present a significant opportunity for synergies in tackling two of the greatest challenges facing humanity: climate change and biodiversity loss[13–16].

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CONTENTS

01

INTRODUCTION TO BIODIVERSITY MONITORING

"YOU CANNOT MANAGE WHAT YOU DO NOT MEASURE"
Pavan Sukhdev, TEEB study leader

The reasons for monitoring biodiversity are outlined in this chapter, highlighting the importance of monitoring for the management of natural resources.
A simple biodiversity-monitoring framework is presented, which is then used throughout this sourcebook to guide the key considerations that can be taken into account when deciding what to monitor for REDD+.

WHAT IS BIODIVERSITY?

Biological diversity, or 'biodiversity', encompasses the variety and variability of all living organisms, including within species, between species and of ecosystems[17]. Biodiversity plays an indispensable role in the functioning and resilience of ecosystems and the benefits that humans derive from them, with these benefits known as 'ecosystem services'[18]. Ecosystem services extend from the local to global scale, delivering vital local livelihood benefits as well as larger scale services such as carbon sequestration and storage, nutrient cycling and water purification[6,18–20].

Global biodiversity is under increasing pressure from anthropogenic activities and evidence indicates biodiversity loss is detrimental to the functioning of ecosystems, and the services they provide, in turn impacting human well-being[21,22]. Increasing recognition of the importance of biodiversity, and the impact of its decline, is driving conservation action from the local to international scale. Effective conservation action and natural resource management are dependent on effective monitoring.

WHAT IS MONITORING?

To monitor is to observe and check the progress or quality of something over a period of time. Monitoring provides a record to track trends in biodiversity over time and is carried out to reinforce knowledge of the ecological system, to raise public and political awareness of environmental issues and stimulate action through the reporting of these trends. A monitoring programme needs to be founded on clear and well-defined objectives to be effective[23].

WHAT ARE BIODIVERSITY INDICATORS?

Given the complexity of biodiversity, and the often-limited resources available for conservation research, it is not always possible to monitor everything of interest. Simplified approaches to monitoring have been widely adopted that involve the selection and adoption of a range of elements, processes and properties, or 'indicators', that can be used to assess the wider integrity and condition of the ecosystem or management system. Biodiversity indicators are widely used due to their ability to capture complex ecological processes while being relatively simple to communicate to stakeholders including project partners and policy makers. However, choosing a good indicator can be a complicated process, not least because of different types of indicators in use. Indicators can range in complexity, from simple process-based indicators (e.g. whether a management policy is in place), to ecological parameters (e.g. number of species) to more complex aggregated indices (e.g. the Living Planet Index, described in Chapter 4).

A good indicator should be Specific, Measurable, Achievable, Relevant and Time-bound (S.M.A.R.T)[24]:

Specific – It should refer to something particular and discrete, and reflect the biodiversity objective.

Measureable – It must be possible to measure and interpret the variable in question without ambiguity and should be comparable across temporal and spatial scales.

Achievable – The resources and tools in hand must be sufficient to make the measurements in the time available.

Relevant – The indicator must relate to an identified biodiversity value, which is relevant to the biodiversity objective.

Time-bound – Results from the indicator must be accessible within the monitoring timeframe, and for trend indicators indicate a change over time.

WHAT IS ADAPTIVE MANAGEMENT?

Importantly, biodiversity monitoring allows for better understanding of the impact of human activities on the environment over time, and for management responses to be adjusted accordingly. Such 'adaptive management' is based upon a learning process to advance and improve long-term management outcomes and is dependent on measurements derived from systematic monitoring initiatives to gauge whether and why the environment is improving or worsening[25]. Monitoring initiatives are not only useful to inform such management decisions at the local project scale, but also contribute towards assessments of international commitments, such as targets set by the Convention on Biological Diversity (CBD)[26].

Adaptive management depends on the ability to detect changes in the environment and attribute these to the management intervention in question. To facilitate this, a widely adopted approach conceptualises ecological systems in terms of pressures, state, benefits and responses (P-S-B-R Framework)[27]. Biodiversity is subject to a number of different pressures, such as habitat change, climate change, overexploitation and pollution. These pressures influence the state of biodiversity that, in turn, affects the benefits, or ecosystem services, that biodiversity provides. In response to changes in these benefits received, society has developed a set of policies and activities to reduce the pressures on biodiversity, managing the ecological system to promote and support the benefits it provides (Figure 1; Box 1).

The intention of the P-S-B-R Framework is to ensure monitoring initiatives do not consider the state of biodiversity in isolation, but rather in combination with the positive and negative influences on biodiversity for more effective long-term management. Monitoring changes over time across pressures, state, benefits and responses helps our understanding of environmental change, its causes, and the effects of management efforts aimed at mitigating these changes, and helps define what to monitor for effective conservation action[27].

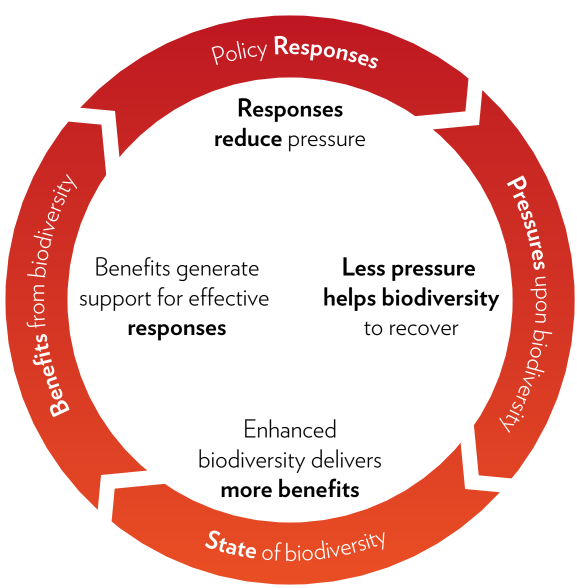

Figure 1. *The Pressure-State-Benefits-Response approach to conceptualising ecological systems[28].*

BOX 1. P-S-B-R DEFINED

Pressures

A range of processes exerts pressures on biodiversity. A key step in monitoring is to identify what pressures are acting on biodiversity. IUCN and The Conservation Measures Partnership (CMP) have categorised pressures into 12 broad classes[29]:

1. Residential Development & Commercial Development
2. Agriculture & Aquaculture
3. Energy Production & Mining
4. Transportation & Service Corridors
5. Biological Resource Use
6. Human Intrusions & Disturbance
7. Natural Systems Modification
8. Invasive & Other Problematic Species, Genes And Diseases
9. Pollution
10. Geological Events
11. Climate Change & Severe Weather
12. Other

State

Biodiversity ranges from the level of genes up to ecosystems. It is important to identify the relevant biodiversity variable that is of interest to, and can be measured by, the monitoring initiative[30]. These variables can be classified into four broad categories:

1. Genes
2. Populations
3. Species
4. Ecosystems

Benefits

Benefits are the ecosystem services that people derive from biodiversity. Ecosystem services are grouped into four classes[18]:

1. Supporting (e.g. primary production, soil formation)
2. Regulating (e.g. climate regulation, water and disease regulation)
3. Provisioning (food, water, fibre and fuel)
4. Cultural (e.g. spiritual, aesthetic, recreation and education)

Responses

These are the range of policies and measures that are implemented in response to changes in benefits, to conserve biodiversity. The CMP has classified responses into seven broad categories of 'conservation actions'[29]:

1. Land/Water Protection
2. Land/Water Management
3. Species Management
4. Education & Awareness
5. Law & Policy
6. Livelihood, Economic & Other Incentives
7. External Capacity Building

A FRAMEWORK FOR MONITORING BIODIVERSITY

In this sourcebook, a framework for monitoring biodiversity for REDD+ is presented (Figure 2). The process of biodiversity monitoring is simplified into four key stages: defining objectives; selecting indicators; implementation of monitoring; and informing against the stated objectives. Given resources for biodiversity monitoring are often limited, it is important that each stage is carefully designed to ensure monitoring provides meaningful results and maximises efficiency. Indeed, for biodiversity monitoring to be meaningful it must be purposeful, effective and realistic[23].

This framework is used to guide each chapter and to define each stage in the monitoring process:

- Objectives: Why monitor biodiversity for REDD+?
- Indicators: What to monitor for REDD+?
- Implementation: How to monitor for REDD+?
- Inform: Sharing and using the information generated

This is achieved through discussion of the REDD+ relevant considerations to be made at each stage of the simple four-stage monitoring framework, irrespective of spatial scale. These considerations are highlighted according to their **purposeful**, **effective** and **realistic** components, to emphasise the importance of designing a meaningful biodiversity monitoring initiative for REDD+.

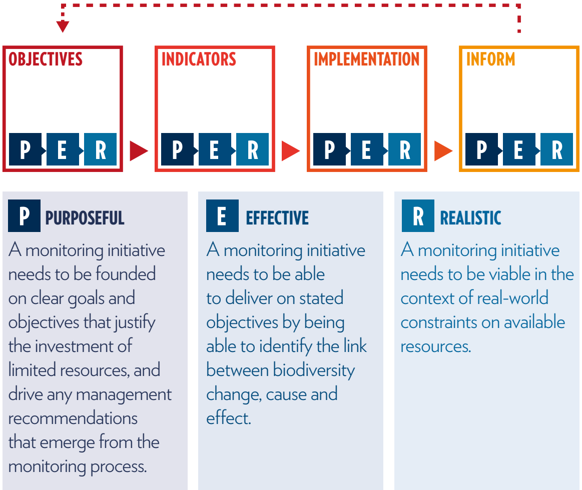

Figure 2. *Conceptual framework of the key stages in the design of a biodiversity monitoring initiative, incorporating the three components of meaningful monitoring[23].*

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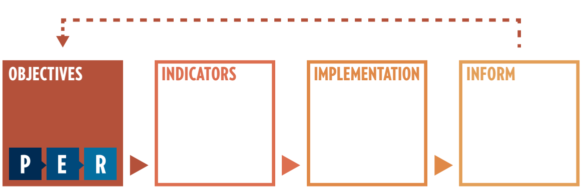
OBJECTIVES: WHY MONITOR BIODIVERSITY FOR REDD+?

In this chapter, the reasons for monitoring biodiversity for REDD+ are identified, and the influence of spatial scale and institutional background introduced.



P PURPOSEFUL
REDD+ risks and opportunities for biodiversity
Addressing safeguards and standards

E EFFECTIVE
Monitoring for management

R REALISTIC
Maximising synergies

P PURPOSEFUL
REDD+ risks and opportunities for biodiversity

REDD+ has the potential to deliver more than just carbon storage and sequestration, with added benefits including the conservation of biodiversity, the maintenance and enhancement of ecosystem services, and livelihood benefits for rural communities. These 'co-benefits' are not just additional to REDD+, they are crucial to providing the supporting environment for emission reductions to be achieved and compensated[31].

However, it cannot be presumed that REDD+ will only provide opportunities, as REDD+ may also negatively impact biodiversity or present trade-offs with ecosystem services other than carbon sequestration[13,14,32]. For example, REDD+ activities that focus solely on high carbon forests may neglect existing important conservation areas, such as savannahs (Table 1).

The potential biodiversity co-benefits of REDD+ activities have been recognised by the UNFCCC within the Bali Action Plan[12]. Much of the international discussions have so far focused on both the social and environmental risks posed by REDD+ and the need to avoid negative impacts. Given this, Parties to the UNFCCC agreed at the 2010 climate talks in Cancún to promote and support seven REDD+ social and environmental safeguards[34]. These so-called 'Cancún Safeguards' are a set of basic principles to help guide REDD+ implementation and ensure that REDD+ 'does no harm' to people and the environment (Box 2).

P PURPOSEFUL
Addressing safeguards and standards

To identify how the Cancún Safeguards are being addressed and respected, the UNFCCC has requested REDD+ countries develop a Safeguard Information System (SIS)[35]. SISs will be country-driven, implemented at the national level and built on existing systems where appropriate, with periodic reporting to the UNFCCC. Indeed, at the 2013 climate talks in Warsaw it was decided that, before results-based REDD+ payments can be received, countries should provide a summary of information on how all of the safeguards have been "addressed and respected"[36].

While the UNFCCC decisions do not specifically mention monitoring, they do recognise the relevance of existing international agreements and obligations to other Conventions. The CBD has gone one step further, calling for countries to identify potential indicators and monitoring mechanisms for assessing the biodiversity impacts of REDD+[37,38]. However, biodiversity information sharing is important not only for addressing these international commitments alone. REDD+ demonstration activities are currently underway at the national and sub-national level with funding from a number of multi-lateral and bi-lateral agreements. These agreements have developed their own set of social and environmental safeguards that activities must comply with to qualify for funding. In addition, donor funding has initiated many REDD+ projects, and, in general these projects need to provide evidence of not just carbon saving, but also biodiversity and human well-being benefits in order to qualify for funding (Box 3). The same is also true for REDD+ activities that aim to sell carbon credits on the voluntary market, with associated certification schemes often requiring demonstration of a project's biodiversity benefits.

While having elements in common, the safeguards, policies and requirements designed by each agreement are not always consistent, and are also not necessarily in line with the Cancún Safeguards[40]. It has been suggested that the resulting multitude of safeguards and requirements that exist could be perceived by countries as a burden on their REDD+ activities and potentially contribute to a political paralysis in widespread REDD+ adoption[31]. Given this, guidance in what biodiversity to monitor for REDD+ is needed. A key challenge is to avoid creating monitoring and reporting systems that will be too difficult and expensive for countries to implement. One way to meet this challenge is to identify synergies between the goals of the UNFCCC and other Conventions, such as the CBD, to increase the cost-effectiveness and efficiency of national and sub-national monitoring activities.

Table 1. *Biodiversity opportunities and risks associated with REDD+ activities. Adapted from Swan & McNally[31] and Miles et al.[33].*

REDD+ activity	Opportunities	Risks
Reducing Emissions from Deforestation	Ecosystem services preserved, conserving biodiversity Forests with high carbon stocks are often species rich Slowed habitat loss/ fragmentation	Displacement of deforestation to non-protected areas (leakage) Agricultural intensification negatively impacting biodiversity
Reducing Emissions from Degradation	Recovery of forest structure and associated resources and habitats	Loss of species that depend on periodic ecosystem disruption e.g. burning
Conserving Forest Carbon Stocks	Built on interventions to conserve biodiversity, including protected areas Recovery of forest structure/composition	Displaced deforestation (leakage)
Sustainable Management of Forests	Reduced logging can improve forest ecosystem stability and benefit biodiversity	Logging in old growth forests can harm biodiversity
Enhancing Forest Carbon Stocks	Plantations composed of diverse and native species can benefit biodiversity Increased connectivity between forest fragments with new forest growth	Increasing growth of low-diversity monoculture plantations replacing diverse natural ecosystems Afforestation of valuable non-forest ecosystems

BOX 2. CANCÚN SAFEGUARDS

Safeguards in *italics* are those that are directly relevant to biodiversity.

(a) *Actions complement or are consistent with the objectives of national forest programmes and relevant international conventions and agreements.*

(b) Transparent and effective national forest governance structures, taking into account national legislation and sovereignty.

(c) Respect for the knowledge and rights of indigenous peoples and members of local communities by taking into account relevant international obligations, national circumstances and laws, and noting that the United Nations General Assembly has adopted the United Nations Declaration on the Rights of Indigenous Peoples.

(d) *The full and effective participation of relevant stakeholders, in particular, indigenous peoples and local communities.*

(e) *Actions are consistent with the conservation of natural forests and biological diversity, ensuring that the actions referred to in paragraph 70 of this decision are not used for the conversion of natural forests, but are instead used to incentivize the protection and conservation of natural forests and their ecosystem services, and to enhance other social and environmental benefits.*

(f) *Actions…address the risk of reversals.*

(g) *Actions…reduce displacement of emissions.*

Kinyongia multituberculata *© Andrew. R. Marshall*

BOX 3. SAFEGUARD AND STANDARD INITIATIVES

The following safeguard initiatives have emerged during the REDD+ readiness phase:[39]:

FCPF-SESA (Forest Carbon Partnership Facility Strategic Environmental and Social Assessment)

This initiative uses the World Bank's 10 Social and Environmental Safeguard Policies. The safeguards are applied to activities funded by the FCPF and supported by the World Bank, and adapted to assist with the REDD+ planning process. The SESA process informs selection of REDD+ strategy options and decision-making in preparation of a REDD+ readiness package and raises attention for the social and environmental priorities of the REDD+ activities.

(https://www.forestcarbonpartnership.org).

UN-REDD SEPC (UN-REDD Programme Social and Environmental Principles and Criteria)

A set of environmental and social principles and criteria, designed to ensure that UN obligations and commitments are met in REDD+ programmes. The SEPC is designed to actively support countries in assessment of the REDD+ risks to the multiple benefits forests provide.

(http://www.un-redd.org/)

REDD+ SES (REDD+ Social and Environmental Standards)

A multi-stakeholder initiative jointly facilitated by the Climate, Community and Biodiversity Alliance (CCBA) and CARE International. The standards are intended to support the design and implementation of government-led REDD+ programmes that respect the rights of local Indigenous Peoples and local communities, generating significant social and environmental benefits. These safeguards are designed to go beyond managing risks to identifying and enhancing benefits.

REDD+ SES is one of two initiatives developed by the CCBA. The second being the CCB standards, launched in 2005, to foster the development of, and investment in, site-based projects that deliver credible and significant contribution to human rights, poverty alleviation and biodiversity conservation. The difference being that REDD+ SES is designed to provide guidance for national and sub-national (e.g. state, province) jurisdictional programs of policies, while the CCB Standards are concerned with project-level impacts on climate, community and biodiversity.

(http://www.climate-standards.org/).

For REDD+ projects a standard to promote and measure REDD+ co-benefits has been developed:

CCB Standards

Terrestrial carbon projects must demonstrate good project design that will generate significant climate, community and biodiversity benefits to be validated. CCB validation helps build support and funding for projects from stakeholders and investors, as investors can use the Standards to identify credible initiatives and minimise risks. Subsequent verification under CCB standards requires evidence of the climate, community and biodiversity benefits collected via a biodiversity monitoring programme, for example. Successful verification enables projects to attach the 'CCB label' to the verified emissions reductions that are produced in line with a carbon accounting standard such as the Verified Carbon Standard (VCS).

Table 2. *Overview of the three national and jurisdictional level safeguard initiatives, and the project level CCB standards. Adapted from Swan & McNally[31].*

	FCPF-SESA	**UNREDD SEPC** *(Final Version, 2012)*	**REDD+ SES** *(Version 2, 2012)*	**CCB Standards** *(3rd Edition, 2013)*
Relevant scale	National and jurisdictional	National and jurisdictional	National and jurisdictional	Project
Basis	10 World Bank Safeguard Policies	7 Principles & 24 Criteria	7 Principles & 28 Criteria	17 Required, and 3 'Gold Standard', Principles
Regulatory Nature	Mandatory for FCPF funding	Yet to be decided	Voluntary	Voluntary
Safeguards Approach	Linked to World Bank Safeguards (similar to UNFCCC safeguards)	Linked to UNFCCC Safeguards	Based on independent multi-stakeholder, multi-country consultation – covers UNFCCC safeguards and more	Aligned with, and help projects demonstrate they meet, UNFCCC Safeguards (except safeguard (b) related to national forest governance structures given project-level focus of CCB standards).
Relevant phase of REDD+ implementation	Predicting impacts at early stages of REDD+ design	Predicting and assessing risks; assessment and monitoring of impacts	Monitoring, Reporting and Verification	Project-focussed
Overall Focus	*Minimizing risk*	*Minimizing risk*	*Enhancing benefits*	*Enhancing benefits*
e.g. Biodiversity-relevant criteria	World Bank Operational Policy 4.04: 'Natural Habitats' seeks to ensure that World Bank-supported infrastructure and other development projects take into account the conservation of biodiversity, as well as the numerous environmental services and products, which natural habitats provide to human society.	Criterion 22 – Ensure that planted and natural forests are managed to maintain and enhance ecosystem services and biodiversity important in both local and national contexts.	Criterion 5.2 – The REDD+ programme maintains and enhances the identified biodiversity and ecosystem service priorities.	Criterion B2 – Net Positive Biodiversity Impacts The project generates net positive impacts on biodiversity within the Project Zone over the project lifetime. The project maintains or enhances any High Conservation Values present in the Project Zone that are of importance in conserving biodiversity. Native species are used unless otherwise justified and invasive species and genetically modified organisms (GMOs) are not used.

Table 3. Biodiversity synergies between REDD+ elements and CBD Aichi targets, adapted from Miles et al. 2013 [33]

CBD Aichi Targets	REDD+ Elements				
	Activities				
	Reducing emissions from deforestation	Reducing emissions from forest degradation	Conservation of forest carbon stocks	Sustainable management of forests	Enhancement of forest carbon stocks
Target 5: By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.	◎	◎	◎		
Target 7: By 2020, areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity.				◎	
Target 11: By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes.			◎		
Target 14: By 2020, ecosystems that provide essential services, including services related to water and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable.			◎		◎
Target 15: By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification	◎	◎	◎	◎	◎

REDD+ Elements			
Safeguards			**Guidance**
(a): Actions complement or are consistent with the objectives of national forest programmes and relevant international conventions and agreements	(d): REDD+ activities should promote and support full and effective participation of relevant stakeholders, in particular indigenous peoples and local communities	(e): REDD+ actions are to be consistent with conservation of natural forests and biological diversity and are to incentivize the protection and conservation of natural forests and their ecosystem services	REDD+ activities should be consistent with the objective of environmental integrity and take into account the multiple functions of forests and other ecosystems
◉			
◉		◉	
◉			◉
◉	◉		
◉			

R REALISTIC
Maximising synergies

The UNFCCC Bali Action Plan also recognises the potential for REDD+ to complement other international environmental agreements such as the CBD. Indeed, the CBD has since called on countries to explore how REDD+ actions can "avoid negative impacts on, and enhance benefits for biodiversity"[37].

In 2010, the CBD adopted a new Strategic Plan that guides the implementation of the Convention over the next ten years. This Plan establishes five strategic goals and 20 headline targets, to be met by 2020[26]. A number of these 'Aichi Targets' are relevant to REDD+ activities under the UNFCCC, creating opportunities for synergies between Conventions given shared social and environmental concerns. For the purpose of this sourcebook, synergies between Conventions for biodiversity monitoring are now outlined and remain the main focus (Table 3).

The majority of REDD+ countries have ratified both the UNFCCC and the CBD. These countries are already obliged to monitor biodiversity to inform the CBD on their progress in support of the CBD Strategic Plan and the Aichi Targets. The Aichi Targets are global in nature, and will be monitored using global indicators that are fed by national and sub-national data[41]. Each country interprets the CBD Strategic Plan through their National Biodiversity Strategy and Action Plan (NBSAP), with associated indicators to monitor biodiversity at the national and sub-national level.

Given this, there is potential for monitoring to be designed in a way that supports countries both in their CBD reporting and their UNFCCC safeguard information commitments. Countries may choose to use information from biodiversity monitoring obligations for the CBD as contributions to their REDD+ SIS, and vice versa. Coordination between national bodies responsible for REDD+ and CBD implementation will allow for complementary efforts with regard to biodiversity information gathering, management and sharing, potentially easing what might be considered a burden on limited national resources. Such coordination could also help improve datasets on forests, biodiversity and national priorities that can assist land-use decisions at the implementation stage of REDD+ and/or Aichi targets[33].

E EFFECTIVE
Monitoring for management

Biodiversity monitoring for REDD+ is important given the potential for both positive and negative impacts of REDD+ activities on biodiversity. Monitoring would provide evidence of the impacts of REDD+ on biodiversity, to help ensure that biodiversity opportunities are enhanced and risks minimized, and to enable the multiple benefits of REDD+ to be realised. Attributing any change in biodiversity to REDD+ activities has been identified as another key challenge for REDD+ biodiversity monitoring[42]. The P-S-B-R framework can help address this challenge by enabling a cause and effect approach to monitoring that can allow management to adapt accordingly. Monitoring changes across pressures, state, benefits and responses over time will enable changes in biodiversity to be detected, and for those changes to be attributed to REDD+ activities. This approach follows that of the 'Theory of Change' advocated by the CCBA, which requires an understanding of baseline biodiversity values and clear consideration of the outcomes and impacts of the conservation action, including projections for what might happen without such action, for attribution to be possible[43].

SUMMARY BOX

The reasons to monitor biodiversity for REDD+ are multiple, and are influenced by the spatial scale and institutional function of interest. These can be summarised into:

1) To minimize the risks and maximize the opportunities that REDD+ presents to biodiversity, across spatial scales;
2) To meet UNFCCC requirements of providing information on the Cancún Safeguards;
3) To meet requirements of national and jurisdictional level safeguards and project standards associated with donor funding;
4) To be able to detect changes in biodiversity and attribute these to REDD+ activities;
5) To maximise synergies, and thus increase cost-effectiveness, between Conventions.

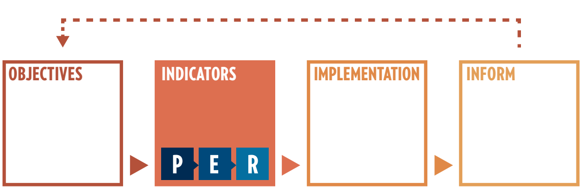
Defining the monitoring objective will assist with the process of deciding what to monitor. For example, a national-level monitoring initiative to mitigate a specific REDD+ risk and address UNFCCC safeguards will differ in complexity and design to a project-level detailed adaptive management plan, that aims to maximise opportunities and realise REDD+ co-benefits. Such considerations are addressed throughout this sourcebook.

Strix leptogrammica © ZSL/PHKA/Jim O'Neill

03

INDICATORS: WHAT TO MONITOR FOR REDD+?

Designing a global biodiversity monitoring protocol for REDD+ is not possible given the spatial variation in biodiversity conservation priorities[44]. Therefore, this chapter summarises the considerations that can be taken into account when deciding what to monitor for REDD+, according to the spatial scale of interest.



P PURPOSEFUL
Risk and opportunity assessments

E EFFECTIVE
P-S-B-R indicators

R REALISTIC
N/A

P PURPOSEFUL
Risk and opportunity assessments

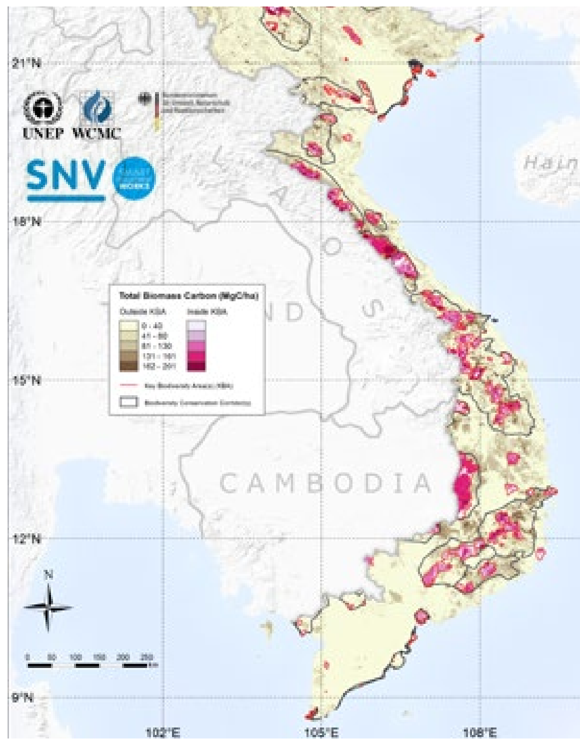
Assessments of the risks and opportunities of REDD+ to biodiversity at the spatial scale of interest are a necessary first step in deciding what to monitor in that such assessments help the selection of indicators for monitoring. Risk and opportunity assessments will depend on knowledge of the REDD+ activity being implemented and its potential impact on biodiversity within the geographic area of interest. Comparable to the theory of change approach[43], indicators that provide the most credible way of attributing the change in biodiversity to the conservation action can then be chosen according to the P-S-B-R framework. For example[45]:

The activity 'reducing (emissions from) deforestation' might be achieved by increasing the protection (response) of a forest subject to anthropogenic threat, such as timber extraction. Such enhanced protection may create opportunities if the forests are important for biodiversity, and an understanding of these opportunities depends upon an understanding of the biodiversity value of the forest (state) and the degree to which it is at risk (pressure). However, enhanced protection of the forest may also pose risks by leading to the displacement of these threats to other less-well protected forest areas ('leakage') that might also be important for biodiversity.

Such risk and opportunity assessments help guide decisions regarding what to monitor. Within the above example it might be decided that state variables both within and outside the area of REDD+ activity would be monitored, to track the positive and negative impacts of the REDD+ activity and potential leakage of threats. If this state monitoring was carried out in combination with monitoring of both pressures and responses, changes in state can be attributed to the REDD+ activity, and management adjusted accordingly to be most effective.

An understanding of the biodiversity importance of the area(s) of interest, and the factors affecting it, is necessary for such assessments. A number of systems exist to help the identification of biodiversity priorities at both national and sub-national scales, such as High Conservation Values (HCVs) and Key Biodiversity Areas (KBAs; Box 4). Such approaches and datasets are well known and useful in defining biodiversity objectives at multiple scales, however, valuable data might also exist at the national and sub-national level within research institutes, government departments and NGOs, and so it is important that relevant stakeholders are identified and consulted during consideration of the REDD+ risks and opportunities for biodiversity.

Figure 3. *Map illustrating forest biomass carbon, Key Biodiversity Areas and conservation corridors in Viet Nam. This map presents an example overlay of biodiversity priorities with forest carbon stocks, clearly illustrating areas where REDD+ activities can be prioritised and co-benefits achieved in the country[53].*



Method and data sources:
The KBA and conservation corridor datasets were provided by Birdlife and Conservation International. KBAs are internationally recognised areas of importance for biodiversity. They are identified at the national, sub-national or regional level by local stakeholders using the two widely accepted criteria for importance: vulnerability and irreplaceability. Additionally, in Viet Nam the Critical Ecosystem Partnership Fund (CEPF) has identified conservation corridors that cover areas that have the potential to become Key Biodiversity areas in their own right (through management or restoration) and areas that contribute to the ability of the conservation corridor to support all elements of biodiversity in the long term. The Forest Biomass carbon is based on the 2005 Viet Nam forest cover map produces by the third cycle of the National Forest Inventory, Monitoring and Assessment Programme (NFIMAP III), Forest Inventory and Planning Institute (FIPI), Hanoi, Viet Nam.

Stakeholder engagement is a vital process in all stages of monitoring, as engaging with such stakeholders will enable interests, experts and potential sources of data to be identified. Stakeholders include experts within universities, research institutes, NGOs and government agencies as well as local community members and community groups. Identification of synergies helps increase cost-effectiveness by enabling the incorporation of information or expertise available within existing monitoring efforts at the geographic scale of interest.

At the national and sub-national scale, mapping such biodiversity priorities along with carbon stocks is a useful approach in assessments of specific REDD+ risks and opportunities and decisions regarding what to monitor. The ability of REDD+ actions to achieve multiple benefits and meet safeguards can be enhanced through such priority planning. Spatial analysis can aid this planning, by using freely available data to map land use, carbon stocks and biodiversity values such as KBAs to illustrate congruence and thus areas where co-benefits are maximised[53] (Figure 3). Maps are particularly useful planning and prioritization tools given they can be rapidly produced, cost-effective, easy to communicate and easily customizable.

At the project scale, systems for prioritisation of species as surrogate indicators of ecosystem health exist to help define what to monitor (Table 4)[54]. However, it is important that indicator species are carefully selected, as using the wrong or inappropriate indicators might result in false scientific interpretations, managerial knowledge and ecological sustainability of the ecosystem[55,56]. To ensure accuracy and confidence in selection, it is important to have a good understanding of the ecosystem and to consult with stakeholders in the decision process. The selection of indicator species is often specific to the area being monitored, as it is dependent on the ecosystem in question, as illustrated by the Emalu REDD+ pilot project in Fiji (Box 5).

Table 4. *Commonly used definitions of indicator species.*

Term	Definition	Example
Bioindicators	Taxa or species that operate as surrogates of attributes of interest, such as other species or ecological integrity[23].	Understorey insectivorous birds are sensitive to degradation in tropical forests[57]
Flagship species	Charismatic species that are considered to encourage societal conservation actions, and the presence of these might drive the location or prioritisation of conservation actions.	Giant panda *(Ailuropoda melanoleuca)*
Keystone species	Species whose addition to or loss from an ecosystem leads to major changes in abundance or occurrence of at least one other species[55].	African elephant *(Loxodonta africana)*
Umbrella species	Are species selected for making conservation related decisions, typically because protecting these species indirectly protects the many other species that make up the ecological community of its habitat.	Cheetah *(Acinonyx jubatus)*
Endemic species	Species unique to a defined geographic location or habitat type, such as a mountain, island or a country.	Ring-tailed lemur *(Lemur catta)*, endemic to Madagascar
Threatened species	Species vulnerable to endangerment in the near future, such as those listed on the IUCN Red List (see Chapter 4).	Sumatran tiger (*Panthera tigris* subspecies *sumatrae*)
EDGE species	Evolutionary Distinct and Globally Endangered species are threatened species that have few or no close relatives on the tree of life. (http://www.edgeofexistence.org/)	Giant ibis *(Thaumatibis gigantean)*

BOX 4. BIODIVERSITY PRIORITIZATION SYSTEMS

This box provides an introduction to frequently used systems of prioritization for biodiversity conservation. A useful resource to understand such approaches further is available online at Biodiversity A-Z.

(http://www.biodiversitya-z.org/).

IUCN Red Lists

The IUCN Red List of Threatened Species is the most comprehensive, objective global approach for evaluating the conservation status of plant and animal species. This is based on a scientifically rigorous approach to determine risks of extinction that is applicable to all species, and has become a world standard. In order to produce the Red List the IUCN draws on and mobilises a network of scientists and partner organisations working in almost every country in the world, who collectively hold what is likely the most complete scientific knowledge base on the biology and conservation status of species.

Further information: http://www.iucnredlist.org/

High Conservation Values (HCVs)

High Conservation Value Areas (HCVAs) are natural habitats, which are of outstanding significance or critical importance due to their high environmental, socioeconomic, biodiversity or landscape values. The HCV concept was originally developed by the Forest Stewardship Council (FSC) in 1999 to designate High Conservation Value Forests (HCVFs) for use in forest management certification[46]. It has since become the cornerstone of sustainability standards for palm oil, soy, sugar, biofuels and carbon, in addition to being widely used for landscape planning and natural resource conservation and management. In 2006 the HCV Resource Network was established by a group of organisations using the HCV approach to provide comprehensive information and support in the use of HCV principles. A number of countries have developed national interpretations of HCVs and their own HCV identification toolkits, available freely on the HCV Network website. In addition Proforest has developed a Global HCV Toolkit that provides guidance on the application of HCV definitions and how to develop National interpretations[47]. Six HCVs define HCVAs, based on the original definition for the identification of HCVFs:

- **HCV1.** Areas containing globally, regionally or nationally significant concentrations of biodiversity values (e.g. endemism, endangered species, refugia)
- **HCV2.** Globally, regionally or nationally significant large landscape-level areas where viable populations of most, if not all, naturally occurring species exist in natural patterns of distribution and abundance
- **HCV3.** Areas that are in or contain rare, threatened or endangered ecosystems
- **HCV4.** Areas that provide basic ecosystem services in critical situations (e.g. watershed protection, erosion control)
- **HCV5**. Areas fundamental to meeting basic needs of local communities (e.g. subsistence, health)
- **HCV6.** Areas critical to local communities' traditional cultural identity (areas of cultural, ecological, economic or religious significance identified in cooperation with such local communities)

Further information: http://www.hcvnetwork.org/

Important Bird Areas (IBAs)

BirdLife International's Important Bird and Biodiversity Area (IBA) Programme aims to identify, monitor and protect a global network of IBAs for the conservation of the world's birds and other wildlife. Terrestrial and marine sites are included in the IBA network, and sites are identified using standardised criteria. IBAs are areas that hold (a) bird species that are threatened with extinction or have highly restricted distributions; (b) species assemblages characteristic of particular biomes and/or (c) exceptionally large numbers of congregatory bird species.

Within IBAs, monitoring of state (both species and habitat), pressures and responses is conducted with the guidance of a global IBA monitoring framework that is based on a simple, replicable and standardised scoring system [48]. This framework is freely available online and provides useful guidance in the practical implementation of monitoring. The quality and reliability of the data upon which scores are awarded is assessed on a sliding scale, and monitoring data are stored in the World Bird and Biodiversity Database managed by Birdlife International and Conservation International.

Further information: http://www.birdlife.org/datazone/site

Key Biodiversity Areas (KBAs)

Key Biodiversity Areas represent sites of global significance for the conservation of biodiversity. These areas are identified nationally using simple, standard criteria that are globally-applicable and based on their importance in maintaining species populations[49,50]. These criteria address the two key issues for setting site conservation priorities: vulnerability and irreplaceability. KBAs extend the IBA approach by incorporating other animal and plant taxa and terrestrial, marine and freshwater environments. KBAs are an umbrella term for globally important sites for different taxa and realms such as IBAs and AZEs (see below). As with IBAs, KBAs are identified based on species that are threatened or geographically concentrated. KBAs are the starting point for conservation planning at the landscape level because they are the building blocks for designing an ecosystem approach to conservation actions.

Further information: https://www.iucn.org/about/union/secretariat/offices/iucnmed/iucn_med_programme/species/key_biodiversity_areas/

Biodiversity hotspots

Biodiversity hotspots are terrestrial areas that hold especially high numbers of endemic species and are considered important focal areas for biodiversity, where conservation action is needed. To qualify as a hotspot, an area must meet two strict criteria: contain at least 1500 species of vascular plants (>0.5% of the world's total) as endemics and have lost ≥70% of its original native habitat. A global assessment of biodiversity hotspots was conducted in the late 1990s, resulting in the identification of 25 hotspots, with these areas collectively holding as endemics ≥44% of the world's species of vascular plants and ≥35% of terrestrial vertebrates in an area that covered only 11.8% of the terrestrial surface of the earth[3]. The most recent re-analysis of global hotspots has identified a total of 34 terrestrial biodiversity hotspots, most of which occur in tropical forests. Between them they contain around 50% of the world's endemic vascular plant species and 42% of all terrestrial vertebrates, but have lost around 86% of their original habitat[51].

Further information: http://www.conservation.org/How/Pages/Hotspots.aspx

WWF Ecoregions

Ecoregions are areas whose conservation would achieve the goal of saving a broad diversity of the Earth's ecosystems and ecological processes[52]. WWF defines an ecoregion as a "large unit of land or water containing a geographically distinct assemblage of species, natural communities and environmental conditions". These ecoregions include those with exceptional levels of biodiversity, such as high species richness or endemism, or those with unusual ecological or evolutionary phenomena.

Further information: http://worldwildlife.org/biomes

Alliance for Zero Extinction (AZE) Sites

AZE is an alliance of 88 non-governmental biodiversity conservation organisations working to prevent species extinctions by identifying and safeguarding the last refuges for endangered or critically endangered species. AZE sites are discrete areas that contain 95% of the known global population of these species, or 95% of one life history segment (e.g. breeding site) of these species. The loss of an AZE site would result in the extinction of a species in the wild. AZE sites form a sub-set of KBAs and IBAs. Site locations and details can be easily searched within the AZE website.

Further information: www.zeroextinction.org.

EDGE Zones

ZSL's 'EDGE of Existence' programme prioritises species for conservation that are both evolutionarily distinct (ED; calculated from a species-level phylogeny (family tree)) and globally endangered (GE; derived from the IUCN Red List). Combining geographic and phylogenetic (evolutionary) information enables the identification of landscapes that contain disproportionate amounts of evolutionary history, where conservation action can secure the future of a larger proportion of the diversity of life. Using data on species distributions, regions of the world where ED species (ED 'zones') and EDGE species (EDGE 'zones') are concentrated have recently been mapped, starting with well-known groups such as mammals and amphibians[97]. The use of ED within EDGE gives it the potential to be used in combination with other prioritisation schemes that are based on species endangerment, e.g. AZE, IBA and KBA.

Further information: http://www.edgeofexistence.org/

Table 5. *Definition and examples of P-S-B-R indicators[28].*

Type	Definition	Category	Measure	Example
Pressure	The extent and intensity of the causes of biodiversity loss	IUCN Threat Categories 1-12	Frequency Scope Severity Irreversibility	The frequency or intensity of anthropogenic impacts that are directly harmful to the biodiversity of interest (e.g. poaching) Frequency of fires in study area over time Trend in scope of mining activities
State	The condition and status of aspects of biodiversity	Genes Populations Species Ecosystem	Diversity Quantity Condition	The population status of plant or animal species that are of special economic, ecological or cultural interest (e.g. HCV species) Extent and distribution of forest ecosystem
Benefit	The benefits that humans derive from biodiversity	Provisioning Regulating Supporting Cultural	Stock Flow Quality	Change in quantity of above ground carbon biomass Change in water quality
Response	The implementation of policies or actions to prevent or reduce biodiversity loss.	Conservation Action(s) 1-7	Frequency, Distribution & Intensity Coverage Effectiveness	The frequency or intensity of conservation actions relevant to the biodiversity of interest (e.g. the number of enforcement patrols/month) Frequency of enforcement patrols over time Trend in coverage of protected areas

Leptopelis flavomaculatus © Andrew. R. Marshall

E EFFECTIVE
Monitoring for management

Indicator choice will depend on the purpose of monitoring, and which aspect of the P-S-B-R framework is to be monitored. Risk and opportunity assessments will help inform this choice, as previously described. For example, it might be decided that aspects of 'state' are to be monitored alone. Or, a more complex monitoring initiative might be desired that considers monitoring across indicators of P-S-B-R, allowing for the attribution and detection of REDD+ activities on changes in state (Table5).

A suite of indicators have been proposed for forest management processes, such as by the CCBA for verification of forest carbon projects[43] and by the Center for International Forestry Research (CIFOR) for sustainable forest management[58]. For example, indicators proposed by CIFOR include measures of landscape pattern such as forest area and fragmentation, community guild structures of especially sensitive guilds such as pollinators, and species richness and diversity of selected species e.g. large butterflies. These indicators provide a useful starting point in the selection of biodiversity indicators relevant for REDD+. Indeed, the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) for the CBD has also suggested possible indicators and mechanisms to assess the impacts of REDD+ measures on biodiversity[38], for example:

- Trends in extent of forest cover
- Extinction risk trends of key forest dependent species
- Trends in extent of different forest ecosystems
- Trends in fragmentation of primary and naturally regenerated forests

Reflecting the need to provide readers with practical and focused information, this sourcebook is focused solely on indicators of the state of biodiversity. Measures of state are categorised into measures of diversity, quantity and condition and in the following chapter, methods to monitor these measures of state are presented according to these measures (Table 6).

Table 6. *Measures of the state of biodiversity*

Measure	Example
Diversity	Species diversity, richness and endemism Species presence/absence
Quantity	Extent and geographic distribution of species and ecosystems Abundance and population size of species Biomass and net primary productivity
Condition	Threatened species and ecosystems Ecosystem connectivity and fragmentation

BOX 5. SELECTING INDICATORS FOR THE EMALU REDD+ PILOT PROJECT IN FIJI

The Fiji Forest Department in collaboration with GIZ, the University of the South Pacific, Emalu Community members and other partners, have established a REDD+ pilot project in Emalu, a 7,200-hectare area of largely untouched tropical rainforest located on the main island of Fiji. Funding was provided by the German Federal Ministry for Economic Cooperation and Development (BMZ) and the German Federal Ministry for Environment, Nature Conservation, Building and Nuclear Safety (BMUB) through two projects: '*Coping with Climate Change in the Pacific Island Region*' (BMZ), and '*Climate Protection through Forest Conservation in Pacific Island Countries*' (BMUB).

The aim of the pilot project is to develop appropriate REDD+ protocols and procedures as part of the national REDD+ readiness phase. The project established a biodiversity monitoring initiative in 2012 to address requirements of national REDD+ policy and international UNFCCC REDD+ safeguards. Indicator species have been selected for monitoring by the project to reflect the condition of the Emalu ecosystem, and focus species identified according to their conservation status as given in the IUCN Red List of Threatened Species (Table 7). Population trends of each indicator and focus species will be assessed at fixed permanent monitoring plots during each monitoring year.

Table 7. *Some of the indicator and focus species used by the Fiji REDD+ pilot project in Emalu*

Species	Reason chosen
Avifauna	
Samoan flying fox *(Pteropus samoensis)*	Fiji's bats play an essential role as seed dispersing agents, major pollinators, and insect control agents in the rainforest and other terrestrial ecosystems. The presence of native bats indicates the health of the forest.
Black-face Shrikebill *(Clytorhynchus nigrogularis)* IUCN vulnerable	The species of endemic birds recorded in Emalu are also listed as focal bird species for national conservation in Fiji due to their vulnerable and endangered status. The bird diversity in Emalu is comparable to the recognised IBAs in the country but with a slightly higher number of endemic species. In terms of species density, it is the highest ever recorded to date anywhere in Fiji. Given these findings, Emalu is proposed as a bird protected area where the monitoring of the identified focal species will provide valuable information on species count, diversity and health in the country as a whole.
Friendly Ground Dove *(Gallicolumba stairi)* IUCN vulnerable	
Pink-billed Parrot finch *(Erythrura kleinschmidti)* IUCN vulnerable	
Long-legged Warbler *(Trichocichla rufa rufa)* IUCN endangered	
Collared Lory *(Phigys solitarius simus)* CITES Appendix II	
Insects	
Nysirus spinulousus and *Cotylosoma dipneusticum* (Order *Phasmida*)	Endemic and rare stick insects recognized to be associated with pristine forest systems.
Coleoptera (beetles) and the *Hymenopteran* (sawflies, wasps, bees and ants)	The great diversity of these insects is a good indication that ecosystem services such as nutrient cycling, decomposition, pollination and seed dispersal are intact. These groups of insects have proven to be excellent indicators of the forest and water systems and their abundance and richness suggests a healthy catchment area.
Vegetation	
Degeneria vitiensis (IUCN vulnerable)	The taxon is a relic to one of the oldest flowering plant families (Degeneriaceae) in the world and is endemic to Fiji.
Equisetum ramossimum subspecies *debile*	Its occurrence indicates intact riparian systems.
Bryophytes	Good indicator of changing climatic conditions. Water retention properties play an important role in a cloud montane forest ecosystem.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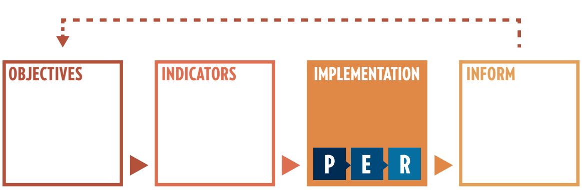
04

IMPLEMENTATION: HOW TO MONITOR BIODIVERSITY FOR REDD+?

In this chapter, methods for implementing monitoring are presented. A guide to both secondary data sources and commonly used methods of primary data collection is presented. The need for careful survey design in monitoring is identified, and options for monitoring given resource constraints are discussed.



P PURPOSEFUL
Monitoring method depends on indicator and taxa of interest

E EFFECTIVE
Careful survey design

R REALISTIC
Available resources

SECONDARY DATA SOURCES

Table 8. *Guide to potential secondary biodiversity data sources and databases according to relevant state indicator category and measure.*

Category	Measure	Description	NFI, FRA & NFMS pg 37	NBSAPs pg 38	BIP Indicators pg 38	GLCF pg 40	GBIF pg 40	MOL pg 40
Populations	Diversity	Diversity within a population (e.g. demographic variation)						
	Quantity	Population abundance or density			●			
	Condition	Threatened status of populations (e.g. geographically or genetically isolated populations)			●			
Species	Diversity	Species richness	●	●	●			
	Quantity	Abundance and geographic extent of species	●	●	●	●	●	●
	Condition	Threatened status of species	●	●	●	●		
Ecosystems	Diversity	Variety of ecosystems in a given place	●	●		●		
	Quantity	Extent of ecosystem (e.g. area of forest)	●	●		●		
	Condition	Fragmentation or connectivity of ecosystem	●	●		●		

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P PURPOSEFUL

Monitoring method depends on indicator and taxa of interest

The process of monitoring involves data collection and analysis. Data collection can comprise of compiling secondary data, measuring primary data or a combination of the two. The choice of data collection method will depend upon the indicator in question and the availability of resources to monitor and will influence the final design of the monitoring initiative.

Primary data are vital for understanding real-time changes in ecological systems and attribution of these changes to management interventions, however careful consideration of methods is needed when collecting primary data. Survey design is an important process of any data collection and requires consideration to ensure bias is minimised and statistical inferences can be made. Bias can influence the inferences made about changes in biodiversity, leading to potentially incorrect interpretation, and thus management actions. For example, species detectability can affect interpretation (for example, detecting elephants using aerial survey is easier in a savannah than in a forested habitat, but does not necessarily mean savannahs contain more elephants) and sample size is an extremely important consideration for the statistical significance of findings[59].

Alternatively, a number of secondary data sources exist that are useful for REDD+ biodiversity monitoring, including global datasets and freely available online data. In addition, countries have a range of existing commitments for which data are already being collected, such as monitoring towards CBD targets as previously discussed. Government agencies, research institutes and NGOs may also have data that are otherwise not part of a larger monitoring initiative, highlighting again the necessity of stakeholder engagement to identify the institutional landscape, available resources and data. The use of secondary data allows for cost-savings and efficiencies within the monitoring initiative, however, such cost-savings must be considered alongside implications on the scale of the data and their accuracy, with it more difficult to attribute observed changes in secondary data to REDD+ given its coarse scale and data gaps in current knowledge[60,61].

In this chapter a guide to data sources and commonly used data collection methods is presented. Firstly, sources of secondary data are presented according to the indicator measure of interest, such as population diversity or species condition (Table 8). Secondly, methods of primary data collection are presented according to the indicator category of interest (population, species, ecosystem) and the taxa (e.g. bird, mammal) as recommended methods differ according to the taxa of interest. The ability of each method to measure diversity, quantity and/or condition is then indicated within the table (Table 9).

NATIONAL AND GLOBAL FOREST MONITORING

National Forest Inventories (NFIs) are usually designed to assess forest extent, forest condition and timber stocks at the national or sub-national level. Their history dates back to about the 15th Century, when growing demand for timber was first met with resource shortages and the need for forest planning became apparent[61]. Since then, forest information has been collected via NFIs driven by forest users in many countries. NFIs can provide information on the status of forests at the sub-national and national level. However, methods and sampling designs for NFI implementation vary by country. In general, NFIs collate data where available on forest biomass to infer carbon stocks, and thus are crucial for reporting emission reductions and removals for REDD+. Most NFIs in developing countries only measure timber stocks and forest conditions, however, the Food and Agriculture Organization of the United Nations (FAO) and UN-REDD Programme are assisting many countries in designing new methodologies and sampling approaches to allow for the collection of data necessary for reporting for REDD+.

The FAO has been collating reports on the world's forests at 5-10 year intervals since 1946. Global Forest Resources Assessments (FRAs) are now produced every 5 years, and are based on country reports prepared by national correspondents and remote sensing data conducted by the FAO and partners (http://www.fao.org/forestry/fra/en/). FRA reports provide estimates of the current status of the world's forest resources and how these have changed over time, and are used by the Biodiversity Indicators Partnership

(BIP; see below) to assess two of their indicators: Extent of forests and forests types, and Area of forest under sustainable management: degradation and deforestation. The reports cover seven thematic elements in their assessments:

1. Extent of forest resources
2. Biological diversity
3. Forest health and vitality
4. Productive functions and forest resources
5. Protective functions of forest resources
6. Socio-economic functions
7. Legal, policy and institutional framework

The UNFCCC has requested developing country Parties that aim to undertake REDD+ activities to develop a robust and transparent National Forest Monitoring System (NFMS) for the monitoring and reporting of REDD+ activities (Decision 1/CP.16) and to measure and report on the mitigation performance of the activities. An NFMS should have two functions: 1) to monitor REDD+ activities; and 2) to measure and report on GHG emissions and removals from forestry and land use activities. This MRV function is based on three main components: 1) the satellite land monitoring system; 2) the national forest inventory; and 3) the national GHG inventory[62]. An NFMS can also provide monitoring information relevant for addressing and respecting UNFCCC Cancún Safeguards (as well as for other Conventions), such as biodiversity monitoring information. However, there are no standardised biodiversity variables that an NFMS should measure and it is up to countries to decide this depending on their national circumstances.

As an example of a NFMS, The Democratic Republic of Congo (DRC) government is developing their monitoring system in collaboration with the FAO and the Brazilian National Institute for Space Research (INPE), with financial support from the UN-REDD programme. The DRC NFMS brings together data from many sources with the aim of creating a forest management tool that can be specifically related to REDD+ activities while also more generally applicable to the DRC's forest policies and measures. http://www.rdc-snsf.org/)

NATIONAL BIODIVERSITY ACTION PLANS (NBSAPS)

National Biodiversity Strategies and Action Plans (NBSAPs) are the key planning instruments at national level for biodiversity. The CBD asks countries to 'develop national strategies, plans or programmes for the conservation and sustainable use of biological diversity, including, how to integrate conservation and sustainable use of biodiversity into sectoral and cross-sectoral activities' (CBD Article 6). The principal aim of the NBSAP is to address threats to biodiversity. Developing and maintaining an NBSAP is an on-going activity, with regular review to ensure it is based on the best available data. The development, implementation and updating of an NBSAP includes seven steps:

1. Identifying and Engaging Stakeholders
2. Assessing National Biodiversity and Its Links with Human Well-being
3. Developing a strategy
4. Developing a plan of action
5. Implementation
6. Monitoring and Evaluation
7. Reporting

Target 7 of the CBD Aichi Targets calls for each party, by 2015, to have developed, adopted as a policy instrument, and commenced implementing an effective, participatory and updated NBSAP. Individual NBSAPs, as well as a range of documents supporting the development and updating of an NBSAP, are on the CBD website. http://www.cbd.int/

BIODIVERSITY INDICATORS PARTNERSHIP (BIP)

The CBD mandated the Biodiversity Indicators Partnership to promote and coordinate development and delivery of biodiversity indicators in support of the CBD, Multilateral Environmental Agreements (MEAs), the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), national and regional governments and a range of other sectors.

The partnership works with over 40 organisations working internationally on indicator development, with the aim of providing the most comprehensive information on biodiversity trends. The global biodiversity indicators developed and brought together by the BIP are the primary mechanism for monitoring progress towards the CBD Strategic Plan and Aichi Biodiversity Targets. Of the 20 Aichi Targets, 17 are covered by at least one of the BIP indicators.

The BIP worked as part of a Cambridge Conservation Initiative project to show the feasibility of establishing linkages between different types of indicators to provide decision-makers with the tools they need to tackle biodiversity loss effectively. Other project Partners include United Nations Environment Programme-World Conservation Monitoring Centre (UNEP-WCMC), BirdLife International, and the University of Cambridge. It was agreed that biodiversity indicators are easier to understand, communicate and act upon when linked together in a set that connects policies to outcomes. To this end, the partnership adopts the P-S-B-R framework to biodiversity monitoring, and currently adopts a total of 43 indicators across this framework. http://www.bipindicators.net/

Example state indicators adopted by the BIP include:

Red List Index (RLI):

The IUCN Red List Index (RLI) is based on the IUCN Red List of Threatened Species and is an indicator of the relative rate at which the extinction risk of sets of species changes over time. It measures the overall rate at which species move through the IUCN Red List categories towards or away from extinction, by using weight scores based on the Red List status of each of the sample species to give a scale of increasing extinction risk. These scores range from 0 for Least Concern species to 5 for Extinct/Extinct in the Wild species. The index is calculated from the number of species in each category, and the number of species changing category between repeated assessments due to genuine improvements of deterioration in extinction risk status. A Red List Index of 1 equates to all species being listed as Least Concern, whereas a RLI of 0 indicates that all species have gone extinct. Red List Indices have been developed for a number of species groups at the global scale (mammals, amphibians, corals, birds) and regionally (e.g. birds in Australia and British Columbia), and sampled indices (Sampled Red List Index – SRLI) are currently developed for species groups which are too species-rich to allow for comprehensive assessment of the species group.

http://www.bipindicators.net/rli/2010

http://www.zsl.org/science/indicators-and-assessments-unit/the-sampled-red-list-index

Living Planet Index (LPI):

The Living Planet Index (LPI) is calculated from trends of vertebrate species collected in the Living Planet Database, which currently comprises over 12,000 population time series of more than 3,000 species from 2,300 individual data sources reporting on monitoring schemes from around the world. As a simple and powerful tool for communicating global trends to a wide audience, the LPI has underpinned a number of international reports and scientific studies, which have made use of the index's potential for disaggregation to smaller spatial and thematic scales (e.g. WWF's biennial Living Planet Report, The Arctic Species Trend Index 2011). The underlying data set can also make a valuable contribution to evaluations of biodiversity change due to REDD+, for example through the calculation of indices of tropical forest vertebrates.

http://www.livingplanetindex.org

http://www.zsl.org/science/indicators-and-assessments/the-living-planet-index

http://www.bipindicators.net/lpi

Wildlife Picture Index (WPI):

The Wildlife Picture Index (WPI) was developed collaboratively by the Wildlife Conservation Society (WCS) and the Zoological Society of London (ZSL), as an indicator derived from primary data from camera traps[63,64]. The WPI monitors ground-dwelling tropical medium and large mammals and birds. The WPI is defined as the geometric mean of the occupancies of the species in the community relative to the first year of sampling (the baseline). The WPI can be aggregated upward from the site to the global level, and it can be disaggregated to capture trends at regional levels, functional groups of interest, or the national level where adequate data are available. The Tropical Ecology Assessment and Monitoring Network (TEAM) operates the largest global camera trap network in tropical forests, and has adopted the WPI to help understand the effects of climate change and land use change on tropical terrestrial mammal and bird diversity.

http://www.bipindicators.net/wildlifepictureindex

http://wpi.teamnetwork.org/wpi/

GLOBAL LAND COVER FACILITY (GLCF)

The GLCF is a centre for earth science data based on remote sensing tools and products. GLCF provides access to and distributes information related to land cover change across local and global scales. GLCF research focuses on determining land cover and land cover change around the world. Land cover encompasses discernible vegetation, geologic, hydrologic and anthropogenic features on the world's surface. Features such as forests, urban areas, agricultural land and sand dunes can be measured and categorised using satellite imagery. Comparing such images over different time periods results in assessments of land cover change. GLCF is primarily funded through NASA, with contributions from other US federal agencies such as the National Science Foundation and the US Geological Survey, in addition to funds from foundations and private organisations.

GLCF currently holds over 50 terabytes of raw and derived remote sensing data. GLCF offers data on forest change, radiative flux and other derived products. Data are useful across local to global scale analyses of land cover, especially when combined with higher resolution data types such as Landsat. Analysis of GLCF data requires users to be familiar with analysis of remote sensing data, image analysis or GIS software, however, the facility does provide data support where possible via its website. (http://www.landcover.org/)

Data are freely available online: http://glcf.umd.edu/data/.

GLOBAL BIODIVERSITY INFORMATION FACILITY (GBIF)

The Global Biodiversity Information Facility is an international open data infrastructure, funded by governments. This multi-lateral initiative was established in 2001 to encourage free and open access to biodiversity data using the Internet. The database holds over 400 million records of over 1.4 million species, and is publically available anywhere in the world, via the Internet. However, gaps and biases in GBIF data exist and these need to be fully understood before data are used and analysed[66].

The GBIF public library shares relevant publications, tagged according to whether data accessed via GBIF are used in research, or whether GBIF is discussed/mentioned, as well as subjects covered and countries of contributing authors. Only abstracts of articles are shared, but links to full articles are available for open access journals and citations for all publications provided.

www.gbif.org

GBIF Public Library:

http://www.mendeley.com/groups/1068301/gbif-public-library/

MAP OF LIFE (MOL)

MOL endeavours to provide 'best-possible' species range information and species lists for any geographic area[60]. MOL is built on a scalable web platform geared for large biodiversity and environmental data. MOL assembles and integrates different sources of data describing the distribution of species worldwide, including expert range maps, species occurrence points, ecoregions and protected areas from providers like IUCN, WWF and GBIF, among others.

http://www.mol.org/


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PRIMARY DATA COLLECTION METHODS

Table 9. *Guide to primary data collection methods according to relevant state indicator category and taxa. Letters indicate method can be used to measure information on indicators of D=Diversity; Q=Quantity; C=Condition.*

Category	Taxa	Method: Animal Trapping Methods pg 43	Point & Line Transects pg 44	Camera Trapping pg 45	Bioacoustic Surveys pg 47	Quadrats & Plots pg 48	Remote Sensing (active and optical methods) pg 49
Species and populations	Birds	D, Q, C	D, Q	D[i]	D		
	Small Mammals	D, Q, C	Q	D[i]	D, Q[ii]		
	Medium-Large Mammals		D, Q, C	D, Q, C	D		
	Primates		D, Q	D[i]	D, Q[iii]		
	Amphibians & Reptiles	D, Q, C	D, Q		D	D	
	Fish	D, Q, C					
	Invertebrates	D, Q				D, Q	
	Plant		D, Q, C	C		D, Q, C	Q, C[iv]
Ecosystems							D, Q, C

i. Can provide information on presence for larger, ground-dwelling birds, small mammals (>0.5 kg) and certain primate species

ii. Bats

iii. For certain primate species

iv. Vegetation classes

© ZSL/Laura Darcy *Harp trapping bats*

© ZSL/Laura Darcy *Harp trapping bats*

ANIMAL TRAPPING METHODS

Traps are mechanical devices used to capture animals. Live trapping techniques involve capturing animals for identification, measurement and tagging before being released.

Live trapping can be used to monitor most taxa, however, the type of trap needed and ease of trapping will depend on the species of interest:

- Small to medium sized mammals: Box traps
- Bats: Harp traps
- Bats and small birds: Mist nets
- Invertebrates: Dry pitfall traps, light traps (moths), sweep nets
- Reptiles and amphibians: Dry pitfall traps
- Fish: Scoop nets, gill nets, cast nets

Traps are often baited using food, pheromones or light, with the type of bait used depending on the target species (e.g. light for moths, peanut butter and oats for rodents).

Live Trapping

Live trapping allows for species inventory in the area of interest. Rarefaction curves (plot of the number of species as a function of the number of samples / effort) can be used to assess species richness across different surveyed areas or over time under standardized conditions. Non-parametric methods such as Jackknife are used to calculate species richness for a given habitat. Relative abundance can also be calculated by dividing the number of individuals captured by the total sampling effort.

Mark-recapture techniques can also be used to calculate densities of some species by laying traps within an organised grid system, marking and releasing captured animals and repeated trapping in a systematic way recording the recapture of marked animals. Specific software such as MARK or DENSITY can then be used to analyse the data generated to estimate densities, and trends in species population can be monitored over time. Live trapping can also be used to tag animals with geo-locators such as radio-collars, allowing for distribution and home range of species to be calculated.

Kill Trapping

Kill trapping is a common method for monitoring arthropods and also amphibians and reptiles; two common methods in forest ecosystems are pitfall traps and canopy spraying:

Pitfall traps are a very easy and cheap method to catch active ground-living arthropods. Pitfall traps are plastic containers sunk into a hole dug in the ground, placed so that the rim is level or slightly below ground. Traps are left and animals fall in with no means of escape. Wet pitfall traps contain water or alcohol to trap and kill the catch; alcohol will preserve the catch for longer and requires less frequent checking and emptying. Leaving traps dry allows for live trapping of animals, however these need to be checked regularly given the chance of predation between trapped animals. Like live trapping, traps should be positioned in a standardised way and monitored for a specific period.

Canopy spraying involves spraying insecticide into the canopy and positioning nets either on or within the canopy or on the ground below. A fast-acting insecticide is usually blown into the foliage in the form of a mist or fog, and animals fall into the well-placed traps. Ideally this is conducted at times of low wind to reduce spread of insecticide and chances of target animals blowing off course from the traps. This is a relatively rapid method of surveying canopy insects, however, larger insects can be missed using this technique.

Strengths	Weaknesses
Relatively low cost equipment (though dependent on trap type/ speciality)	Labour intensive and time consuming, requires regular and timely checks for animal welfare purposes
Gives quick results for presence/ absence surveys	Requires careful training in handling of live, wild animals
Freely available software for analysis of mark-recapture data for density estimates	Species identification may require expert knowledge (e.g. for invertebrates and small mammals)
Easily repeatable across spatial and temporal scales	License sometimes needed to handle certain species
	Can be used to survey multiple taxa, however different trap types would be required for different taxa
	Requires trained personnel in the use of specialist software for density estimation

Resources:

DENSITY software is available for free download:
http://www.otago.ac.nz/density/index.html

Mark software is available for free download. Includes explanation of how to analyse capture mark recapture data to estimate population density.

www.warnercnr.colostate.edu/~gwhite/mark/mark.htm

See information sources at the end of this chapter (P.53) for general method guidance regarding animal trapping methods.

POINT AND LINE TRANSECTS

Survey walks recording animal sightings (seen or heard) and signs (e.g. spoor/nests/dung) are a common monitoring method in forest systems. Survey walks are used in two ways: reconnaissance survey (rapid assessment) or more systematic survey through the use of carefully positioned transects (straight trails).

The distance of sightings and signs of both plants and animals are recorded from line transects or within/from fixed points. This is referred to as 'distance sampling' and allows for calculation of species density.

Transects are normally traversed by foot in forests. Transects should be cut (3-5 km in length) and carefully located (at least 300-500 m apart) to sample different vegetation types and levels of human disturbance in proportion to their estimated occurrence in the study area. The angular distance and bearing of each animal or group of animals plus group size, or perpendicular distance of each dung pile or group of piles or nest from the centre of the transect is measured, so that an estimate of population density (or dung/nest density) can be made. Age class and sex can also be recorded for certain species. For indirect sightings (dung or nest) the age of the sign should be approximated where possible. For population estimates, a minimum of 40 sightings per species in each habitat is necessary, and ideally over 100 sightings should be used. Therefore, transect surveys can only generate population estimates for species that are seen relatively often. In practice, sightings of all species are recorded, and different techniques are used to analyse data for each species, depending on the amount of information gathered. Dung density estimates are used as a measure of relative abundance. Population density can be obtained from dung density based on the defecation rate and dung-decay rate. However, these two variables are affected by several factors making it difficult to obtain reliable estimates. Similarly for nest sighting based estimates, decay rates need to be taken into account and these can vary according to habitat type and geographic region, making it difficult to obtain reliable estimates.

Track (footprint) surveys can give vital information on the presence of rare or hard to spot species. However, this method is less reliable than dung counts for estimates of relative abundance because track densities are affected by the type and dampness of the soil substrate, rainfall and the movement patterns of animals through the survey area.

Timed species count method is often used for surveying forest birds, observers walk slowly and quietly along a preset and mapped route recording all birds seen or heard over a fixed time period (e.g. 60 minutes). Observers also record whether the birds are more or less than a set distance (e.g. 25 m) and whether they are above or below a set height (e.g. 3 m) so that undergrowth and higher-level birds can be distinguished.

Fixed-point sampling involves recording sightings of species of concern when the observer stands at a fixed point for a fixed period of time. Fixed-width point count method can be used for surveying forest birds where counts are made along a cut transect at a fixed time interval (e.g. every 15 minutes, i.e. the observer spends eight minutes walking along the transect followed by a two-minute settling-in period and counting all the birds seen and heard for the next five minutes within a fixed radius of 25-50 m). Species detected outside the limits may be recorded to build up the species list. It can be useful to record whether birds are above or below a certain height (e.g. 3 m) so that undergrowth and higher-level birds can be distinguished.

Observation point surveys are also useful for regularly monitoring forest mammals at attractants such as natural salt licks, waterholes and wallows, heavily fruiting trees, tree-fall gaps with a flush of new foliage, forest glades, bat roosts and areas with regular signs of tracks.

Strengths	Weaknesses
Relatively low cost equipment (depending on method of transport if transect)	Time and labour intensive, often requiring large survey team
Low technical demands given basic equipment required	Elusive, inactive or small species can be easily missed
	Detection rate depends on observer experience
	Data analysis can be time-intensive, requiring trained personnel
	Species identification requires expert knowledge (signs, birds etc.)

Further information:

Buckland, S. T., Anderson, D. R., Burnham, K. P. et al. (2001). Introduction to Distance Sampling: Estimating Abundance of Biological Populations. Oxford, Oxford University Press.

Buckland et al. (2004). Advanced Distance Sampling – Estimating Abundance of Biological Populations. Oxford, Oxford University Press.

DISTANCE software is available free to download, the website also offers user support and links to distance sampling text books: http://www.ruwpa.st-and.ac.uk/distance/

CAMERA TRAPPING

The use of camera-trapping as a survey tool for medium-to-large, and sometimes also small, terrestrial mammals and birds has become increasingly common over recent years[92, 93] and is a particularly suitable technique in forest habitats with significant advantages over alternative methods based on sign recognition.

Camera trapping is particularly useful to monitor elusive, nocturnal and wide-ranging species that are otherwise hard to detect. The survey method consists of remotely stationed motion and heat-sensitive cameras that take photographs or videos of passing animals. Technological advances have made camera trapping effective in recent years, and digital cameras are the standard[94], operating 24 hours a day. At night, infrared flash photography that is not visible to animals can be used to minimise startling the animals within the camera zone.

Standardised methodologies for systematic camera-trap based monitoring are now available[95, 96]. Cameras are systematically placed at intervals on a regular grid for routine monitoring. Random or semi-random deployments may be preferred in some specific applications. Surveys are generally recommended to achieve a minimum of 1000 camera-trap days of survey effort. The size of the survey area and camera spacing is influenced by survey objectives, biology and particularly by ranging behaviour of the target species.

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One/two km camera spacing is recommended for mammal community surveys. For medium/large carnivores and herbivores 1 km spacing is recommended. For small carnivores and herbivores 500 m – 1 km spacing should be used.

Several tools exist for data management (e.g. DeskTEAM) and analysis[94, 95] and the main data compilation and processing steps are:

Preparing raw CT image data for analysis: There are several software packages available to extract the image metadata (date and time of photo taken, image name, trigger image sequence etc. plus camera type/model specific data such camera serial no, temperature, moon phase, etc.).

Image processing (species identification): classifying images to species, and individuals (for mark-recapture analysis of individual animal identifiable species)

Modelling and estimation: The compiled data can then be used to calculate:

- o Sampling effort
- o Species richness and diversity
- o Species occupancy and distribution
- o Index of relative abundance and in some circumstances density and abundance
- o Species behaviour

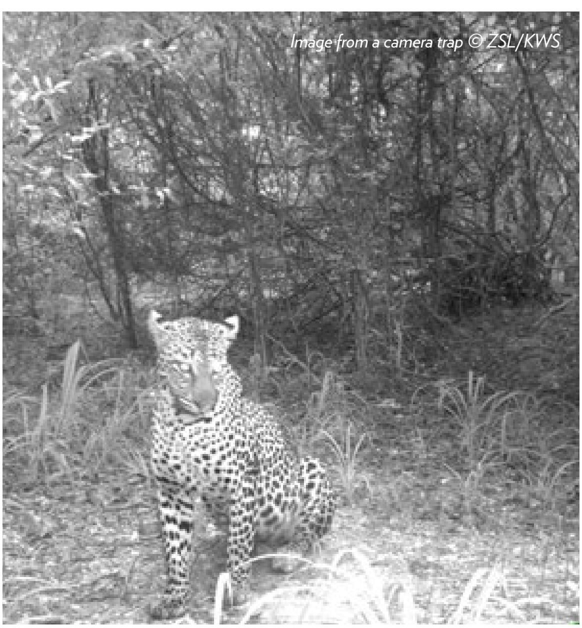
Image from a camera trap © ZSL/KWS

Strengths	Weaknesses
Cost-effective in consideration of effort vs. data generation	Initial cost of purchasing equipment (although this cost offsets over time as indicated above)
Operate day and night in a range of habitats, dependent on length of battery-life	Possible theft from the field (although can come in camouflage packaging and be secured with a lock), or damage by curious species
Detects species that are otherwise hard to monitor	Can be time consuming to identify some species and individuals, depending on quality of photograph
Non-invasive monitoring method with minimal bias	Vulnerable to false triggers, particularly in response to vegetation movement and plant growth in front of camera
Digital photographs provide permanent record, date and time stamped for easy archiving and analysis	
Allows modelling of various environment variables and anthropogenic pressures on species occupancy	
Standardisation allows comparison across survey sites and over time	

Further information:

Davey, K. Wacher, T. & Amin. R. (In Prep.) Analysis tool for camera trap survey data. Zoological society of London, United Kingdom.

O'Brien, Tim. Wildlife Picture Index: Implementation Manual Version 1.0. WCS Working Papers No. 39, June 2010.

TEAM Network. (2011). Terrestrial Vertebrate Protocol Implementation Manual, v. 3.1. Tropical Ecology, Assessment and Monitoring Network, Center for Applied Biodiversity Science, Conservation International, Arlington, VA, USA.

Tobler, M. (2011). Camera Base 1.3.

http://www.atrium-biodiversity.org/tools/camerabase/

Ahumada, J. A., Silva, C. E., Gajapersad, K., Hallam, C., Hurtado, J., Martin, E., ... & Andelman, S. J. (2011). Community structure and diversity of tropical forest mammals: data from a global camera trap network. Philosophical Transactions of the Royal Society B: Biological Sciences, 366(1578), 2703-2711.

MacKenzie, D.I., Nichols, J.D., Royle, J.A., Pollock, K.H., Bailey, L.L. and Hines, J.E. (2006) Occupancy estimation and modelling. Amsterdam, The Netherlands: Elsevier.

O'Brien, T.G., Kinnaird, M.F. and Wibisono, H.T. (2003). Crouching tigers, hidden prey: Sumatran tiger and prey populations in a tropical forest landscape. Animal Conservation 6, 131–139.

O'Connell A.F., Nichols J.D. and Karanth K. U. (2011). Camera traps in animal ecology – methods and analyses. Springer.

Rowcliffe, J. M., Carbone, C., Jansen, P. A., Kays, R., & Kranstauber, B. (2011). Quantifying the sensitivity of camera traps: an adapted distance sampling approach. Methods in Ecology and Evolution, 2(5), 464-476.

Rowcliffe, J. M., Field, J., Turvey, S. T., & Carbone, C. (2008). Estimating animal density using camera traps without the need for individual recognition. Journal of Applied Ecology, 45(4), 1228-1236.

Tobler, M. W., Carrillo Percastegui, S. E., Leite Pitman, R., Mares, R., & Powell, G. (2008). An evaluation of camera traps for inventorying large and medium sized terrestrial rainforest mammals. Animal Conservation, 11(3), 169-178.

Wearn, O. R., J. M. Rowcliffe, C. Carbone, H. Bernard, and R. M. Ewers. (2013). Assessing the status of wild felids in a highly-disturbed commercial forest reserve in Borneo and the implications for camera trap survey design. PloS one 8 (11)

BIOACOUSTIC SURVEYS

Animal vocalizations often contain species-specific information that can be recorded and analyzed by experts, or using specialized equipment, analysis and classification software using species call libraries. This approach is particularly useful in visually restrictive habitats, such as dense forests, for vocalizing species. Depending on the type of signals and taxonomic group, species identification, relative abundance estimation or behavioral assessment is possible. Recent progress in audio signal processing and pattern recognition make it possible to identify species by their vocalizations using automated methods, which is particularly useful for monitoring birds, bats, elephants and some species of amphibians in forest ecosystems. For example, the Elephant Listening Project uses acoustic monitoring to evaluate the relative abundance and health of elephants in dense forests (http://www.birds.cornell.edu/BRP/elephant/). A number of species call libraries are also being developed/expanded such as the Indicator Bats Program (iBats: http://www.ibats.org.uk/).

Strengths	Weaknesses
Can be used to identify species that might otherwise be missed using other census techniques	Data analysis and species identification often are time-intensive
Non-experts can be easily trained to collect data over a large spatial scale using standardised protocols	Expert experience necessary for data analysis, however software available to help analysis
Non-invasive monitoring technique	Technical equipment can be costly

Further information:

Bioacoustics survey website, a useful resource for research in bioacoustics methods: http://bioacoustics.myspecies.info/

Aide TM, Corrada-Bravo C, Campos-Cerqueira M, Milan C, Vega G et al. (2013) Real-time bioacoustics monitoring and automated species identification. PeerJ 1:e103 http://dx.doi.org/10.7717/peerj.103

Sueur, J., Pavoine, S., Hamerlynck, O. and Duvail, S. (2008). Rapid Acoustic Survey for Biodiversity Appraisal. PlosOne 3(12)

Bardeli, R., Wolff, D., Kurth, F., Koch, M., Tauchert, K. H. and Frommolt, K. H. (2010). Detecting bird sounds in a complex acoustic environment and application to bioacoustic monitoring. Pattern Recognition Letters 31:1524-1534.

QUADRATS AND PLOTS

Quadrats and plots are commonly used methods for surveying plants, and can also be used to survey amphibians and reptiles and larger invertebrates that can be easily observed.

Quadrats can be systematically placed (e.g. in a grid or along a transect to monitor changes in vegetation along an environmental or disturbance gradient) or randomly within the target habitat to record species within. Quadrats should be searched systematically from the outside edge to the middle. Species (or higher taxonomic groups) present, and percentage vegetation cover (e.g. using the Braun-Blanquet scale), within each quadrat are recorded. Frequency (i.e. the probability of finding a plant species in a sample area) is estimated as the proportion of quadrats in which the species has been recorded. A local measure of frequency can be obtained by dividing the quadrat into a grid, and the percentage of grid squares containing the species is calculated. Density is measured by counting the number of individuals of a given species or taxon (for large or obvious plants that are present at low density) that falls within the quadrat. A process for determining whether a plant species that fall on the edge of the quadrat is counted is usually determined prior to sampling. Species richness and diversity estimates are obtained using standard calculation methods. Plotless sampling is suitable for sparsely distributed trees and shrubs, where laying down sufficiently large quadrats and counting all the individuals in each is conducted, however this can be very time-consuming.

© Fiji National REDD+ Programme

Surveys for animals involve thoroughly searching areas/plots within suitable habitats. GPS waypoints should be taken for all areas surveyed, and all signs and direct observations of target species recorded as carried out for quadrat methods. Detection probability and occupancy estimates can be derived from multiple site visits.

Permanent or temporary plots, either in the form of quadrats or transects, are used to measure individual trees. Plots can be used to measure changes in ecosystem composition and structure. Permanent plots are samples that are marked in such a way that sampling can be repeated and records made at the same point, to be comparable over time. To monitor change in the ecosystem composition and structure, enough randomly distributed plots must be recorded on each sampling occasion to give a representative sample of the ecosystem. Temporary plots are plots that are recorded only once, to provide information on the habitat at a point in time and used for general habitat composition surveys.

For both quadrat and plot methods, every adult tree and pole present will have the species name recorded (when identification is possible) as well as the diameter at breast height (dbh) and the height.

Strengths	Weaknesses
Basic equipment required and easy to use	Sampling can be time-consuming and difficult to carry out in rough terrain or to sample large quadrats
Little expertise required, can be carried out by non-experts with training	Species identification, where required, can require expertise

Further information:

See information sources at the end of this chapter (P.53) for general method guidance regarding animal trapping methods.

REMOTE SENSING

Remote sensing is any method of observing the Earth's surface without being directly in contact with it. Information about the Earth's surface is gathered using sensors on board aircraft or satellites to measure the electromagnetic radiation (or energy) reflected, scattered or emitted by the surface[67–70].

Remote sensing is complementary to in situ 'field' measurements. The latter are traditionally collected at small spatial and temporal scales, they vary in their type and reliability, and are therefore difficult to use for assessing or predicting regional or global change[71]. Conversely, satellite remote sensing is a relatively cheap and consistent means of long-term, large-scale habitat monitoring. Satellite data can provide valuable information on both the state of biodiversity (e.g. forest distribution, forest composition, primary productivity, phenology, and level of degradation[72] and the pressures acting upon it (e.g. droughts, fires, frosts, floods and human activities such as agriculture, night-time light brightness or road density[68,73]). However, validation with 'ground truth' data collected in situ or by high resolution remote sensing data are needed to confirm remote sensing-based analyses.

Four primary variables can be observed from space: colour (considered in its wider sense to include near to mid-infrared reflected radiation), temperature, roughness and height. The sensors used to gather this information are categorised as 'passive' or 'active'. Passive sensors measure natural radiation that is emitted or reflected by the Earth. Active sensors, such as radar and LiDAR, emit a pulse of energy and measure the energy that bounces back to a detector. Vegetation structure/height and ground surface elevations are often measured using active sensors[70].

Sensors collect information at different resolutions:

- Spatial: the size of the ground element represented by an individual pixel.
- Radiometric: the number of distinct intensity levels that the sensor can distinguish, so the lowest possible radiometric resolution would be a sensor producing only two levels of intensity, i.e. black and white.
- Spectral: the width of the electromagnetic spectrum to which a band of the sensor responds, and the number of bands available; the narrower the range of wavelengths a particular bands responds to, and the larger the number of bands, the finer its spectral resolution.
- Temporal: refers to the time between successive images of the same features, usually set by the time it takes a satellite to orbit the Earth[71,74].

Strengths	Weaknesses
Provides a continuous and repetitive means to map habitat variables across large spatial scales	Storing, analysing and interpreting remotely sensed data requires significant human, technical and financial resources
Lower need for human labour than would be required to monitor at such a scale in situ, and makes monitoring in remote or inaccessible locations more feasible	'Ground truthing' of remote sensing data can be laborious and costly, and geographically calibrating these data can sometimes be very complicated
Remote sensing data are becoming more readily available at relatively low cost or, as in the case of Landsat data, the new EU Sentinel satellite series, and many coarse resolution satellites, are now free	Requires significant training and expertise
A relatively cheap and rapid method of gathering timely information across large geographic areas	
Generates multiple analytical options that can be used in combination with analytical programmes such as ArcGIS	

Further Information:

Horning et al. (2010). Remote sensing for ecology and conservation: A handbook of techniques. Techniques in Ecology and Conservation Series. Oxford University Press.

Strand, H., Höft, R., Strittholt, J., Miles, L., Horning, N., Fosnight, E., Turner, W., eds. (2007). Sourcebook on Remote Sensing and Biodiversity Indicators. Secretariat of the Convention on Biological Diversity, Montreal, Technical Series no. 32, 203 pages.

Forthcoming GOFC-GOLD & GEOBON Sourcebook:

The Global Observation of Forest Cover and Land Dynamics (GOFC-GOLD) and the Group on Earth Observations - Biodiversity Observation Network (GEO BON) have started the development of a sourcebook aimed at providing guidance on biodiversity monitoring (including proxies and pressures) using remote sensing, to inform national and sub-national policy in the context of Convention commitments. A section will identify possible synergies with REDD+ activities, facilitating a joint use with this sourcebook. This first version of the sourcebook is expected to be released mid 2016, after a peer-review process. The document will be updated annually to report on the latest scientific and policy developments.

ACTIVE REMOTE SENSING (RADAR AND LIDAR)

Active remote sensing methods can be used to assess structural attributes of ecosystems, such as forest cover (extent), type, fragmentation, biomass and degradation. Active sensors such as radar and LiDAR emit pulses of energy and detect the energy that is 'backscattered' to build a picture of the land surface structure. Such data, if coupled with ground data from plots, can be converted into forest cover and structure (such as the height and density of the canopy, and sub-canopy layers), vegetation height and biomass estimates. Both radar and LiDAR data need a high level of technical expertise, and often require commercial software to perform analyses. Processing to obtain basic georeferenced images is often hard with both LiDAR and radar data, especially aircraft-derived data, and then interpreting the results is normally more difficult than the equivalent optical data.

Active remote sensing methods require a high degree of technical, human and financial capacity. LiDAR, in particular, is associated with high costs in part due to the costs associated with their deployment on airborne platforms (radar data are, unlike LiDAR, systematically collected from space). Recent advances mean that it is now possible to deploy lidar on unmanned aerial vehicles (UAVs). Maps of canopy height and vertical forest profiles (from LiDAR or interferometric radar) can be used to map forest area, type and biomass. Radar backscatter data can be used to map landcover classes, and, especially if cross-polarised data are available, forest type and biomass.

Strengths	Weaknesses
Penetrates through forest canopy to detect features of forest structure and thus forest types	Lack of data availability, especially at longer radar wavelengths and for LiDAR (for which there are no current satellites)
Parameters such as height or biomass can be measured consistently through time, enabling detection of degradation	Obtaining and processing data is financially costly
Broadly less sensitive than passive data to seasonal changes	Expert skills required for data interpretation
Can penetrate cloud cover (radar only)	
Generates multiple analytical options that can be used in combination with analytical programmes such as ArcGIS	

Further information:

ALOS PALSAR (L-band radar) global mosaics for 2007-2010 available free at
http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/fnf_index.htm

Sentinel 1, part of the EU's Copernicus programme, will provide frequent free C-band radar data from mid-2014, with funding for a constellation of two satellites secure into the next decade
http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-1/

First paper using LiDAR specifically to map and predict breeding habitat of an animal species
http://ir.library.oregonstate.edu/xmlui/handle/1957/16737

OPTICAL REMOTE SENSING

Optical remote sensing methods can be used to measure a range of features at the ecosystem level, including forest cover (extent) and fragmentation, disturbance regime such as fire occurrence, and taxonomic diversity of the tree canopy. Additionally, the number and distribution of species can be determined for large organisms, for example, large mammals (including cetaceans) and large trees.

Images captured by multispectral sensors on board satellites are used to generate maps of forest cover and forest cover change. Such data have been used to produce long-term, global assessments of forest cover change[75]. The methods involve classifying pixels based upon the spectral reflectance characteristics of the canopy, e.g. chlorophyll absorbs blue and red light but reflects green. Pixels are classified into forest and non-forest based on the estimated density of the tree canopy. Vegetation indices such as the Normalized Difference Vegetation Index (NDVI) are routinely used to monitor the condition or 'greenness' of vegetation, which can indicate phenological cycles and disturbance regimes such as drought [71], as well as being used to directly estimate percentage canopy cover[76].

In addition, the thermal wavelengths measured by sensors such as MODIS are used to derive fire 'hotspot' maps, which can be overlaid on forest cover and cover change maps to determine disturbance regimes that exert pressures on forests. Hyperspectral sensors measure reflected radiation across a very large number of narrow discrete bands, giving a much higher spectral resolution than multispectral sensors, and can therefore detect subtle differences in tree canopy chemistry. Such sensors are used to map canopy tree diversity from local to landscape scales[77], but are not currently used in operational monitoring systems.

As the outputs from optical satellites are effectively images, initial interpretation is far easier than outputs produced by active sensors. However significant time and expertise is necessary to correctly process imagery (georeferencing, atmospheric correction, classification). Some pre-processed products are available, for example, landcover maps (e.g. Globcover) or maps of deforestation[75], which require only basic GIS training to be used. Several datasets and data products are freely available, e.g. pre-processed Landsat and MODIS data archives can be downloaded for free. The cost is therefore associated with having a sufficient level of technical expertise and resources to store and analyse (e.g. classify) the imagery. In addition, remote sensing data need to be ground-truthed using field data collected across the range of forest or habitat types. New free products are now available which reduce costs through the use of cloud storage, standardised toolkits and online training, making remote sensing methods more readily accessible (see Further Information). Hyperspectral methods require significant resources since the sensors tend to be mounted on aircraft rather than satellites. However, hyperspectral sensors can be loaded on UAVs, which are becoming increasingly affordable for local-scale forest mapping and monitoring. Hyperspectral methods could therefore become a useful forest biodiversity monitoring tool in the future.

Optical remote sensing methods generate raster layers or vectorised maps which are stored and analysed using Geographical Information Systems (GIS) software. GIS analysis produces maps and statistics, e.g. of forest cover change over time. Emerging national SIS use interfaces such as Google Earth to share such information.

Strengths	Weaknesses
Some optical datasets can be free and readily downloaded while user-friendly processing tools are also now becoming available, reducing costs further.	Optical data suffer from cloud interference, particularly in the Tropics.
Since optical sensors capture visible wavelengths, the data can be interpreted visually be trained personnel.	Forest degradation is difficult to detect since the canopy density might remain higher than the detection threshold in optical images. Very high spatial resolution data can be used for degradation monitoring.
Some sensor platforms have long archives (over 40 years in the case of Landsat), providing historical baselines.	Very high spatial resolution sensors tend to be run by commercial satellite operators, which therefore have a higher cost than the lower resolution datasets.

Further information:

Centralised information platform for joint approaches in Remote Sensing, Biodiversity and Conservation:
http://remote-sensing-biodiversity.org/

Landsat: The Landsat Program is a series of Earth-observing satellite missions jointly managed by NASA and the U.S. Geological Survey, collecting data at a 30 m resolution (15 m in the panchromatic, black-and-white, band). Data are available to download at no charge within 24 hours of reception.
http://landsat.usgs.gov/

MODIS: Two identical sensors have been collecting data at a 250 m resolution globally since 2000, operated by NASA. Data are available free of charge at many levels of post-processing at https://lpdaac.usgs.gov/products/modis_products_table

Fire Information for Resource Management System (FIRMS): Delivers global MODIS-derived hotspots and fire locations. The active fire locations represent the centre of a 1 km pixel that is flagged by the MOD14/MYD14 Fire and Thermal Anomalies Algorithm as containing one or more fires within the pixel. https://earthdata.nasa.gov/data/near-real-time-data/firms/

University of Maryland's Global Forest Change: Annual data from time-series analysis of 654,178 Landsat images in characterising forest extent and change, 2000–2012.
http://earthenginepartners.appspot.com/science-2013-global-forest

Global Forest Watch 2.0: Daily, monthly, quarterly and annual data on forest cover and change from a range of remote sensing sources. http://www.globalforestwatch.org/

Terra-I: Quarterly deforestation early warning system based on analysis of moderate spatial resolution satellite data.
http://www.terra-i.org/

Carnegie Landsat Analysis System – Lite (CLASlite): Software package designed for highly automated identification of deforestation and forest degradation from remotely sensed satellite imagery, e.g. Landsat. http://claslite.carnegiescience.edu/

GOFC-GOLD Sourcebook provides methods for forest cover and deforestation assessment:
http://www.gofcgold.wur.nl/redd/

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E EFFECTIVE
Careful survey design

Careful survey design increases the reliability of the data and any management recommendations that emerge from data analysis. Data collection and analysis can be costly to implement, often requiring specific technical expertise. The level of complexity will depend upon the biodiversity objective of the monitoring initiative and the information needs of the audience, considering once again the human, financial and technical resources available for analysis. The amount of time needed to complete this step is often underestimated by project managers, leaving them with large amounts of data that they have collected but have not analysed or used.

Detailed information and guidelines regarding how to collect and analyse primary data are available and well established, with numerous manuals, toolkits, online resources and textbooks available to guide the implementation of standardised, replicable monitoring methods to generate comparable data. Some key texts to help guide the implementation of monitoring (survey design, method explanation and analysis) include:

Hill, D. et al. 2005 Handbook of Biodiversity Methods: Survey, Design and Monitoring[77].
This handbook provides guidance on standard procedures for biodiversity monitoring, including: experimental design, sampling strategy, methods for monitoring major taxonomic groups and data analysis and evaluation.

Sutherland, W. J. 2006 Ecological Census Techniques: A Handbook[78].
This practical handbook provides information on how to plan and conduct a census, with worked examples how to analyse the results and expert description of appropriate methods for monitoring major taxonomic groups.

Gardner, T. 2010 Monitoring Forest Biodiversity: Improving Conservation through Ecologically-Responsible Management[23].
This book identifies the key elements of a robust and pragmatic framework for how monitoring and evaluation programmes can make a more meaningful contribution to the development of an ecologically sustainable system of forest use. While not a technical manual, the book addresses the challenges of scoping, designing and implementing a forest biodiversity monitoring programme including defining goals and objectives, selecting indicators, data collection and analysis and interpretation.

Newton, A., C. 2008 Forest Ecology and Conservation, a handbook of techniques[79].
This book presents a wide range of techniques and research methods relevant to forest ecology, with a focus on forest management. Specific topics covered include plant surveys, measures of forest extent and condition, forest dynamics, indicator selection and adaptive management.

Royal Geographical Society (RGS) Field Technique Manuals
The RGS has published a series of manuals providing guidance on how to conduct field surveys according to the taxonomic group of interest. Manuals are freely available online:
http://www.rgs.org/OurWork/Publications/EAC+publications/Field+Technique+Manualss.htm

Social and Biodiversity Impact Assessment (SBIA) Manual for REDD+ Projects
The SBIA Manual provides guidance for land-based carbon project personnel on how to monitor the ways in which projects impact the local biodiversity and the livelihoods of the people living in and around the project site, focusing on monitoring to meet CCB Standards. The Manual is divided into three parts, the third being a biodiversity impact assessment toolbox, and is freely available online.
http://www.climate-standards.org/resources/

Center for International Forest Research (CIFOR) Criteria and Indicators Toolbox
The toolbox series was developed during the CIFOR project on Testing Criteria and Indicators for Sustainable Forest Management. The tools are aimed to help users develop and assess Criteria and Indicators (C&I) of sustainable and equitable forest management and are available online.
http://www.cifor.org/acm/pub/toolbox.html

Monitoring matters network
The Monitoring Matters Network is an international network of researchers and practitioners working with innovative approaches to monitoring of natural resources, livelihoods and governance.
http://www.monitoringmatters.org/

R REALISTIC
Available resources

Biodiversity monitoring for REDD+ faces the challenge of resource shortage regardless of the spatial scale at which it is carried out, and thus the choice of indicators must be considered in conjunction with resources needed to measure them. To assist with this challenge, methods can be chosen according to whether they require expert skills or can be relatively easy to implement with the help of training. For example, the use of remote sensing requires technical capabilities, whereas including community members through participatory biodiversity monitoring has multiple social and environmental benefits and can be relatively easily achieved through careful training (Box 6).

Choosing which method to adopt will depend not only on the indicators chosen, but also on the ability to monitor them given real-world constraints. When choosing methods it is important to take into account the financial, technical and human resources available for monitoring, as this will further refine what to monitor for REDD+. Monitoring activities can be expensive, difficult to implement or require expertise to interpret. A guide to the level of resources required to implement each method presented in this sourcebook is provided (Table 10). However, it is important to note that this is an abstract comparison intended to provide guidance, exact resource requirements will vary by spatial scale and the ecosystem in question. Once again, stakeholder engagement at the scale of interest will aid consideration of available resources; as existing data or available tools and expertise might be identified to reduce costs.

BOX 6. PARTICIPATORY MONITORING

Participatory biodiversity monitoring is an approach to monitoring that engages the range of stakeholders in an area being conserved or managed, from the national to the grassroots level. Participatory monitoring has been summarized into six key features[80]:

1. Engages different stakeholders, performing different functions based on complementary mandates and skills, from national government to the grassroots level.
2. Recognises the rights and knowledge of local stakeholders, particularly indigenous people and local communities, in managing and monitoring forests.
3. Applies local knowledge and capitalises on the different capacities and competencies of other local stakeholders, particularly forest managers and local government officers.
4. Is not restricted to any particular forest tenure arrangement or management and governance system, including Participatory Forest Management (PFM), public or privately owned forests.
5. Is likely to be more cost-effective and sustainable than monitoring conducted solely by (non-local) technical experts, yet, at the same time still producing reliable data for use by national monitoring systems.
6. Employs a variety of data collection, management and analysis protocols including forest carbon stocks, other ecosystem service indicators, biodiversity and social impacts of REDD+ implementation.

Participatory monitoring can be used to collect data on a variety of biodiversity variables through standardised monitoring protocols[81]. Such protocols also exist for participatory carbon monitoring[82], which has been shown to be as accurate as carbon monitored by professional foresters[83,84].

Participatory biodiversity monitoring can be used to address multiple REDD+ Cancún Safeguards: not only can it be used to track the potential biodiversity impacts of REDD+ but participatory monitoring can also strengthen stakeholder engagement, helping REDD+ activities to meet the 'full and effective participation of relevant stakeholders' and 'respect for the knowledge and rights of indigenous peoples and local communities' Safeguards[85].

Participatory monitoring can also be more cost-effective and allow more frequent data collection than involving external (non-local) technical experts due to lower labour, transport, subsistence and accommodation costs[86]. In addition, research has shown that monitoring schemes at the village level are much more effective at influencing decisions which are implemented faster than those influenced by expert-led monitoring[87].

Strengths: Can enhance monitoring outcomes through the inclusion of local ecological knowledge and local capacities; address both social and environmental safeguards; enhance long-term management success through stakeholder empowerment; reduce monitoring costs while still being scientifically rigorous

Weaknesses: Can require extensive training

BOX 7. LINKING CARBON AND BIODIVERSITY MONITORING IN FIJI

In Fiji, the Forestry Department has established the Emalu REDD+ pilot site to develop appropriate protocols and procedures as part of the national REDD+ readiness phase, with partners GIZ, The University of the South Pacific, Department of Agriculture, Ministry of iTaukei (Indigenous) Affairs, iTaukei Land Trust Board and site resource owners. The Emalu REDD+ pilot project has linked their biodiversity-monitoring plan to their carbon-monitoring plan, both being implemented and managed under the Fiji NFMS. Carbon stocks and biodiversity components (such as key species) are to be measured in the same areas, with Permanent Sample Plots (PSPs) identified for the forest inventory and biomass measurements, and Permanent Monitoring Plots (PMPs) used for measuring biodiversity components. PMP measurements will be taken every four or eight years to coincide with the PSP measurements that are taken every two years. The project managers decided to undertake biodiversity monitoring at four or eight year intervals, rather than every two years as for PSP measurements, for the following reasons:

a) Given that Emalu is a conservation site, rapid changes in biodiversity are not anticipated in a two-year period to warrant a full-scale monitoring programme.

b) Small-scale participatory monitoring will be taking place in the period between the full-scale monitoring years.

c) The PSP measuring team will also undertake field observations and recording of any biodiversity impact that warrants immediate follow up.

For each year of measurement, there will be two monitoring surveys, conducted in both wet and dry seasons to capture seasonal variations. The Emalu project chose to adopt this approach to increase the efficiency of REDD+ monitoring activities and help reduce the costs, such as through the sharing of monitoring tasks by both carbon and biodiversity monitoring teams; avoiding duplication of logistical arrangements; and streamlining stakeholder involvement such as supporting agencies or participatory monitoring. For more information: http://fiji-reddplus.org/

It is likely that a trade-off will be necessary between which indicator captures the most relevant information for the REDD+ activity versus what is realistically feasible to measure. However, this need not be considered a deterrent, as monitoring at a coarse scale is preferable to no monitoring at all. Consultation with experts will enable identification of options to gather existing biodiversity information such as linking biodiversity monitoring to required forest carbon monitoring for REDD+.

Measurement, Reporting and Verification (MRV) of greenhouse gas (carbon) emission reductions and removals is a required component for the implementation of REDD+ activities, and is crucial for compensation of emission reductions and forest carbon stock enhancements. Unlike biodiversity monitoring, carbon MRV is standardised across geographic scale and guidelines for carbon MRV have been established[88,89]. MRV relies on some form of remote sensing coupled with ground-based forest biomass measurements within permanent monitoring plots to enhance the precision of the data[42].

Remote-sensing methods can deliver information on biodiversity-relevant information such as changes in land use, and habitat extent and composition. When coupled with existing knowledge on the conservation importance of the area (such as those outlined in Box 4), or existing scientific understanding of the relationship between forest composition and biodiversity groups, coarse-scale inferences about biodiversity change can be made[16,42]. At a finer scale, the collection of biodiversity data can be integrated with the collection of carbon stock data in the same set of monitoring plots/sites, conducted as part of the ground-based forest inventory[16] (e.g. Box 7). For example, such an approach can be achieved using quadrat and plot methods to measure vegetation and by placing camera traps within these plots to monitor key species. Given the relatively low resources required for these biodiversity monitoring methods, and the relative ease with which they can be incorporated within carbon monitoring plots, the cost-effectiveness of monitoring can be increased by linking carbon and biodiversity monitoring.

By considering such possibilities, it becomes possible to adopt a phased approach to biodiversity monitoring for REDD+, commencing with MRV requirements coupled with globally available habitat and biodiversity data, building upon this with primary biodiversity data at finer resolution where and when possible. Such an approach will allow for constant review and refinement of monitoring approaches that can be improved upon as further resources and opportunities become available.

Table 10. *Relative level of resources required to implement each method*
1 = *Low* **2** = *Medium* **3** = *High*

Method	Resources required		
	Human	Technical	Financial
Animal Trapping Methods	3	3	2
Point and Line Transects	2	2	2
Camera Trapping	2	2	3 *
Bioacoustic Surveys	2	2	3 *
Quadrats & Plots	3	3	2
Remote Sensing	1	3	2 **

* Initial cost of equipment plus ongoing replacement costs

** Software and high resolution satellite images depending on requirements

Human resources = personnel requirements, including labour required for both training and implementation, and skilled personnel required

Technical resources = specifications of method requirements including specialist equipment or analytical software

Financial resources = the cost of the monitoring process, including the cost of acquiring specialist skills, data handling and equipment

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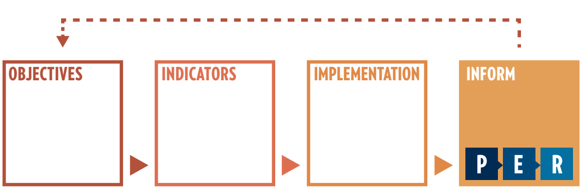
05

INFORM: SHARING INFORMATION AND ADDRESSING REDD+ OBJECTIVES

In this chapter, the need to use monitoring data to inform against the stated objectives is introduced. Procedures for informing will vary depending on the objective, however an option for standardising reporting at the project level is presented. Adopting such standardised approaches allows data to be scaled-up, creating opportunities to inform on sub-national, national and international trends in biodiversity.



P PURPOSEFUL
Informing against objectives

E EFFECTIVE
N/A

R REALISTIC
N/A

P PURPOSEFUL
Informing against objectives

Reporting and sharing of results is necessary to meet the stated objectives of the monitoring initiative. Informing may take the form of written or verbal communication, and requires careful documentation of the monitoring process and archiving of data. Information from biodiversity monitoring initiatives can be used to broaden knowledge of an ecological system, such as through peer-review publication to reach third-party audiences. Such reporting can often be complex and require expertise.

Reporting may be for internal assessment of management, or to address project standards (e.g. CCB Standards) or international commitments (e.g. CBD Aichi targets/UNFCCC Safeguards), in which case the information may feed into standardised information-sharing templates or into wider databases such as those listed in this sourcebook. For example, the Spatial Monitoring and Reporting Tool (SMART; Box 8) can assist reporting for adaptive management through the standardisation of site-level monitoring and communication of results. SMART allows for statistics to be generated for both site managers and summary reports can also be generated for government agencies. This could provide a mechanism for feeding information into REDD+ biodiversity assessments and SIS.

As with data analysis, such reporting can vary in complexity and will depend on the objective of the monitoring initiative and the information needs of the target audience.

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BOX 8. THE SMART TOOL

SMART has been developed by a consortium of global conservation organisations, in close collaboration with protected area authorities and other key stakeholders, to improve and simplify existing technologies for monitoring efforts to tackle poaching and other illegal activities.

SMART makes it possible to collect, store and evaluate data on patrol efforts (e.g. time spent on patrols, areas visited and distances covered), patrol results (e.g. snares removed, arrests made) and threat-levels. When effectively used to create and sustain information flows between ranger teams, analysts and conservation managers, the SMART approach can help to substantially improve protection of wildlife and their habitats. The SMART approach can be introduced to any conservation area that relies on patrol teams to protect wildlife and the natural ecosystems they depend upon. This approach has already demonstrated its effectiveness in improving law enforcement effort, improving morale of enforcement teams, and reducing poaching levels in multiple sites across the world. New releases of the SMART software will include an ecological monitoring plug-in and associated monitoring protocols for biodiversity state variables, enabling the SMART monitoring teams to simultaneously monitor biodiversity state and pressures. The SMART system is designed to be flexible so that it can be

SMART in Viet Nam

In Phong-Na – Ke Bang National Park in Viet Nam, the People's Committee of Quang Binh Province in collaboration with the Forest Protection Department and GIZ, are monitoring biodiversity as part of an Integrated Nature Conservation and Sustainable Management of Natural Resources project. The project is funded by the German Federal Ministry for Economic Cooperation and Development (BMZ).

One of the main challenges for protection in this National Park and its buffer zone is weak law enforcement. Therefore the biodiversity monitoring initiative contributes to improved monitoring of the pressures on biodiversity such as illegal poaching, logging and mining activities. Participatory approaches and SMART are used to monitor these illegal activities. Specifically, staff from the Forest Protection Sub-Department and the Protection Forest Management Boards carry out field patrols jointly with local community members that live both within and around the protected areas. Opportunistic data on key species is collected during patrols, focusing on economically important species (high market value species which are targeted by poachers) as they are better known and so easier to identify, and they also can be used as 'indicator species' of pressures on biodiversity

The project has experienced the following strengths and weaknesses with using the SMART tool:

Strengths	Weaknesses
Easier to learn than GIS or Database programs which take time and experience to utilise. SMART combines specific parts of both programmes, which is especially suitable for ranger-based data collection.	Learning another computer programme without being able to master existing ones (like GIS), which will need to be used for other tasks by some of the rangers.
Opportunity to monitor field operation efforts and the ability to easily adjust operations based on field and geospatial data (geo-information is not yet used for patrol planning in many of those areas).	Piloting the tablet approach (as offered by the project) would most likely be too expensive for partner organisations.
Easily adjustable (open source) by someone with a certain degree of programming skills and thus can also be made available in the local language.	
Inter-operable between different programmes and operating systems.	
With the use of tablets (as suggested by the project), time consumption and human error in data input are reduced to a minimum.	

adapted to individual situations, thus simplifying the data entry, management and reporting process whilst maintaining standardised and robust approaches, enabling effective adaptive management.

In 2014, SMART is being implemented in more than 120 conservation areas in 27 countries worldwide and fast becoming a global standard for law enforcement monitoring and management. The number of SMART sites is steadily growing and an up-to-date list of conservation areas where SMART has already been introduced is available online.

http://www.smartconservationsoftware.org/

The project has experienced the following strengths and weaknesses with using participatory monitoring:

Strengths	Weaknesses
Inclusion of local knowledge on distribution of biodiversity (certain species as well as specific illegal activities).	Data integrity (data from different sources – with different educational background - might have different quality and thus could result in problems when trying to combine all the data together).
Generation of additional data supporting both Law Enforcement and Biodiversity Monitoring.	Low capacities of local people, low awareness regarding joint-governmental forest protection responsibilities.
Opportunity to cross-reference data between villagers and Rangers.	
Ensures additional data collection, forest protection and sustainability outside of governmental structures.	
Ensures additional data collection, forest protection and sustainability outside of governmental structures.	

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06

FRAMEWORK SCENARIOS OF BIODIVERSITY MONITORING FOR REDD+

In this chapter, the framework for monitoring used throughout this sourcebook is illustrated using five REDD+ related biodiversity-monitoring initiatives, from projects across the globe. Each scenario presents a different purpose for monitoring and is used to illustrate the key considerations that influenced the design of each project monitoring initiative.

Following the sourcebook framework, these considerations are organised by both the stage in the monitoring process (e.g. objective, indicators) and the components that make it meaningful (purposeful, effective, realistic), as identified and discussed in Chapters two-five. Each key consideration is illustrated using a question to help easily identify the considerations at each stage of the monitoring process.

SOURCEBOOK FRAMEWORK

Objective	Indicators
P PURPOSEFUL	**P PURPOSEFUL**
REDD+ risks and opportunities for biodiversity: Have specific biodiversity risks and opportunities been identified in the project area? **Addressing safeguards and standards** Is the project addressing specific standards, safeguards or targets?	**Risk and opportunity assessments informed by biodiversity priorities:** Have specific biodiversity priorities been identified in the project area?
E EFFECTIVE	**E EFFECTIVE**
Monitoring for management: Is monitoring needed to support adaptive management?	**P-S-B-R indicators:** Which type of indicator is the project monitoring?
R REALISTIC	
Monitoring for management: Can the monitoring data be used to inform against other standards, safeguards or targets?	

Implementation	Informing
P PURPOSEFUL **Monitoring method depends on indicator and taxa of interest:** What methods are being used by the project to measure their indicators?	**P PURPOSEFUL** **Inform against objective(s):** How is the project informing against its stated objective(s)?
E EFFECTIVE **Careful survey design:** Is the project considering survey design?	
R REALISTIC **Maximising synergies:** Has the project taken into account available resources and how?	

FRAMEWORK SCENARIOS: THE GLOBAL OVERVIEW


#5: Piloting REDD+
in the Philippines
#4: Maximising synergies
in Berbak, Indonesia
#3: Achieving co-benefits
in Makira, Madagascar

#1
NATIONAL-SCALE MONITORING IN MEXICO

Name of Project
National biodiversity monitoring initiative for REDD+ Safeguards

Project Location
Nationwide in selected plots

Project Partners:
CONABIO (National Commission for Knowledge and Use of Biodiversity), CONANP (National Commission of Natural Protected Areas), CONAFOR (National Forestry Commission), INECC (National Institute of Ecology and Climate Change) and GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH)

Aim of Project
To build an operational standardised monitoring system at the national scale

About the Project
Mexico has suffered relatively little loss of carbon through deforestation activities, however, forest degradation is a major carbon emission activity. REDD+ is the vehicle for Mexico's government to implement a much more sophisticated and thorough strategy on biodiversity assessment and degradation mapping. To measure forest degradation, Mexico aims to monitor vegetation density as well as measures of forest structure and composition, as these are important for forest recruitment and ecosystem health. As such, Mexico focuses on biodiversity and ecological integrity by taking into account the composition, function and structure of the ecosystem.


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Monitoring details:

Objective

In the frame of the national REDD+ strategy (ENAREDD+, 2012), Mexico is employing the 2004-implemented national forest and soil inventory (INFyS – Inventario Nacional Forestal y de Suelos). The national initiative will monitor the state of biodiversity (species and habitat), ecosystem services and threats. In addition, since biodiversity is unevenly distributed, additional forest plots will be monitored in Protected Areas (PAs). Mexico plans to develop a new network of areas for regular and intensive biodiversity assessments (about 8000 plots) that will be complemented by annual land cover and land cover change mapping (RapidEye, SPOT6 and SPOT 7 satellite imagery data) using the MAD-Mex tool (Monitoring, Measuring, Verification Activity Data Mexico).

Indicators

Indicators of ecosystem integrity and degradation are currently being developed, and will be used to assess the efficiency and effectiveness of national programs such as PES to improve ecosystem health and stop biodiversity loss. Workshops and interviews with national and international biodiversity and climate experts will be held to determine these indicators taking into account financial, technical and human resource capacity.

Implementation:

Additionally, to close the existing data gap on specific biodiversity related features (function, fauna) two systems are being implemented in the form of pilots to test methods in the field:

- With the national forestry commission, CONABIO is currently implementing the Large Area Coverage – Diversity Monitoring System (SAC-MOD: Sistema de Alto Cubrimiento – Monitoreo de Diversidad), which covers 8000 1 ha plots nationwide in a five-year cycle.
- With the national commission on protected areas, CONABIO is implementing the High-Resolution Diversity Monitoring System (SAR-MOD: Sistema de Alta Resolución – Monitoreo de Diversidad), which covers 2500 plots in PAs during a one-year cycle.

Informing

Biannual monthly reports for the national REDD+ initiative will focus on REDD+ co-benefits, with databases created for the new biodiversity monitoring system as well as socio-economic information. Biodiversity data will feed into Mexico's NBSAPs as well as High Conservation Value (HCV) Assessments. This information will also feed into CBD Aichi Targets and Indicators and address UNFCCC Safeguards.

#1 - NATIONAL-SCALE MONITORING IN MEXICO

Objective

P PURPOSEFUL

Have specific biodiversity risks and opportunities been identified in the project area?

Forest degradation is a risk for Mexico's biodiversity and a major source of carbon emissions

Is the project addressing specific standards, safeguards or targets?

Project addresses both National REDD+ Initiative and International UNFCCC Safeguards

E EFFECTIVE

Is monitoring needed to support adaptive management?

Monitoring data will be used to assess the efficiency and effectiveness of national programmes such as Payments for Ecosystem Services (PES) to improve ecosystem health and stop biodiversity loss

R REALISTIC

Can the monitoring data be used to inform against other standards, safeguards or targets?

Data can also feed into:

- HCV Assessments
- NBSAP
- CBD Aichi targets

Indicators

P PURPOSEFUL

Have specific biodiversity priorities been identified in the project area?

Biodiversity priorities include measures of ecosystem integrity and health and also HCV areas

E EFFECTIVE

Which type of indicator is the project monitoring?

State indicators:

Ecosystem quantity and condition is used as an indicator of forest degradation (specifically: ecosystem composition, structure and function is measured)

Quantity (abundance and distribution) of selected bird, mammal and invertebrate species

Implementation	Informing
P PURPOSEFUL	**P PURPOSEFUL**
What methods are being used by the project to measure their indicators? ☐ Animal trapping ☑ Point and line transects ☑ Camera trapping ☑ Bioacoustic surveys ☑ Quadrats and Plots ☑ Remote sensing	**How is the project informing against its stated objective(s)?** New biodiversity and socio-economic database created Information shared via dedicated geospatial web server shared by three government institutions (CONAFOR, CONABIO, CONANP) Biannual monthly reports to the National REDD+ Initiative
E EFFECTIVE	
Is the project considering survey design? Workshops and interviews with national and international biodiversity and climate experts to determine relevant monitoring parameters	
R REALISTIC	
Has the project taken into account available resources and how? Biodiversity monitoring is linked to carbon monitoring (utilising national forest inventory monitoring plots) Utilises existing remote sensing and national forest inventory datasets Data collection costs are low considering the size of spatial and temporal coverage	

#2
PROTECTED AREA MONITORING IN BRAZIL

Name of Project
Climate-relevant in situ biodiversity monitoring in protected areas

Project Location
Protected Areas in the Amazon, the Atlantic Forest and the Cerrado

Project Partners:
Brazil Environment Ministry (MMA), Chico Mendes Institute for Biodiversity Conservation (ICMBio) and GIZ.

The project is funded by the German Federal Ministry for Environment, Nature Conservation, Building and Nuclear Safety (BMUB).

Aim of Project
1) To implement an in-situ biodiversity monitoring system within PAs in the Amazon, the Atlantic Forest and the Cerrado
2) To integrate different information systems of biodiversity and climate data
3) To offer capacity building for different actors in the context of biodiversity monitoring

About the Project
Brazil is home to 15-20% of global biodiversity and to safeguard this, the country has set up a national PA system (SNUC) that contains about 700 public and 900 private PAs. To measure the effectiveness of these PAs, as part of appropriate adaptive management, Brazil has identified the need for a national biodiversity monitoring. Brazil already has a well-established remote-sensing based system for monitoring forest cover that detects deforestation and fire (such as PRODES, DETER and DETEX) focused mainly in Amazonia, and being extended across other regions. However, locally based field monitoring within PAs is still in its early stages. Given this, Brazil is beginning to implement an in situ monitoring programme in the PAs of the Amazon, Cerrado and Atlantic Forest biomes. With the involvement of local people, the status of biodiversity in these areas and its response to anthropogenic disturbances, particularly the impact of climate change is being continually evaluated.

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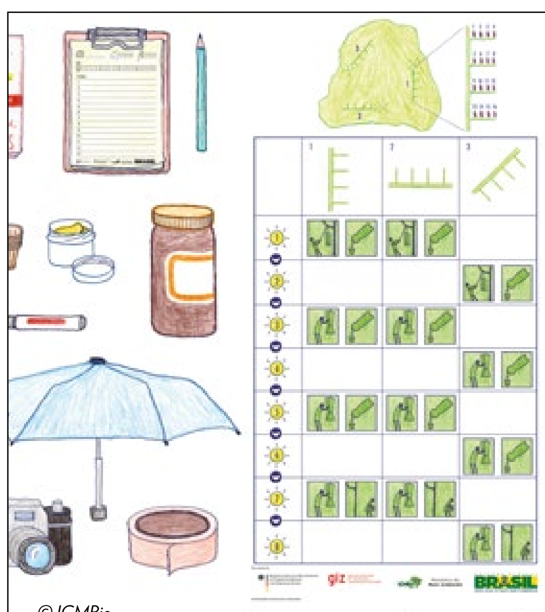

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Monitoring details:

Objective

This monitoring initiative seeks to answer two main questions:

(i) Are Brazilian PAs effective at conserving biodiversity?

(ii) What are the impacts of climate change on Brazilian biodiversity?

Indicators

To answer these questions, the project has selected a minimum set of indicator groups, along with methods for local-scale monitoring: medium and large-sized mammals, selected sets of birds, fruit feeding butterflies and arboreal plants. In a national participatory process with the support of Universities, NGOs, research institutes and specialists in Brazil, these biological indicators were selected and simplified monitoring protocols developed.

Implementation:

In the minimum protocol, mammals and birds are monitored using fixed line transects, butterflies are monitored in baited traps and plants are monitored using the same protocol as the NFI for sampling arboreal biomass in permanent plots. The combination of these four indicator groups allows analysis of the status and changes in local biodiversity, and the data can be scaled up to allow for analysis of regional and national level trends in biodiversity. The integration of data with other databases is possible given consensus at the national level regarding what and how to monitor. In the case of carbon monitoring through plant biomass, data can be integrated with datasets of the National Forest Service and, as a consequence, complement the field monitoring of biomass in PAs all over the country.

Informing

In order to guarantee standardised and high quality data handling, the project is developing an integrated information system, from the local up to the national level. Collected biodiversity data are entered into a user-friendly computer application in each PA. The information passes through an integrating server at the national level, which receives data from all of the PAs participating in the monitoring system. Finally, the information is visualized and analysed on a national biodiversity portal for simultaneous internal and public use. The data portal allows the integration of different datasets, allowing biodiversity data to be analysed in combination with information such as satellite-based fire and deforestation monitoring, or climate information from other institutions. This will allow the prediction of the impacts of climate change on biodiversity to inform policy measures on climate change and biodiversity at different spatial scales, and can also feed into international CBD Aichi Targets and Indicators. The monitoring scheme is highly applicable and replicable across spatial scales making it easily adaptable to other contexts that seek to monitor the status and change in biodiversity, such as REDD+ projects.

Further information on the project can be found within the following:

Monitoramento in situ da biodiversidade: Proposta para um Sistema Brasileiro de Monitoramento da Biodiversidade. Raul Costa Pereira, Fabio de Oliveira Roque, Pedro de Araujo Lima Constantino, José Sabino, Marcio Uehara-Prado. Brasília/DF: ICMBio, 2013.

Monitoramento da Biodiversidade: Guia de procedimentos de BORBOLETAS frugívoras. Arthur Brant Pereira, Pedro de Araujo Lima Constantino, Marcio Uehara-Prado. Brasília/DF: ICMBio, 2013.

Monitoramento da Biodiversidade: Guia de procedimentos de MAMÍFEROS E AVES. Arthur Brant Pereira e Pedro de Araujo Lima Constantino. Brasília/DF: ICMBio, 2013.

Monitoramento da Biodiversidade: Guia de procedimentos de PLANTAS. Arthur Brant Pereira e Pedro de Araujo Lima Constantino. Brasília/DF: ICMBio, 2013.

Monitoramento da Biodiversidade: GUIA DE IDENTIFICAÇÃO DE TRIBOS DE BORBOLETAS FRUGÍVORAS. Jessie Pereira dos Santos, Andre Victor Lucci Freitas, Pedro de Araujo Lima Constantino, Marcio Uehara-Prado. Brasilia/DF: ICMBio 2013

Monitoramento da biodiversidade: roteiro metodológico de aplicação.Rodrigo de Almeida Nobre... [et al]. - Brasília: ICMBio, 2014."

#2 - PROTECTED AREA MONITORING IN BRAZIL

Objective

P PURPOSEFUL

Have specific biodiversity risks and opportunities been identified in the project area?

The impact of climate change on Brazil's biodiversity is a national concern and project results will help to conserve biodiversity through enhancing management effectiveness of PAs

Is the project addressing specific standards, safeguards or targets?

Monitoring data can be used to address CBD Aichi Targets and Indicators

E EFFECTIVE

Is monitoring needed to support adaptive management?

Data will be used to evaluate the effectiveness of the protected areas using an adaptive management approach

R REALISTIC

Can the monitoring data be used to inform against other standards, safeguards or targets?

Monitoring data can be used for REDD+ purposes and thus data can also be used to address UNFCCC Safeguards

Indicators

P PURPOSEFUL

Have specific biodiversity priorities been identified in the project area?

Biodiversity indicators were selected during a national participatory process with the support of stakeholders such as Universities, NGOs, research institutes and specialists in Brazil

Indicators were chosen based on four criteria: rationale, implementation, performance and surrogacy

The selected indicators were the most cost-effective according to these criteria

E EFFECTIVE

Which type of indicator is the project monitoring?

State Indicators:

Trends in abundance and distribution of selected medium-large mammals, birds and butterflies

Trends in aboveground plant biomass

Implementation

P PURPOSEFUL

What methods are being used by the project to measure their indicators?

- [x] Animal trapping
- [x] Point and line transects
- [ ] Camera trapping
- [ ] Bioacoustic surveys
- [x] Quadrats and Plots
- [ ] Remote sensing

E EFFECTIVE

Is the project considering survey design?

Expert assistance with monitoring protocols provided by universities, NGOs, research institutes and specialists

The protocols were chosen based on four criteria: rationale, implementation, performance and surrogacy

R REALISTIC

Has the project taken into account available resources and how?

Participatory monitoring conducted with the use of standardised field guides and training to encourage systematic monitoring at local level

Utilises NFI datasets and remote sensing data in subsequent analyses

Uses simplified protocols to reduce costs

Informing

P PURPOSEFUL

How is the project informing against its stated objective(s)?

Data collection is standardised across PAs and entered into an integrated information system (data portal) to allow sub-national and national level analysis

Data portal is accessible internally and publically

The data portal allows forecasting of climate change impacts on biodiversity to inform conservation measures and policies at different spatial scales

#3
ACHIEVING CO-BENEFITS IN MAKIRA, MADAGASCAR

Name of Project
Makira Forest Protected Area Project

Project Location
Makira Protected Forest and surrounding community management areas, north-east humid forest region, Madagascar

Project Partners:
Wildlife Conservation Society and Government of Madagascar (Ministry of Water and Forests)

Aim of Project
Establishment and sustainable financing of a large protected area with benefits for climate change mitigation, exceptional biodiversity and local farming communities

About the Project
In 2001, the Government of Madagascar, in collaboration with WCS, created the 1438 sq. miles Makira Forest Protected Area. Through carbon credit sales from avoided deforestation, the Makira Forest Protected Area Project aims to finance the long-term conservation of one of Madagascar's most pristine remaining rainforest systems, home to rare and threatened biodiversity. In addition, it aims to improve community land stewardship and governance and support sustainable livelihood practices for local people.


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Monitoring details:

Objective

Monitoring is conducted to demonstrate the environmental co-benefits of the Makira project, in addition to meeting the standards of the CCB. Monitoring allows for communication of project impacts to stakeholders including government agents, local communities, potential buyers/financers and other interested parties. Engaging with local communities is achieved through participatory monitoring of the communities own resources.

Indicators

Indicators for monitoring were chosen using the HCV framework. Most of Makira supports multiple HCVs across all six HCV categories; many species contribute to its CCB status as a Gold-level site for biodiversity; and there are many Red List species present. The selected indicators capture a wide cross-section of these various values, with an emphasis on the more socially relevant ones in community-managed areas and on globally important ones in the core PA. The scientific monitoring system includes a cross-section of habitat, species and ecosystem function indicators, and seeks a balance between comprehensiveness and simplicity. Indicators are intended to be aspects of biodiversity which are evidently important in their own right and correlate with the status of a broader range of biodiversity values (e.g. other species susceptible to the same kinds of hunting).

Implementation:

Scientific literature was consulted to assist with choice of methods, and feasibility assessments conducted through field trials. Constraints on monitoring included the availability of established methods, achievability (e.g. the very rarest species may be too scarce to monitor with adequate statistical power) and overall cost/complexity. Forest cover and condition are assessed using satellite imagery combined with ranger-based monitoring of tree loss on transects and measurement of forest condition at restoration plots. Camera trapping is used to assess key species presence and absence. As an index of hunting threat, trap/snare density is calculated using distance-sampling techniques on transects.

Informing

Data analysis is conducted by WCS staff, jointly with community members, or with consultants in some cases. The results are formally reported to the CCBA; shared with local and national stakeholders (through document sharing and public events); and fed into scientific publications by WCS staff or visiting researchers. The reserve and the community-managed areas all have adaptive management planning cycles that can incorporate these data to help improve management practices.

Further information on the project can be found within the following:

WCS Madagascar 2012. The Makira Forest Protected Area Project in Madagascar. VCS Project Description version 9.0. Wildlife Conservation Society.

WCS Madagascar 2013. The Makira Forest Protected Area Project. CCB Project Design Document version 6.0. Wildlife Conservation Society."

#3 - ACHIEVING CO-BENEFITS IN MAKIRA, MADAGASCAR

Objective	Indicators
P PURPOSEFUL	**P PURPOSEFUL**
Have specific biodiversity risks and opportunities been identified in the project area? Opportunity to conserve rare and threatened biodiversity through carbon credit financing **Is the project addressing specific standards, safeguards or targets?** Monitoring to meet CCB standards	**Have specific biodiversity priorities been identified in the project area?** Scientific monitoring focuses on 18 conservation-priority localities within PA Indicators chosen to directly relate to recognised HCV values and for ease of interpretation Indicators chosen to cover multiple dimensions of biodiversity (habitat, key species, ecosystem function) Exact indicators are locally determined and tested Indicators respond quite quickly and sensitively to key threats chosen
E EFFECTIVE	**E EFFECTIVE**
Is monitoring needed to support adaptive management? State, Pressures and Benefits are monitored for scientific rigour and effective, adaptive, management of National Parks	**Which type of indicator is the project monitoring?** **State Indicators:** Extent and condition of forest ecosystem Presence/absence of key floral and faunal species such as 8 key endemic lemur species and the endemic *Fossa Cryptoprocta* ferox **Benefit indicators:** Water quality in main rivers to measure erosion and indirectly deforestation and forest fragmentation using parameters such as temperature and sediment load **Pressure indicators:** Nature, importance and frequency of pressures Level of infractions Types, abundance and locality of resource use
R REALISTIC	
Can the monitoring data be used to inform against other standards, safeguards or targets? A finite number of targets were selected to ensure costs were within acceptable limits and indicators not so numerous as to cause confusion Monitoring can also be used to address UNFCCC Safeguards and CBD targets	

Implementation

P PURPOSEFUL

What methods are being used by the project to measure their indicators?

- ☐ Animal trapping
- ☑ Point and line transects
- ☑ Camera trapping
- ☐ Bioacoustic surveys
- ☑ Quadrats and Plots
- ☑ Remote sensing

E EFFECTIVE

Is the project considering survey design?

Data collection approaches shown to be feasible during early years of project development

R REALISTIC

Has the project taken into account available resources and how?

Monitoring conducted by both scientific experts and local communities (participatory monitoring)

The two approaches are complementary and ensure both scientific rigour and increased engagement in Makira project aims through involvement in participatory monitoring

Informing

P PURPOSEFUL

How is the project informing against its stated objective(s)?

The results are formally reported to CCBA; shared with local and national stakeholders (through document sharing and public events); and fed into scientific publications by WCS staff or visiting researchers

#4
MAXIMISING SYNERGIES IN BERBAK, INDONESIA

Name of Project
Berbak REDD+ Demonstration Activity

Project Location
Berbak National Park and buffer zone forests, Jambi Province, Indonesia

Project Partners:
ZSL, Indonesian Ministry of Forestry (MoF), Government of Jambi, District Governments of Mauro Jambi and Tanjung Jabung Timur

Aim of Project
To maintain and enhance biodiversity within Berbak and buffer zone, through increasing the effectiveness of the protected area management while maintaining or enhancing the environmental, social and cultural values of this critical wetland ecosystem.

About the Project
At c. 250 000 ha, Berbak and its buffer zone are one of the largest areas of intact tropical peat swamp forest (TPSF) in Sumatra. Berbak is internationally recognised as a key Tiger Conservation Landscape and was Indonesia's first RAMSAR site due to its importance for migratory birds. The TPSF provides ecosystem services to 67 000 people living adjacent to the forest. Recognising the threats to the site's biodiversity and ecosystems services (including carbon storage), ZSL is working with the MoF, Berbak NP Authority and local stakeholders to develop an official REDD+ Demonstration Activity (DA) that supports Indonesia's biodiversity conservation, sustainable development and greenhouse gas mitigation goals.


© ZSL *Panthera tigris sumatrae*


© ZSL *Tapirus indicus*

Monitoring details:

Objective

Monitoring was originally designed to support adaptive management of Berbak National Park and its buffer zone. Berbak National Park and the neighbouring Sembilang National Park have been listed by the Indonesian government as National Targets for addressing CBD Aichi Target 15: 'By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks have been enhanced, through conservation and restoration'. With the progression of REDD+ strategies at both national and provincial levels, the monitoring system is being framed as a means to achieve cost-effective monitoring for both CBD and UNFCCC objectives.

Indicators

Indicators were chosen that were relatively cheap and simple to measure, which did not require intensive and long specialist training for data collection or analysis. In line with the CCB, Berbak's HCVs and KBA trigger species were assessed through baseline surveys. Foremost is the Sumatran tiger (*Panthera tigris sumatrae*), a critically endangered flagship species facing acute threats from human pressures. Tiger prey species such as wild pigs (*Sus scrofa*) were also chosen as indicators of tiger habitat suitability and carrying capacity, as well as the potential for human-wildlife conflict through crop-raiding. Birds across a range of trophic (food chain) levels were chosen as a broad indicator of pressures on the Berbak ecosystem and forest structural integrity, e.g. hornbills are primary forest specialists. The endangered Malayan tapir (*Tapirus indicus*) was chosen as an indicator of terrestrial species that respond to disturbance and hunting pressure. Finally, Agile gibbon (*Hylobates agilis*) was chosen as an indicator species as they are highly sensitive to disturbance such as forest fires.

Implementation:

A key monitoring constraint was the difficulty of undertaking surveys in semi-flooded terrain with limited visibility and access, particularly in the wet season. Some of the species chosen such as gibbons are best suited to monitoring in the dry season while camera trapping can be undertaken all year round, access permitting. Monitoring methods follow standard approaches for camera trapping and observation of bird vocalisations, and followed Cheyne et al 2008[91] in the triangulation of gibbon calls.

Monitoring data on Pressures are stored in SMART software (Box 8) which allow for queries to be run, to generate spatial and temporal maps of threats, graphical representation frequency of patrols, encounter rates of threats, biodiversity as well as generating alerts if threat frequency levels or species presence levels fall below certain thresholds.

Further information and guidance on methods used by the project can be found within the toolkit: D'Arcy et al. 2012. A practical toolkit for setting baselines and monitoring biodiversity. ZSL, London, UK.

Informing

The monitoring indicators chosen provide useful information about whether National Park management objectives are being met and can provide quantitative results to aid reporting for REDD+ and the CBD as well as measuring management success. As the REDD+ DA develops, reports will be submitted to provincial and national authorities established by the Indonesian REDD+ Agency and the Jambi REDD+ Pilot Province management body.

#4 - MAXIMISING SYNERGIES IN BERBAK, INDONESIA

Objective	Indicators
P PURPOSEFUL	**P PURPOSEFUL**
Have specific biodiversity risks and opportunities been identified in the project area? Opportunity to conserve rare and threatened biodiversity through effective PA management and habitat restoration **Is the project addressing specific standards, safeguards or targets?** Global and national tiger initiatives Indonesian Biodiversity Strategy and Action Plan (IBSAP) CBD Target 15 CCB Standards	**Have specific biodiversity priorities been identified in the project area?** HCV species were identified through baseline surveys TPSF are nationally-recognised ecosystems for biodiversity conservation and carbon storage
E EFFECTIVE	**E EFFECTIVE**
Is monitoring needed to support adaptive management? Pressures (P), State (S) and Responses (R) are monitored for an adaptive PA management approach. ZSL is building NP ranger capacity to use the Spatial Monitoring And Reporting Tool (SMART) for monitoring Pressures. This will be expanded to monitor State indicators	**Which type of indicator is the project monitoring?** **State Indicators:** Sumatran tiger (*Panthera tigris sumatrae*) Agile gibbon (*Hylobates agilis*) Wild pig (*Sus scrofa*) Malayan tapir (*Tapirus indicus*) **Pressure indicators:** Poaching (e.g. snares) Illegal logging (e.g. tree stumps, sawn timber) **Response indicators:** Patrolling intensity (assessed using SMART)
R REALISTIC	
Can the monitoring data be used to inform against other standards, safeguards or targets? Data can be used to address UNFCCC environmental safeguards, but Indonesian-level Safeguard indicators are still being refined , CCB standards are being referred to for guidance in the interim	

Implementation	Informing
P PURPOSEFUL	**P PURPOSEFUL**
What methods are being used by the project to measure their indicators? ☐ Animal trapping ☑ Point and line transects ☑ Camera trapping ☐ Bioacoustic surveys ☑ Quadrats and Plots ☑ Remote sensing	**How is the project informing against its stated objective(s)?** Carbon monitoring will feed into subnational REDD+ MRV systems, i.e. as part of Jambi Province's REDD+ Strategy and Action Plan. Biodiversity data collected by Berbak NP rangers already contribute to Berbak NP's reporting requirements into national reporting systems, e.g. CBD national communication
E EFFECTIVE	
Is the project considering survey design? Considers monitoring complications caused by waterlogged, flat terrain, dense vegetation and seasonal effects including flooding. The sampling method used for indicator species lends itself to the wetland environment	
R REALISTIC	
Has the project taken into account available resources and how? SMART increases patrolling efficiency by providing analytics and maps of survey effort and pressure hotspots GIS expertise available but RS expertise limited. RS support has been sourced pro bono from Universities and consultants	

#5
PILOTING REDD+ IN THE PHILIPPINES

Name of Project
Climate-relevant modernisation of forest policy and piloting of REDD+

Project Location
REDD+ pilot site in Southern Leyte & Mount Nacolod Key Biodiversity Area (KBA)

Project Partners:
Department of Environment and Natural Resources and GIZ.

The project is funded by the German Federal Ministry for Environment, Nature Conservation, Building and Nuclear Safety (BMUB).

Aim of Project
1) To secure the survival of key threatened species in the Mt. Nacolod KBA

2) To improve forest policies and create incentives for forest protection and rehabilitation

3) To reduce GHG and to conserve biodiversity, and build capacities of partner institutions in the process

4) To support the Philippine National REDD-Plus Strategy (PNRPS) to prepare the country for the full implementation of REDD+ that embodies the Project's aims

About the Project
Forests contain most of the rich terrestrial biodiversity in the Philippines and are threatened by shifting cultivation, mining, land use change and illegal logging and poaching. With significant decline in forest cover in recent years, and the resultant threat to the ecosystem services these forests provide, the Philippine government endorsed the Philippine National REDD-plus Strategy (PNRPS) in 2010 as part of its National Framework Strategy on Climate Change (NFSCC). Since 2009, the Department of Environment and Natural Resources (DENR) and GIZ have been implementing joint projects to support the implementation of the PNRPS. The "Climate-relevant Modernization of the National Forest Policy and Piloting of REDD Measures in the Philippines" (2009 – 2013) and the "National REDD-Plus System Philippines" (2012 – 2017) are both funded under the International Climate Initiative (IKI) of the of the German Federal Ministry for the Environment, Nature Conservation, Building, and Nuclear Safety (BMUB) and support the Philippines' efforts toward forest and climate protection and the creation of a national REDD+ framework based on recognised ecological and social safeguards. The current on-going National REDD+ System Project specifically targets the achievement of co-benefits of livelihood improvement and biodiversity conservation.


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Monitoring details:

Objective

To determine the impacts of REDD+ measures on biodiversity, two baseline studies were conducted. Specifically, monitoring was carried out to provide biodiversity baseline assessment, to propose appropriate biodiversity management options and to recommend the integration of results into a REDD+ MRV System. Thus, monitoring was conducted to both improve management in the area and to address REDD+ safeguards.

To reinforce mutually supporting objectives of the UNFCCC and CBD, and to streamline approaches in forest conservation in the Philippines, the links between REDD+ and the Aichi Targets were analysed. With support from UNEP-WCMC, under the IKI-funded REDD+ Policy Assessment Center Project, stakeholders from government agencies and conservation organisations explored the opportunities for synergies. This involved: improving the understanding of the spatial distribution of biodiversity and ecosystem services in the country; demonstrating how such spatial data can be used to plan REDD+ activities that contribute to biodiversity conservation; and assessing the possibility of using the results from the analyses in the identification of indicators to report on progress towards achieving the Aichi Targets[33].

Indicators

Baseline studies showed that species that are sensitive and intolerant to forest degradation as well as those tolerant to land use change (forest to non-forest) should be monitored, as they were good indicators of forest quality and habitat degradation. These indicator species included flora, birds, amphibians, reptiles and mammals.

Implementation:

Two baseline studies were conducted:

1. Forest carbon baseline study (forest resource assessment or FRA) of Leyte Island, including the assessment of vascular plants and tree species

2. Biodiversity Baseline Assessment in Mt. Nacolod and REDD pilot site, including dry and wet season faunal and habitat assessment surveys

Monitoring builds upon existing data sources and methodologies such as FRA. Forest habitat was assessed by remote sensing methods coupled with field measurements using a combination of transect and permanent plot methods. Transect methods were also used to monitor birds, reptiles and amphibians; with animal traps set adjacent to transects to monitor mammals. Household surveys were used to assess socio-economic and land use pressures on biodiversity in the area, such as use of non-timber forest products. Monitoring was carried out by the Department of Environment and Natural Resources (local field offices), local government units, forest user group associations, project partners, NGOs and the community using participatory methods.

Further information on baseline monitoring indicators and methods can be found in the reports:

Mallari, Neil Aldrin et al. 2013: Biodiversity Baseline Assessment in the REDD-plus Pilot Area on Leyte Island as an Input for the Elaboration of a MRV System for REDD-plus Including Biodiversity Co-benefits. March 2013. Manila, Philippines: GIZ.

Mallari, Neil Aldrin et al. 2013: Biodiversity Baseline Assessment in the REDD-plus Pilot and Key Biodiversity Area in Mt. Nacolod, Southern Leyte: Final technical report 2013. December 2013. Manila, Philippines: GIZ

And on the website: www.international-climate-initiative.com

Informing

Stakeholders of the Mt. Nacolod KBA used findings to develop their Conservation Management Framework (CMF), used by local government units in their land management processes, specifically in the development of forest land use plans and comprehensive land use plans. Information from monitoring also feeds into national HCVAs and KBA assessments, and is relevant for addressing REDD+ Cancún Safeguards. It is planned that the sub-national MRV will be up-scaled to the national level in the future, and will inform the process of establishing a REDD+ SIS, required under the UNFCCC. Further, data and methodologies of the project could feed into the NBSAP and inform the reporting process towards the CBD Aichi Targets.

#5 - PILOTING REDD+ IN THE PHILIPPINES

Objective	Indicators
P PURPOSEFUL	**P PURPOSEFUL**
Have specific biodiversity risks and opportunities been identified in the project area? Opportunity to conserve rare and threatened biodiversity as part of the PNRPS as part of eligible REDD+ activities (Reducing emissions from deforestation, Enhancement of forest carbon stocks, Conservation of natural forests) **Is the project addressing specific standards, safeguards or targets?** National MRV system for PNRPS UNFCCC Safeguards Assessments of HCVAs and KBAs Land management processes (Forest Land Use Planning [FLUP] and Comprehensive Land Use Planning [CLUP])	**Have specific biodiversity priorities been identified in the project area?** HCV species present Mt Nacolod is a KBA
E EFFECTIVE	**E EFFECTIVE**
Is monitoring needed to support adaptive management? The project is monitoring state, pressure and response indicators as part of an adaptive management approach	**Which type of indicator is the project monitoring?** **State Indicators:** Trend in abundance and distribution of selected bird, mammal, reptile and amphibian species Trend in structure and composition of selected ecosystems **Pressure indicators:** Trend in frequency and scope of threat (slash and burn agriculture, illegal logging, mining, infrastructure) **Response indicators:** Trend in coverage of forest protection and rehabilitation
R REALISTIC	
Can the monitoring data be used to inform against other standards, safeguards or targets? Monitoring data also feed into the Philippine NBSAP and are used to address CBD Aichi Targets	

Implementation

P PURPOSEFUL

What methods are being used by the project to measure their indicators?

- ☑ Animal trapping
- ☑ Point and line transects
- ☐ Camera trapping
- ☐ Bioacoustic surveys
- ☑ Quadrats and Plots
- ☑ Remote sensing

E EFFECTIVE

Is the project considering survey design?

Monitoring was conducted in both wet and dry seasons to account for seasonal variation

R REALISTIC

Has the project taken into account available resources and how?

FRA data available

NFMS data available

Remote Sensing data available through a joint collaboration with the University of the Philippines Diliman and GIZ, which was produced and pre-processed by the Japan Aerospace Exploration Agency (JAXA). The analysis of the dataset requires high technical expertise, from DENR, Fauna & Flora International, GIZ and the University of the Philippines.

Informing

P PURPOSEFUL

How is the project informing against its stated objective(s)?

Impact of threat assessed by combining state monitoring with pressure monitoring

The results of the biodiversity assessment are made available to the DENR and the broader public

Developed methodology will feed into national biodiversity monitoring approaches

The results of the biodiversity assessments used in the formulation of the Conservation Management Framework (CMF) by stakeholders from local governments and civil society organisations of the Mt. Nacolod area

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NOTES

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