# The Internet of Things for Protected Areas:

## The Application of Innovative Technologies to Improve Management Effectiveness

### First report of IUCN Mission to PNP


**Photo credit: Jeff Kirby, Conservation Drones**


**Edited by Simon Hodgkinson & Daniel Young**

## Foreword

The species with which we share the planet, and the ecosystems on which we depend, are being destroyed at an unprecedented rate. Conservationists today seem powerless to stem the tide. The causes include, inter alia, habitat destruction, poaching, pollution and climate change. Reversing this decline is one of the biggest challenges of our times. This is one of two reports (the other is titled The Internet of Things for PNP: A Phased Innovative Technology Investment Strategy to Improve Management Effectiveness) commissioned by the International Union for the Conservation of Nature (IUCN) showing very practically how a new technology revolution, the Internet of Things, has the potential to transform the management effectiveness of protected areas in Africa and elsewhere in conserving nature. They show how innovative technology can help us to better understand what is going on, and how they can increase the capacity to identify and address threats, as well as help local communities and visitors.

The reports were based on a mission in Benin focused on the Pendjari National Park (PNP) undertaken by a team of IUCN PAPACO (Program on African Protected Areas & Conservation), Smart Earth Network and Eridanis in collaboration with the Ministère du Cadre de Vie et du Développement Durable, and with the Centre National de Gestion des Réserves de Faune (CENAGREF), the Fondation des Savanes Ouest Africaines (FSOA), as well as local community groups, NGOs, the Zoological Society of London, and the Benin University of Science and Technology. A number of other technologists also contributed including Day Systems and Matt Taylor. Without this considerable body of support and help this important work would not have been possible.

It is now up to us all to learn from this substantive work and start to apply the lessons on the ground in a collaborative, scalable and repeatable way to help build the capacity to reverse the decline in our biodiversity.

Signed,

**Geoffroy Mauvais**
**Coordinator of the Program on African Protected Areas & Conservation (IUCN-PAPACO)**
**International Union for the Conservation of Nature**

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# 1. Introduction

This report summarises key challenges faced by Protected Areas (PAs), particularly in Africa, and the opportunities to use emerging technologies, particularly the Internet of Things (IoT), to address these challenges. It is the result of a mission commissioned by the International Union for the Conservation of Nature– Program on African Protected Areas & Conservation (IUCN-Papaco), with financial support from the French Agency for Development (AfD) and conducted in Benin's Pendjari National Park (PNP) by a team of conservationists and technologists:

- Smart Earth Network, a social enterprise that brings together conservationists and technologists to develop and deploy technological solutions to address conservation challenges;
- Eridanis, an Internet of Things consultancy that advises and supports organizations to capture the value of emerging technologies.

In conducting the mission the team from IUCN-Papaco, Smart Earth Network and Eridanis toured the park guided by staff from the Benin Park Agency. The team also met with key stakeholders:

- CENAGREF (Centre National de Gestion des Réserves de Faune), responsible for PNP management. Meetings have been organized with people involved in managing the park (Cotonou and locally in Tanguiéta), tourism, ecological monitoring and surveillance.
- Government: Didier José Tonato, Ministre du Cadre de Vie et du Développement Durable
- AVIGREF (Associations Villageoises de Gestion des Réserves de Faune) and U-AVIGREF (Union of AVIGREFs)
- Partners: FSOA (Fondation des Savanes Ouest Africaines), GIZ (Gesellschaft für Internationale Zusammenarbeit), UNDP (United Nations Program for Development)
- NGOs : Nature Tropicale, CREDI (Centre Régional de Recherche et d'Education pour un Développement Intégré), BEES (Bénin Environment and Education Society), OE Bénin (Organisation pour la promotion de l'Education)
- Research: University of Abomey-Calavi, ZSL (Zoological Society of London), Eco-Consulting, ENSAGAP (École Nationale Supérieure d'Aménagement et de Gestion des Aires Protégées).

The conservation challenges of the PNP are representative of issues faced by many other Protected Areas (PAs) in Africa and indeed in other parts of the world. This report's conclusions and recommendations are therefore of value for conservation practitioners and policy-makers not just in PNP, but in Africa and more widely, as well as for technologists seeking to understand the opportunities for their solutions in the domain of nature conservation.

The Internet of Things, or IoT, is a term commonly used for an emerging technology revolution that the World Economic Forum[1] and others believe is driving a new era of global economic growth driven by efficiency and effectiveness benefits. The IoT is enabled by low-cost powerful sensors and other devices connected to the Internet which can be powered remotely for long periods. These sensors and devices can be left in the field operating autonomously, potentially for years, automatically providing information and alerts on key management indicators which can be analysed and acted upon in real-time through manual or automated processes. A range of sectors such as smart cities, health, and energy are already attracting significant IoT investment and achieving rapid benefits.

To date, IoT investments in conservation have at best been ad-hoc and piecemeal. The aim of this report is to raise awareness of the IoT opportunity to address key biodiversity conservation challenges, and to provide a roadmap for developing successful investment programmes that can sustainably improve efficiency and effectiveness of conservation efforts. The return on many IoT investments is counted in months and so investing in them should rapidly result in savings and more effective operations. Having said this, it is important that investments are carefully selected, planned and executed if their potential is to be realised.

[1] 'Unleashing the Potential of Connected Products and Services'; World Economic Forum, in collaboration with Accenture, 2015

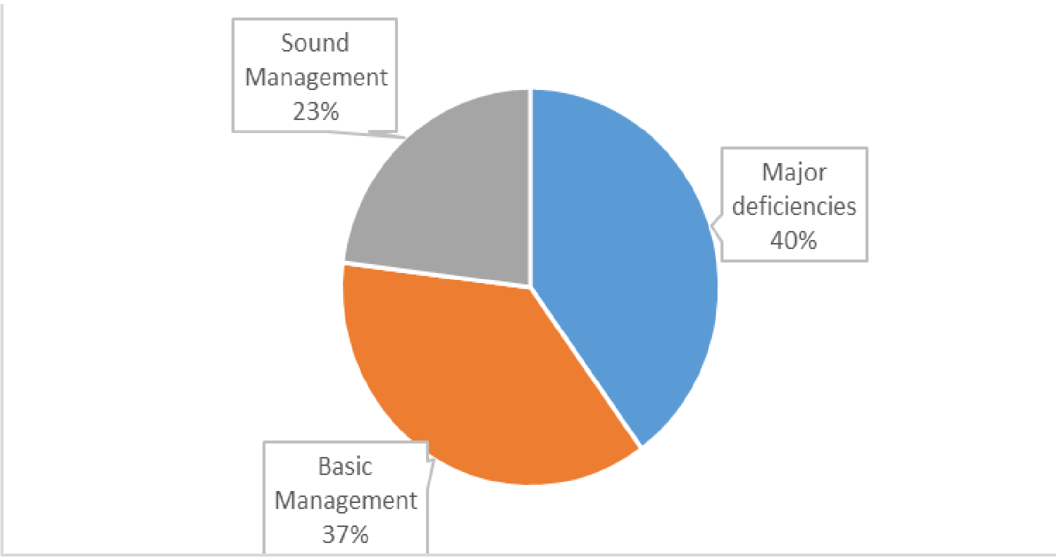
# 2. Protected Area Management Challenges

Despite the concerted efforts of governments, conservationists and citizens to conserve our nature, loss of biodiversity continues at an alarming rate. The Worldwide Fund for Nature estimates we have lost half our wildlife in the last 40 years.[2] The International Union for the Conservation of Nature believes we are losing species at 1000 times the natural rate.[3] Human population growth, habitat loss, wildlife trade, climate change, and invasive species are all factors.

The designation of Protected Areas (PAs) is seen as a way to safeguard nature and wildlife within defined boundaries. There are now over 200,000 PAs globally covering over 15 per cent of the world's land area and almost 10 per cent of the global ocean area. These PAs have boundaries and objectives enshrined in law, governance aimed at protecting nature while serving the interests of indigenous populations, and budgets and skilled human resources dedicated to these tasks. It is surely in PAs that we have the best opportunity to learn how to successfully stem the tide of biodiversity loss.

There is evidence that PAs globally are helping to reduce habitat and species loss, and alleviate deforestation while continuing to support local livelihoods.[2] Yet all is not well in PAs. A global study[3] of management effectiveness across 8,000 PAs showed that about 40% showed major deficiencies, and a further 37% were only achieving 'basic management'. The major weaknesses found were inadequate resourcing of funding, people, and equipment.

PA Management Effectiveness performance found by Leverington et al 2010




Another study[4], more focused on internal PA management processes, found that the ability of parks to evaluate the impact of their activities in managing key biodiversity values was poor. Pressey et al believes that that PA management effectiveness evaluations in the past have, in the absence of

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[2] Effectiveness of the global protected area network in representing species diversity
ASL Rodrigues, SJ Andelman, MI Bakarr, L Boitani, TM Brooks, ...
Nature 428 (6983), 640-643

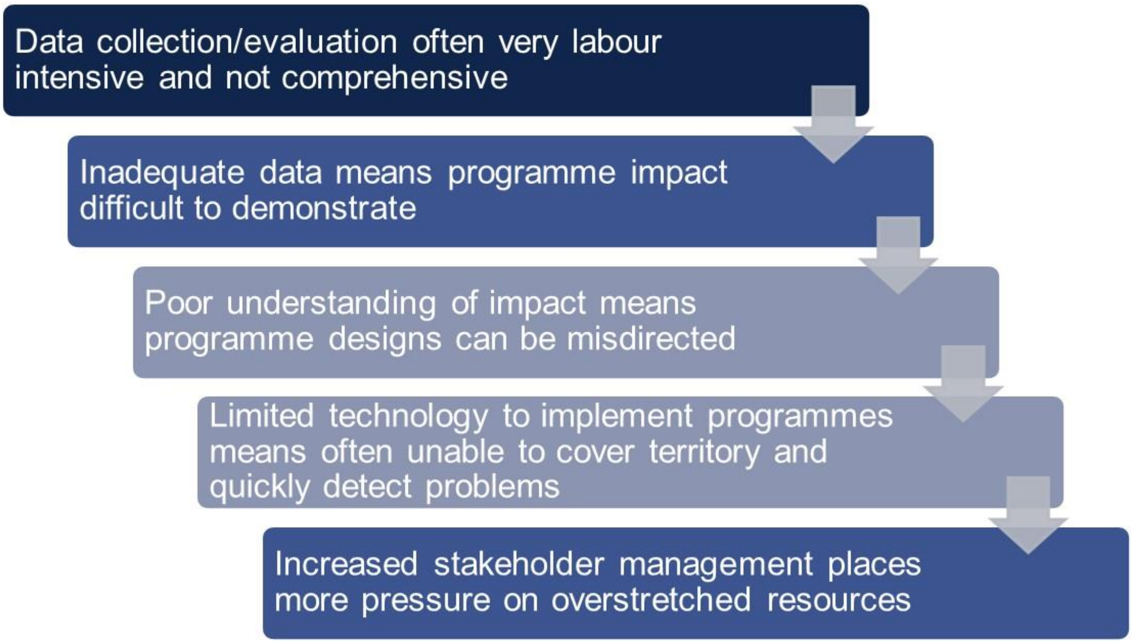
[3] A Global Analysis of PA Management Effectiveness; Fiona Leverington, Katia Lemos Costa, Helena Pavese, Allan Lisle, Marc Hockings Received: 20 December 2009 / Accepted: 2 September 2010 Springer Science+Business Media, LLC 2010

[4] Making parks make a difference: poor alignment of policy, planning and management with protected-area impact, and ways forward; Robert L. Pressey, Piero Visconti, Paul J. Ferraro,Published 12 October 2015.DOI: 10.1098/rstb.2014.0280

reliable impacts data, been based on the assumption that inputs (money invested, staff employed) are leading to desired outputs (successful conservation). They argue that there is an urgent need to move to an evidence based model in which measurement of impacts and proof of causality drives programme design and provides the confidence needed that resources are being used to good effect.

The problem however is not simply related to the design of conservation programmes, but also to delivery. The resourcing issues identified by Leverington et al limit the capacity of park management to manage complex stakeholder environments, as well as to execute programmes.

The Key Issues Impacting Protected Area Management Effectiveness



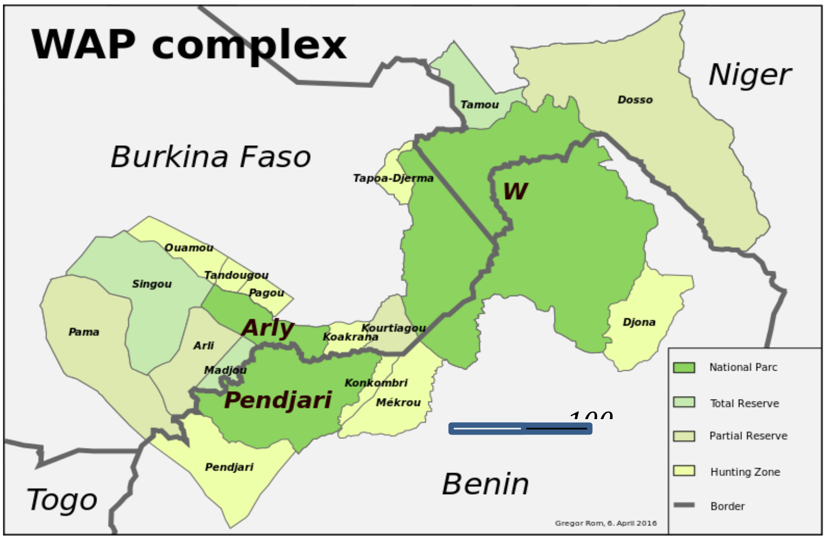

This report will show that carefully planned and targeted IoT enabled investments address a number of these core challenges faced by PAs and help to:

- better evaluate the impact of conservation programmes through automated ecological monitoring;
- more quickly identify and control threats to biodiversity;
- redirect resources from low value-added manual data collection and untargeted patrolling activity, to focus on understanding and dealing with threats in real-time;
- facilitate communications and collaboration between the various park stakeholders.

## 3. Challenges and Opportunities in PNP

The PNP, which covers an area of 2,755 $km^2$ in north western Benin, is part of the WAP complex of PAs spanning the borders of Benin, Niger, and Burkina Faso. PNP is home to some of the last West African populations of elephants, West African lions, hippopotamuses, buffalo and various antelopes. The park is also famous for its richness in bird species.

The WAP complex of Protected Areas in West Africa




Credit: Gregor Rom, Wikimedia Commons

The diagnostic of the PNP identified six major management challenges where technology could help achieve significant efficiency and effectiveness gains:

1. **Collection of ecological data to establish trends, threats and causality to support the planning of conservation programmes**: Today this work in PNP is labour intensive, expensive, and often ineffective:

    a. A manual transect study, for instance, takes several dozen people trekking across the park on foot several weeks to complete, is undertaken infrequently (every 2-3 years) and may still produce only partial data insufficient to demonstrate biodiversity threats and their causality, and programme impacts.

    b. Camera traps are also used in the park by various organisations, but these are not connected. Consequently significant manual effort is required to retrieve the SD cards and to classify the data. Moreover the data is not shared between the organisations resulting in a duplication of effort.

    c. Surveys of big mammals are undertaken using fixed wing aircraft. These are expensive and conducted too infrequently (every five to ten years) for effective conservation planning.

    Networks of sensors, camera traps and drones connected to information platforms shared between collaborators within a PA (and ultimately between PAs) could greatly increase collection speed data completeness and accuracy, and free scarce skilled resources to focus on more value-added analysis, effective programme design, law enforcement and management.

2. **Surveillance of the park to identify threats from poaching, logging, and transhumance**: Today scarce ranger resources, the sheer scale of the park and the limited road access, all

make comprehensive patrolling difficult. In the rainy season, when the animals disperse, patrolling becomes even more difficult, and parts of the park may not be reached for months. Poachers, illegal loggers and pastoral farmers are largely able to operate with impunity.

New technology has the potential to transform this challenge enabling the mapping of incidents so as to deploy resources effectively, automated patrols of the park on a daily basis, identifying threats in near real-time, providing rangers and others with high quality information on the precise location and nature of the threat, to which they are then able to develop a rapid and appropriate response.

3. **Security of staff and tourists in the park:** Today PNP, like many national parks, lacks an effective mobile communications system. A radio system installed for rangers has not functioned since its installation. Rangers use walkie-talkies, but these have limited range. Therefore, in many cases there is no way for rangers or visitors to the park to communicate with each other whilst in the PA, nor with others outside the park. This not only limits coordination and collaboration, but also creates a security issue: it is impossible to call for help in emergency situations (e.g. if a vehicle breaks down, or a person is injured).

   Systems are available today which can enable those at risk in the park to notify rescue services immediately and provide them with an accurate location, enabling a rapid and appropriate response.

4. **Threats to livestock and crops of local communities bordering the park**: Local communities can suffer from predation of livestock by carnivores or destruction of crops by large herbivores. There are solutions now which can notify communities of imminent threats and deter the animals on arrival.

5. **The experience of tourists planning and during their visit**: Tourists today increasingly use platforms like Tripadvisor to research and plan travel, and whilst on their travels, to get location based advice on activities, restaurants, etc. Tourism destinations that are absent from such platforms face a competitive disadvantage. As GPS and smartphones are ubiquitous technologies among tourists, it is now possible to provide apps which can provide location based advice, even where there is no access to the Internet. In addition citizen science type apps can provide visitors with tools to help them identify flora and fauna, and even contribute sightings of rare species by taking smartphone photos which are geo-located and time-date stamped.

6. **Communications, collaboration and governance between the stakeholder groups:** Park management is hindered by poor collaboration between key stakeholders, ranging from local community groups, to national and international NGO's, universities, and business interests. Despite sharing the same interests, parties work in isolation, duplicating efforts and even sometimes, working against each other. Lack of effective communications channels is hindering co-ordination and causing mistrust which is harming the cause of effective conservation.

   There are many powerful collaboration platforms today that facilitate effective communications between disparate stakeholder groups, enabling the sharing and discussion of ideas, information and best practices. While this technology is not a panacea to resolving ingrained cultural issues, it has the power to open channels of communications, even with those who only have access to a mobile phone. Over time, if the political will and leadership are there, these platforms can also facilitate the transformation of a culture of mistrust and lack of collaboration into one of effective networking, discussion, sharing, and collaboration.

The illustration below summarises the potential of a well-designed IoT deployment to transform the key challenges of PA management described above.

## Outline vision for the transformation of PA processes using IoT

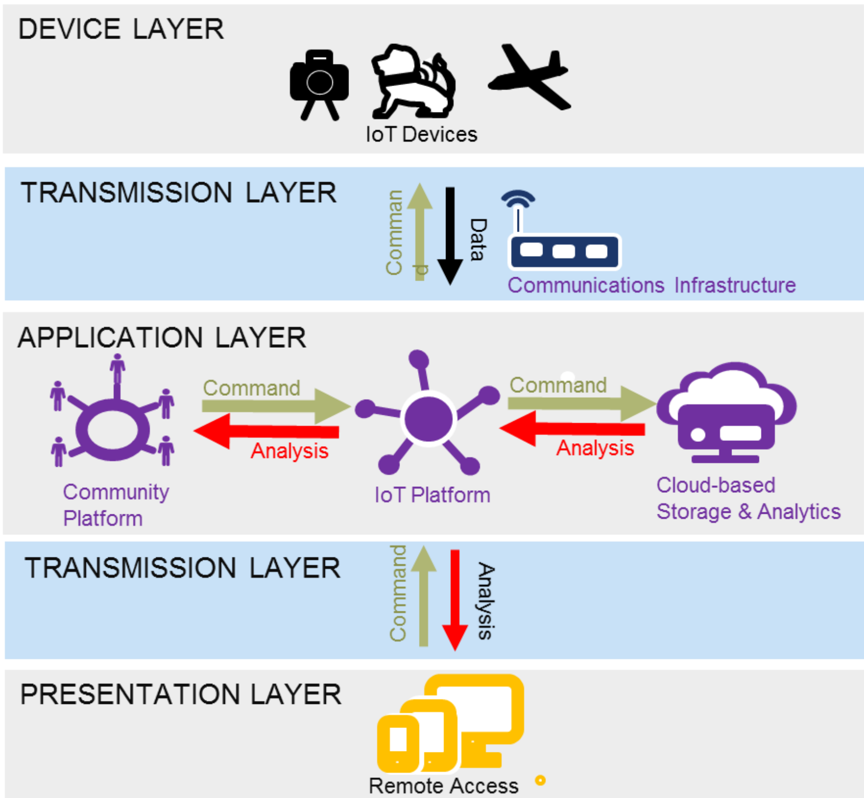
| | Typical As-Is | To-Be |
|---|---|---|
| Monitoring, Evaluation & Programme Design | Manually intensive data collection. Inadequate evidence base for timely impacts evaluation, rendering confident programme design difficult. | Drones and remote sensor network supported by more powerful analytics to improve evidence base, and facilitate effective programme design. |
| Conservation Management | Limited resources and highly manual work processes constrain patrolling and limit effectiveness of detection and response to threats. | Use of technology to automate patrolling, alerts and activate remedial actions reducing need for random patrolling, focusing effort on real-time threats. |
| Security | Both park staff and visitors lack ability to raise the alert in the case of emergency. | Security systems allow the alert to be raised with geolocation and details on the nature of the emergency. |
| Communities | Local community lose livestock and crops dues to predation and trampling. | Notifications enabled by IoT devices allow deterrent action to be taken. |
| Tourism | Poor use of tools to help potential visitors to plan their trips and to guide them when in the PA | Mobile apps with GPS enable visitors to plan in advance and to effectively navigate the PA and interpret what they see. |
| Governance | Lack of effective communications between stakeholders causes poor coordination and collaboration, duplication of work and mistrust. | Use of advanced stakeholder management and comms tools streamline coordination, promote collaboration, and engender trust |

# 4. The Internet of Things Architecture

PAs in remote regions generally have limited access to IT and other resources. It is therefore important to avoid complex grandiose approaches that will fall into disrepair and disuse, and to ensure that the proposed approach is as elegant and simple as it can be. The deployment of an IoT capability should be designed to be scalable and repeatable. It is recommended that all aspects of the deployment are piloted, and generally it will neither be possible nor wise to attempt a single deployment phase, but rather to have a number of phases which mature the capability over time. As a part of this it important to not just mature the technical capability but also to evolve a strong governance approach with clear roles and responsibilities covering management, support, maintenance and training. This is a key to the development of a sustainable capability.

Internet of Things solutions in PAs will have an architecture comprising five layers. Physical devices must be placed remotely in the field (sensors, cameras, drones, etc.), they must use a transmission layer which captures the data from the devices and transmits it to an application layer which manages the data, stores and processes it. The results must be presented to users via a range of devices (phones, smartphones, tablets, etc.). These layers are illustrated and described below.

Key Components of Internet of Things Architecture for Protected Areas




## a) Device Layer

In PAs this may include sensors, cameras, trackers, drones, and any other hardware that captures data from, or interacts with, the environment. They will need to be robust to the elements they will encounter, able to operate independently, and be powered generally by battery or solar power, potentially for years. Devices with these capabilities are becoming more common, more powerful, and less expensive every year.

There is considerable interest in the use of Unmanned Aerial Vehicles (UAVs or 'drones') in PAs as potentially they can support a range of PA management activities from ecological monitoring to park patrolling. They can allow the systematic gathering of photographic, video, infrared and multispectral data from large geographical areas without the need for skilled pilots. Consisting of fixed wing or rotor design, the drones can be manually controlled or fly by autopilot according to predefined routes at a constant altitude, allowing the systematic and repeatable collection of high quality data. Currently most fixed wing drones need to be manually launched and retrieved. The management and maintenance of a drone capability and their related PA applications is complex, however, and should not be undertaken without the support of skilled resources for the operation and maintenance of the drones, and for the configuration and use of the devices (e.g. on board cameras) and software. The drones themselves and the services needed to support them are comparatively expensive, and the business case for deploying drones needs to be considered carefully. Nonetheless the benefits across a range of applications may make the investment worthwhile, so long as the governance issues are manageable. Drones can not only greatly reduce manual effort, but also potentially enable more effective operations than is otherwise possible.

### b) Transmission Layer

The deployment of IoT solutions in a PA will in the absence of adequate public network, probably need to be enabled by the installation of a private communications network of some kind. This field of technology is moving fast and there are both established and new options available including:

- **VHF radio** (broadcast and 2-way) is well established and the equipment is relatively inexpensive, though to cover a large PA like PNP, masts require solar power. The radios can be fixed, vehicle based, or hand-held, and can support voice, text and GPS. VHF can also be used for low speed (9.6kb) data transfer.
- **LTE/4G**: Private mobile networks now enable a self-contained, privately owned and managed mobile network based on standard 4G LTE protocols, providing the ability to provide high speed DATA services for IoT devices and mobile handsets. These networks require masts also and solar power, but can reach significant distances (30km diameter or more depending on the terrain). They can be connected to the public network.
- **Satellite**: There are satellite network operators (such as Iridium and Globalstar) who provide internet connectivity and voice communications. These networks may be useful for point solutions such as security systems, but are generally too expensive for day-to-day use, or data heavy applications.
- **LoRaWan/Sigfox:** New long range radio systems designed for the IoT suitable for low power and low bandwidth operations and supporting encrypted data transfer over a wide area.
- **APRS:** An APRS radio network can comfortably cope with 30km per node. Range only limited by the density of the installed APRS network, with ranges of tens of kilometres per node possible. Good for voice communications.
- **Google/Facebook:** New solutions are being developed by Google and Facebook to provide affordable internet connectivity using high altitude solar powered drones and satellites. Technically these should have the advantage of avoiding the need for masts and the consequential security vulnerability.

A PA seeking to deploy IoT devices and install a communications system will need to give careful consideration to the phased deployment of a capability which provides a sustainable and scalable capability.

**Case study: Facebook bringing networks to rural areas**

Facebook's OpenCellular is an open source and cost-effective, software-defined wireless access platform aimed to improve connectivity in remote areas of the world.

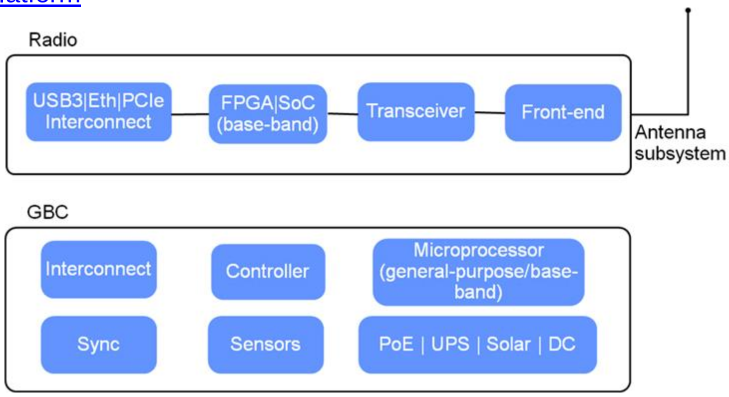
The platform is designed to improve connectivity since it can be deployed to support a range of communication options, from a network in a box to an access point supporting everything from 2G to LTE.

Facebook are working with Telecom Infra Project (TIP) members to build an active open source community around cellular access technology development and to select trial locations for further validation of technical, functional, and operational aspects of the platform.

The platform consists of two subsystems:

1. General-baseband computing (GBC)
2. Radio with integrated front-end

https://code.facebook.com/posts/1754757044806180/introducing-opencellular-an-open-source-wireless-access-platform




## c) Application Layer: Internet of Things Platform

Most sensor applications require a solid back-end to communicate with, which may be called an IoT Platform. Mostly used by PA technical teams or suppliers, such a platform enables the management of all the devices in the field. It provides an interface to connect devices securely and easily to a database, and allows the secure storage of the data collected by the devices. The IoT platform controls the behaviour for each device and provides automatic processing of the data collected for reporting. The IoT Platform is the key enabler for a sustainable use and aggregation of connected devices. There are now cloud based providers of IoT platforms, and this service can be purchased on a 'pay as you use' basis relatively inexpensively. Skilled resources are needed to configure the platform to the requirements of the devices in the field.

## d) Application Layer: Data Storage and Analytics

This platform receives and stores the data from the devices in the field and is able to inspect, clean, transform, and model with the goal of discovering useful information, suggesting conclusions, and supporting decision-making. There are now cloud based providers of these services, and they can be purchased on a pay as you use basis relatively inexpensively. Again skilled resources are required to configure and use these capabilities.

**Case study: Big Data Analytics Platform**

Hewlett Packard (HP) recently teamed up with Conservation International to analyse camera trap and sensor data using their dedicated analytics platform, HP Vertica. This sped up the processing speed by 90%, provided an earlier warning system to detect when populations are declining and freed up the scientists' time for other activities.


## e) Application Layer: Community Platform

There are many powerful collaboration platforms today that facilitate effective communications between disparate stakeholder groups, enabling the sharing and discussion of ideas, information and best practices. These are described further in section 5.

Application layer components can be provided via the 'Cloud'. This Internet-based computing enables access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications and services), which can be rapidly provisioned and released with minimal management effort. Cloud computing and storage solutions can provide a PA, for instance, with an IoT platform and storage and analytics capabilities in third party data centres, in a manner which avoids up front infrastructure costs (they are often based on a 'pay as you go' model), and reduces maintenance and servicing issues (these can be handled remotely). A key benefit of cloud computing for PA IoT investment is that once configured for one PA, the same resource can be used to deploy and use IoT devices in other areas, and that the integration and deployment costs second time around are much reduced. Cloud services require good internet connectivity so where such connectivity is not present, they are not a good option.

## f) Presentation Layer

There will be a large number of potential users of the information provided by PA IoT devices. These will include park managers and rangers, ecologists working for the park agency, NGOs, or universities, and members of the local communities who may need to be alerted to issues (eg. roaming elephant that could destroy their crop). These users will use different tools to access the information, ranging from simple 2G phones which can receive SMS, to smartphones, tablets and computers. Consideration needs to be given to the attractive and effective presentation of the information needed for each of these device types.

## g) Security

Security, to prevent hacking that destroy systems or extract sensitive information (e.g. on locations of poached species) is a serious issue. The gateways that connect IoT devices to networks need to be secured as well as the devices themselves. Security is also required for the data collected. Advances are being made in all of these fields in relation particularly to critical non-conservation applications of the IoT.

# 5. Applications for Innovative Technologies

Below is a list of applications of technologies for addressing the key terrestrial PA challenges outlined in section 3. For each concept there is a high-level description of the challenge addressed and the potential solution, and a ranking based upon the potential conservation and other benefits, technology readiness, ease of implementation and cost-effectiveness. Please note that most of the solutions mentioned below require a communications network to be in place to support connectivity. The judgments on cost-effectiveness assume that such a network is already in place, and so do not count the costs of the communications network as a part of the business case.

The table below describes the rating approach used.

| **Criteria** | **Rating** | | |
|---|---|---|---|
| | ★☆☆☆☆ | ★★★☆☆ | ★★★★★ |
| **Conservation Benefits** | Limited benefit. | Moderate potential benefit. | Significant potential benefit. |
| **Other Benefits** | Limited benefit. | Moderate potential benefit. | Significant potential benefit. |
| **Technology Readiness** | Technology does not exist/needs to be developed. | Some components are readily available, others may be in development/piloting phases. | Technology exists and is easily acquirable. |
| **Ease of Deployment** | There are significant barriers to deployment. | Is feasible to deploy, but there are hurdles to overcome. | Can be deployed immediately with limited effort. |
| **Cost Effectiveness** | The costs outweigh the benefit gained. Assumes necessary comms network is in place. | Costs and benefits are balanced. Assumes necessary comms network is in place. | Benefits greatly outweigh the costs of deployment. Assumes necessary comms network is in place. |

## a) Automated collection of ecological data

### Connected Camera Traps and Security Cameras

Camera traps are valuable tools to detect species and help create species checklists, estimate relative abundance and density, monitor populations and analyse habitat associations.[5] However up until recently the data collection, processing and reporting process was a manual, time-consuming and costly task that requires frequent travelling to camera trap locations. This limits how many camera traps can be deployed and their effectiveness as a conservation tool.

It is now commonplace where there is connectivity to deploy a network of connected camera traps that can automatically upload their images centrally for processing. This reduces the requirement for travelling to the camera trap locations and allows the cameras to be reconfigured remotely as required. Centrally, trained image recognition algorithms are in development which can support the image processing by discarding empty images and identifying the presence of the specific wildlife species or individuals. The processed data can be integrated with a shared Geographic Information System (GIS) for analysis by researchers/conservationists, and automatically reported via a dashboard for PA managers. This solution would be a scalable and cost effective platform for deploying camera traps across a PA to improve research and conservation.

[5] “Which camera trap type and how many do I need?” A review of camera features and study designs for a range of wildlife research applications;; Rovero F., Zimmermann F., Berzi D. & Meek P., 2013.. *Hystrix Ital. J. Mammalogy*, **24**(2), 148-156

| | | |
|---|---|---|
| **Conservation Benefits** | ★★★★☆ | Data from ecological monitoring camera traps can become more rapidly and more widely available, enabling more informed conservation decisions. |
| **Other benefits** | ★★★☆☆ | Greatly reduces the effort related to ecological monitoring using non-connected camera traps. |
| **Technology Readiness** | ★★★★☆ | Connected camera traps are commercially available. The image recognition software is in development but has already been successfully used. Expect this software to develop quickly in the coming period. |
| **Ease of Deployment** | ★★★★☆ | Connected cameras can be deployed easily and quickly if the connectivity is available. |
| **Cost Effectiveness** | ★★★☆☆ | If a communications network is in place allowing upload of the photos/videos, the business case for deploying camera traps over existing non connected camera traps is strong. The installation costs are similar, but the running costs are much lower. |

**Case study: Instant Wild**

Network connected camera traps have several advantages over offline camera traps. They are currently used in ZSL's Instant Wild project:

http://www.edgeofexistence.org/instantwild/


## Acoustic Sensor Networks

Identifying the presence of specific species and illegal activity within PAs is challenging due to the large size of the areas and difficult terrain. Established approaches such as camera traps are limited to observing small areas, and manual surveillance is labour-intensive and infrequent.

A network of acoustic sensors can help overcome these limitations. The sensors collect audio recordings which are constantly processed to distinguish the individual audio sources and provide matches against databases of known audio signatures. In this way the calls and locations of wildlife, vehicles, gunshots and chainsaws are automatically identified or flagged. This data would be automatically entered to the GIS, reported in management dashboards, and signals of illegal activity (i.e. gunshots & chainsaws) would trigger alerts (by SMS for instance) that would facilitate enforcement.

| | | |
|---|---|---|
| **Conservation Benefits** | ★★★☆☆ | Automated identification of species supporting ecological monitoring and alerts of potential illegal activity enabling corrective action to be taken. |
| **Other benefits** | ★★★☆☆ | Reduced emphasis on proactive patrolling, more emphasis on reactions to threat alerts. |
| **Technology Readiness** | ★★★☆☆ | Several hardware providers. The software needs to be configured to local acoustic requirements and to provide automated alerts and reporting. |
| **Ease of Deployment** | ★★★☆☆ | There is effort in installing the sensors and configuring the software Once up and running there is minimum effort to maintain. |
| **Cost Effectiveness** | ★★★★☆ | The sensors are inexpensive, so cost effectiveness is high assuming that the sensors replace current manual patrolling and ecological monitoring, |

**Case study: Response of elephants to oil exploration (Wrege et al 2010)**

Acoustic sensor networks set up in Gabon detected elephant behavioural response to nearby noise from oil exploration.

http://onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.2010.01559.x/full

## Bio-tracking

In order to establish effective conservation strategies, knowledge of the movements and habitat usage of species is required. Large, free-ranging species can be difficult to monitor due to wide ranges and relatively low density populations. Traditional VHF devices attached to the animal produce a radio signal allowing the individual to be tracked using a directional antenna.  Many hours have to be spent in the field following focal animals and in doing so there is also a risk of human-led disturbance impacting on the animals' natural behaviour.

Scientists can track fine-scale movements of individual animals remotely using GPS technology. Devices can store GPS locations at specific intervals before later retrieval or can relay data using embedded cellular, radio or satellite modem. GIS software can be used to plot the tracks against a map or chart for further analysis. GPS devices for large animals are commonly encased in durable collars that are fitted to sedated animals. Devices can also carry sensors which measure the health of the animal.

| | | |
|---|---|---|
| **Conservation Benefits** | ★★★★☆ | Provides vital movement and habitat use data to inform policy decisions. Also possible to track health and alert conservationists to threats. |
| **Other benefits** | ★★★☆☆ | Reduces field effort relative to previous generation devices. |
| **Technology Readiness** | ★★★★★ | A range of devices are currently available and are widely used on a range of species. |
| **Ease of Deployment** | ★★★★☆ | The devices must be initially attached to an individual animal, which requires it to be tracked and sedated. Once attached, GPS-satellite devices relay data automatically. |
| **Cost Effectiveness** | ★★★★☆ | Devices which relay data via satellite are more expensive than traditional radio collars, but provide data with unprecedented levels of precision. Priced at $1000 and above. |

**Case study: Lion tracking in Hwange National Park**

The Hwange Lion Research Project, which has been running for 15 years, is aimed at understanding, managing and conserving the lion population of Zimbabwe's Hwange National Park through the collection of valuable long-term monitoring data of population demographics, ecology and behaviour. The project is supported by researchers from Oxford University's Wildlife Conservation Research Unit (WILDCRU) who have fitted GPS-radio and GPS-satellite collars to lions. Cecil, the famous lion killed in Zimbabwe last year, wore a GPS-radio tracking collar and was being monitored by the project.

http://www.satibtrust.com/en/projects/hwange-lion-research/
http://www.ox.ac.uk/news/science-blog/life-lions-revisited

## Habitat Monitoring Software

Visibility of habitat changes can also be improved by using advanced GIS change detection and prediction algorithms, the increased quality and types of remote sensing data available, and the availability of computational capacity through cloud computing. This GIS software can utilise high-resolution data collected by periodic drone surveys, together with the remote sensing data from satellites such at Landsat, process it in the cloud to produce summaries and forecasts for the changes in PA habitats. This automation reduces the on-going requirement for specialised analysts to prepare updates, and provides the insights on changes to allow informed conservation and management decisions.

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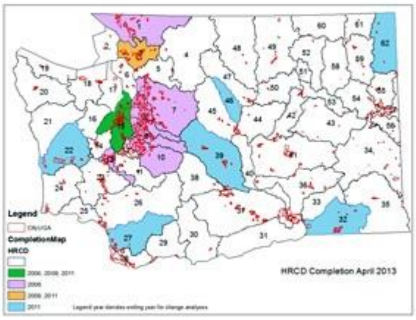
| **Conservation Benefits** | ★★★☆☆ | Regular visibility of habitat changes and trends allow better informed conservation and management decisions. |
| **Other benefits** | ★★★☆☆ | Reduces analytical effort required to identify habitat changes. |
| **Technology Readiness** | ★★★★★ | The required software and satellite data is commercially available. |
| **Ease of Deployment** | ★★★☆☆ | The automated workflow and the PA specific analysis needs to be configured by GIS specialist in the set-up phase. |
| **Cost Effectiveness** | ★★★☆☆ | The software can greatly reduce manual effort. Cost effectiveness is dependent on the cost of satellite or drone data. |

**Case study: High Resolution Aerial Imagery Change Detection**

HRCD was used to track major vegetation changes in 4 of 19 water resource inventory areas (WRIAs) in the Puget Sound Basin.

http://wdfw.wa.gov/conservation/research/projects/aerial_imagery/index.html




## Drones for Monitoring Wildlife Populations

It is now possible to monitor trends in wildlife populations using manually controlled or automated drones to conduct surveys on a more frequent basis (i.e. monthly, quarterly) than is possible through current methods such as manual transect surveys. The photos and videos gathered by the drones are processed manually, or assisted by automated image processing software, to determine the populations of key wildlife. This data can then be analysed for trends and presented in forms useful for conservation planning. By increasing the frequency, standardisation and reproducibility of the surveys, prompt and effective decisions can be taken to improve conservation.

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| **Conservation Benefits** | ★★★★☆ | Improves timeliness and accuracy of data. Allows conservation decisions to be taken promptly, and programme impacts to be better assessed. |
| **Other Benefits** | ★★★☆☆ | Can greatly reduce the manual effort taken both to collect and analyse data. |

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| **Technology Readiness** | ★★★☆☆ | There are many drone hardware providers. The automated image recognition software is still in development, though has been demonstrated. |
| **Ease of Deployment** | ★☆☆☆☆ | Drones are difficult to deploy in PAs. Skilled resources and training are required to conduct drone launches and retrievals. Drone servicing in remote areas may be a challenge. |
| **Cost Effectiveness** | ★★★☆☆ | Cost effectiveness depends on the range of drone applications. The benefits of this application would be expected to outweigh the marginal costs of deployment if the drone capability is already in place. |

**Case study: Counting elephants** (Vermeulen et al 2013)

The use of a UAS (Unmanned Aircraft System) was tested to survey large mammals in the Nazinga Game Ranch in the south of Burkina Faso.

http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0054700

## Drones for Monitoring Habitat Changes

Traditional methods for monitoring changes in habitats include visual surveys and satellite data analyses. Similar to wildlife population monitoring, visual surveys are labour intensive, and tend to be conducted infrequently. Satellite vegetation mapping is readily available but may lack the granularity required.

Automated drones carrying traditional and multispectral cameras can capture high-resolution images that can then be consolidated into geo-referenced image maps. Pattern recognition and change detection software can then be used to automatically highlight changes in habitats and land usage over time. This visibility of habitat change can enable PA management to better plan, execute and assess habitat and species conservation programmes.

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| **Conservation Benefits** | ★★★★☆ | Visibility of habitat changes enables a better understanding of threats to species and the design of more effective conservation programmes. |
| **Other benefits** | ★★☆☆ | Can reduce the manual effort required for collection and analysis of data. |
| **Technology Readiness** | ★★★★☆ | There are many drone hardware providers, The required image management software is readily available. |

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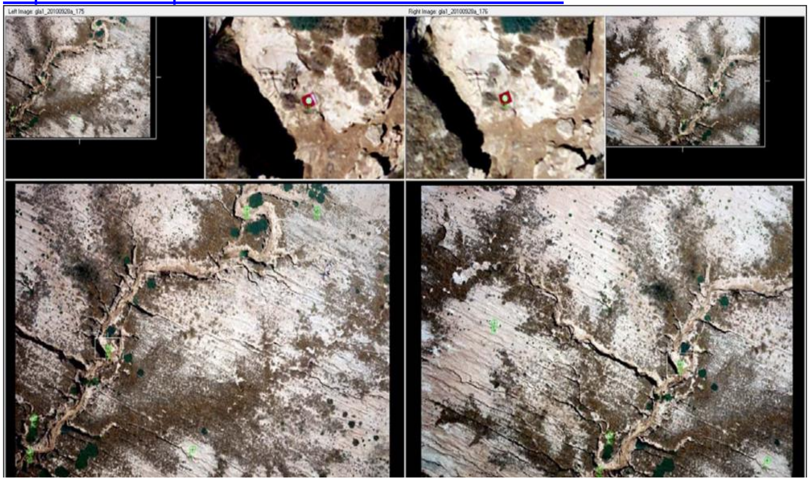
| **Ease of Deployment** | ★☆☆☆☆ | Drone capabilities are difficult to deploy in PAs. Skilled resources required to conduct drone launches and retrievals. Drone servicing in remote areas may be a challenge. |
| **Cost Effectiveness** | ★★☆☆☆ | Cost effectiveness depends on the range of drone applications. The benefits of this application would be expected to outweigh the marginal costs of deployment if the drone capability is already in place. |

**Case study: Detecting soil erosion in Morocco (d'Oleire-Oltmanns et al 2012)**

An environmental remote sensing application was used on a drone for quantifying gully and badland erosion in 2D and 3D as well as for the analysis of the surrounding areas and landscape development for larger extents.

http://www.mdpi.com/2072-4292/4/11/3390/htm



## Drones for Invasive Species Monitoring

The challenge is to identify clearly where non-native plant species are becoming an issue so that action can be taken. Traditionally this identification requires manual visual identification by specialists who are rarely available or analysis of multispectral satellite data which is only available at lower resolutions.

Multispectral cameras capture the reflectance of plants across different wavelengths, which allows different plant species to be differentiated. Capturing multispectral images as part of automated drone surveys allows changes in the type and distribution of flora to be identified on the geo-referenced image maps either manually or using change detection software. Efforts taken to eradicate invasive plant species can then be assessed using subsequent surveys.

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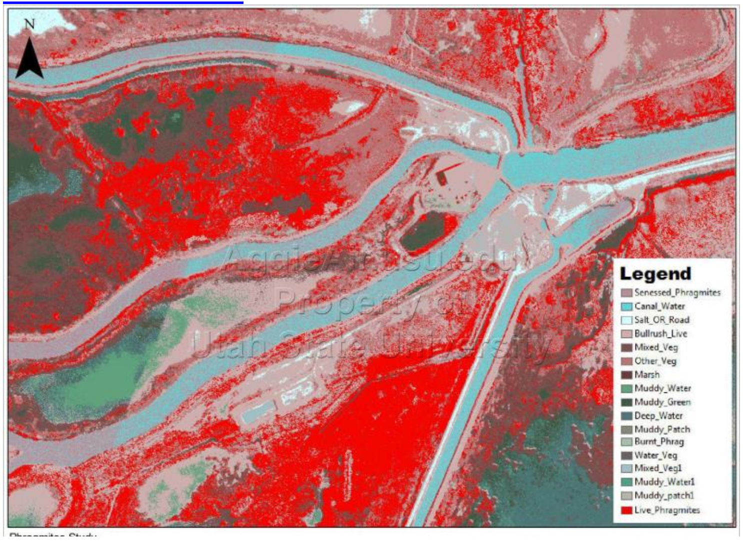
| **Conservation Benefits** | ★★★☆☆ | Invasive species can be readily identified, allowing decisions to be taken promptly. |
| **Other benefits** | ★★☆☆☆ | Reduces the need for manual surveys. |
| **Technology Readiness** | ★★★★☆ | There are many drone hardware providers, Combined traditional-multispectral cameras are available as is the analytical software. |
| **Ease of Deployment** | ★☆☆☆☆ | Drones are difficult to deploy in PAs. Skilled resources required to conduct drone launches and retrievals. Drone servicing in remote areas may be a challenge. |
| **Cost Effectiveness** | ★★☆☆ | Cost-effectiveness must be seen in context of multiple applications for the drones. |

**Case study: AggieAir™ (UAV) used to track spread of invasive *Phragmites australis***

The combination of high resolution multi-spectral images (in space and time) and the classification algorithm based on advances in statistical learning theory produce quantitative land cover descriptions that identify *Phragmites* locations with an accuracy of 95 percent.

https://www.infona.pl/resource/bwmeta1.element.ieee-art-000006049252




## Automated Species Identification Software

Identification of observed species is commonly restricted to a few skilled individuals. This is generally an important resource limitation on the amount of imagery that can be classified. Image recognition software can be applied to images and videos of wildlife to automate the identification of specific species. The algorithms are automatically trained and their accuracy improved as the quantity of data increases. The key advantages of automation are real-time identification of key species, a reduction in the manual effort to process the increasing quantity of imagery available, and reuse of the algorithm in different applications and locations once trained.

Potential applications include:

- Automated counting of species from drone footage, camera traps & rangers photographs.
- Automated identification of individual animals from their natural markings.
- Automated identification of species from images of their footprints.

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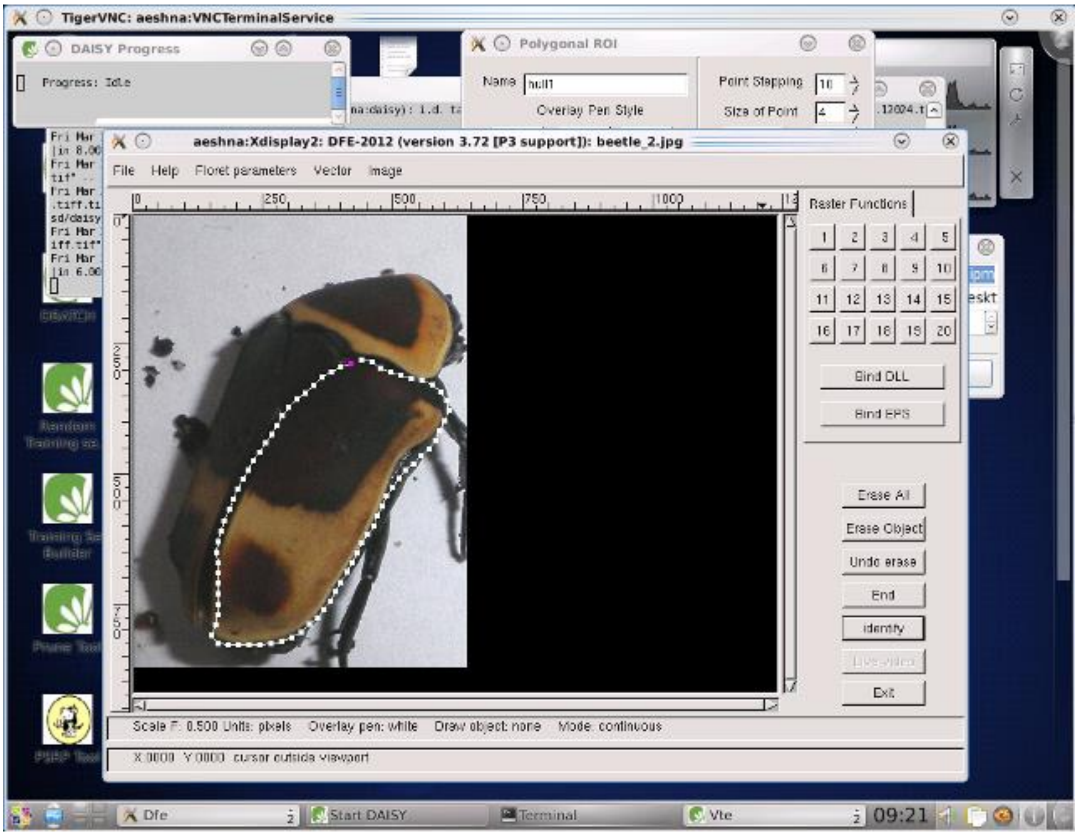
| **Conservation Benefits** | ★★★☆☆ | Enables increased scale of monitoring and better informed decisions. |
| **Other benefits** | ★★★☆☆ | Reduces ecologist classification effort. |
| **Technology Readiness** | ★★☆☆☆ | The current algorithms require high quality images to be effective and specialists to configure them for requirements. |
| **Ease of Deployment** | ★★☆☆☆ | The algorithms currently require a significant amount of training data (classified images) and configuration to setup. |
| **Cost Effectiveness** | ★★★☆☆ | Over time the effort saved in classification of species, and refocused on more value-added tasks, should far outweigh the cost of the software and its set up. |

**Case study: DAISY (Digital Automated Identification System)**

Daisy is a universal identification system. It can be applied to anything: images, sounds, chemical spectra and molecular data. This is because Daisy's pattern matching technology is generic - it can be trained to recognise almost anything. There are no limitations to what Daisy can identify – it just needs to be trained first.

http://science.sciencemag.org/content/328/5986/1628
http://www.tumblingdice.co.uk/daisy




## Automatic Weather Stations

Knowledge of the meteorological conditions is important both for daily decision-making for PA staff and visitors as well as a component of ecological monitoring.

Automatic weather stations (AWS) consist of meteorological sensors, a data logger, a wireless communications unit, a mast and solar panels or wind turbines depending on the environment. The AWS units can report in near real-time by either via satellite or mobile networks, and the data can be automatically fed into a Geographical Information System (GIS) for analysis and reporting or onto visitor websites.

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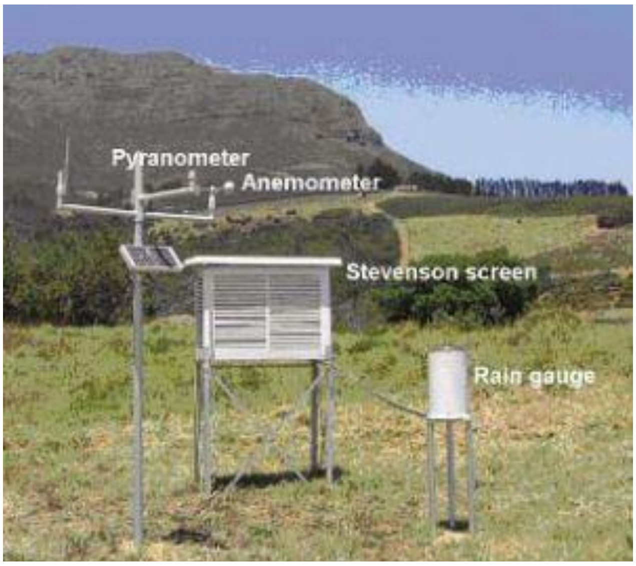
| **Conservation Benefits** | ★☆☆☆☆ | The AWS provides useful background information to support conservation efforts. |
| **Other benefits** | ★★★☆☆ | Provides useful information for park staff and tourists when planning their day. |
| **Technology Readiness** | ★★★★★ | Automatic weather stations are available from a number of providers. |
| **Ease of Deployment** | ★★★★☆ | Installation is simple, though the automatic import into the GIS system requires configuration. |
| **Cost Effectiveness** | ★★★☆☆ | Limited savings may exist where an AWS replaces regular manual collection of meteorological data. |

**Case study: Automatic Weather Stations help Africa reach new goals on climate change**

A project called the Trans-African Hydro-Meteorological Observatory (TAHMO), which seeks to install 20,000 automatic weather stations across sub-Sahelian Africa.

http://news.trust.org//item/20150929152434-4yz6b/




## b) Automated surveillance of the park

### Anti-poaching/illegal logging sensor networks

Illegal poaching of wildlife is on the rise again. Elephants are being killed in their thousands for their ivory and rhino numbers are rapidly shrinking due to massive demand for their horn. Poaching teams are becoming ever more sophisticated and difficult to detect. The sheer scale of the protected areas means that rapid detection and response to the poaching scene is nearly impossible.

A variety of connected sensors (acoustic, seismic, infrared) and cameras can be deployed to help detect potential poaching activities and illegal logging activities. When triggered, these can send alerts via wireless networks and provide rangers with information about the location and nature of the threat. These can be linked to advanced security cameras which relay high quality images for confirmation of a poaching incident, and later, to help in the conviction of criminals.

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| **Conservation Benefits** | ★★★★★ | Poaching is one of the biggest threats to species. This solution improves detection and response to poaching. |
| **Other benefits** | ★★★★☆ | Enables a shift in ranger focus from general patrolling to a proactive response to specific threats. |
| **Technology Readiness** | ★★★★☆ | Sensors and camera traps are in existence and have been deployed in anti-poaching projects. |
| **Ease of Deployment** | ★★★☆☆ | May take some time to configure sensors, but will be straightforward to maintain after. |
| **Cost Effectiveness** | ★★★★☆ | Sensors are cheap but wireless network much more expensive. If wireless network already in place it becomes very cost effective to deploy the network of sensors and cameras. |

**Case study: Instant Detect**

Instant Detect is a collaborative anti-poaching project between Zoological Society of London (ZSL), Kenya Wildlife Service and Seven Technologies Group that provides detection and real-time alerts of poaching incidents to rangers. Instant Detect relies on several technologies:

Hidden seismic and magnetic sensors that are triggered by proximity of humans, sending alerts to rangers. They can identify the direction of movement the poachers are travelling in and estimate the number of people in the party.

Camera traps which sense presence of activity remotely and capture high-resolution images to aid identification and retrospective convictions.

Hidden waterproof and weatherproof containers to house the cameras so it is difficult for poachers to identify surveillance areas.

When activated, the cameras and ground sensors send information to a central satellite node which uses a Raspberry Pi computer to process the data. The images and sensor alerts are then sent over the Iridium satellite network in near real-time to a secure server to be accessed by individual users.

https://www.zsl.org/conservation-initiatives/conservation-technology/instant-detect


ZSL LIVING CONSERVATION

KENYA WILDLIFE SERVICE

## Incident mapping and reporting

Rangers face numerous challenges managing and carrying out anti-poaching patrols. With the poachers operating within increasingly complex networks it is becoming more difficult to isolate and deal with threats. The ranger teams, with stretched resources, often cannot compete with the heavily equipped criminals. In addition to the obvious negative impact on wildlife populations, rangers themselves suffer from low morale and motivation, further impacting the quality of their work.

Better reporting and monitoring systems need to be in place to empower the rangers on the ground and give them the support needed to combat poachers. Rangers within the field can report incidents which builds maps of poaching hotspots, and improves management decisions. The maps help ensure a more intelligent use of resources by allowing the strategic deployments of fully equipped ranger teams to problematic areas. A focused response such as this increases the capture rate of incidents and the chance of apprehending and arresting those responsible, protecting the wildlife and boosting the confidence of the ranger teams.

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| **Conservation Benefits** | ★★★★★ | With a more focused response to poaching areas, there is a greater likelihood of preventing incidents and capturing individuals responsible, thus protecting the wildlife. |
| **Other benefits** | ★★★★☆ | Maximises benefits of ranger patrols and ensures best use of ranger resources. Empowers rangers in the field so improves morale and motivation. |

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| **Technology Readiness** | ★★★★★ | Monitoring and reporting tools already available. |
| **Ease of Deployment** | ★★★★★ | Can be made compatible with any existing technology in place. Requires only the ability to collect GPS data. Full training and site assessments included in deployment. |
| **Cost Effectiveness** | ★★★★★ | Resource is free and complements any existing system in place. |

**Case Study: SMART (Spatial Monitoring and Reporting Tool)**

SMART is a free-to-use software solution that supports rangers in the fight against poachers and other threats. It was developed by a partnership of leading conservation organisations. It offers capabilities for rangers to record, map and evaluate locations of threats. The simple and easy-to-use interface reduces the time spent writing reports or collecting data, and more time patrolling the field and responding to incidents. Resources can be better allocated to the most at-risk areas increasing the survival of wildlife populations and the chance of capturing the criminals. It has been trialled in over 100 protected areas in 31 countries so far.
http://www.smartconservationtools.org/materials

## Drones for Surveillance

Fixed wing drones with a long range (up to 100km) can be configured to automatically cover susceptible areas of the park and provide alerts to rangers of the location and nature of threats they need to respond to. This can include areas which in the rainy season, for instance, cannot be reached by foot or vehicle patrols and where illegal activity can continue with impunity. The use of drones with forward looking standard and infrared (FLIR) cameras can identify unauthorised individuals and vehicles. FLIR cameras can be used at night to monitor large areas for bush fires and fires for smoking of bush meat.

Quadcopter drones are also useful tools for shorter range surveillance, possibly by a ranger operating from a vehicle wishing to reach hard to access locations.

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| **Conservation Benefits** | ★★★★☆ | Acts both as deterrence and as an enabler to enforcement. Can help the war against poaching and illegal logging, as well as transhumance. |
| **Other benefits** | ★★★☆☆ | Reduces the need for manned patrols, and focuses ranger efforts on dealing with the issues that arise. |
| **Technology Readiness** | ★★★☆☆ | The drones and cameras are commercially available. Ability to conduct effective surveillance of PAs yet to be demonstrated. |
| **Ease of Deployment** | ★☆☆☆☆ | Drones are difficult to deploy in a PA.  Skilled resources required to manage drone launches and retrievals. Drone servicing in remote areas is a challenge. |
| **Cost Effectiveness** | ★★★☆☆ | This is in most cases the central business case for the use of drones. In parks where the war against poaching is being lost, this |

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| | | may well be a cost-effective way of reversing the balance in favour of protection. |

**Case study: Drones for rhino anti-poaching efforts** (Mulero-Pázmány et al 2014)

This study concluded that drones were effective at detecting rhino and human presence
http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0083873

Air Shepherd is a manufacturer of anti-poaching drones in Africa, aimed at preserving rhino populations. http://airshepherd.org/where-we-fly/

## c) Security of staff and tourists

### Satellite Emergency Messaging Devices

Some PAs have no or limited cellular network coverage. This limits the operational effectiveness of PA teams, and increases the safety risk to tourists and rangers. With no way to call for help, incidents like vehicle breakdown, accidents, and aggressive poachers can be life threatening.

Satellite devices exist which allow SOS alerting and 2-way messaging. When the SOS alert is activated the device sends an emergency alert that includes the location to emergency services and predefined contacts. This will allow PA operations and emergency services to respond rapidly and appropriately. In addition the devices provide location updates and last location alerts if a signal is not received or the location doesn’t change for many hours. These devices can provide a life-saving service and the 2-way messaging can enable better coordination of PA teams where there is no cellular coverage. Devices use the Iridium, Globalstar or Cospas-Sarsat satellite networks for global coverage.

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| **Conservation Benefits** | ★★☆☆☆ | More effective communications between rangers can improve responses to poaching alerts. |
| **Other Benefits** | ★★★★☆ | The ability to coordinate by 2-way messaging will improve the coordination and effectiveness of PA staff, and provide security to both staff and visitors. |
| **Technology Readiness** | ★★★★★ | Devices are commercially available. |
| **Ease of Deployment** | ★★★★★ | Devices are quick to setup and easy to learn to use utilise. |
| **Cost Effectiveness** | ★★★☆☆ | Costs are high relative to normal mobile networks. Devices range from $150-$500, and require annual subscriptions ranging from $150 to $300 depending on the usage required. However this may be considered a small price to pay of the security benefits, and visitors could be charged for the hire of a device. . |

**Case study: SPOT**

**SPOT Gen3**® provides location-based messaging and emergency notification technology that allows you to communicate from remote locations around the globe.

http://www.findmespot.com/en/index.php?cid=120


## d) Security of local communities

### Automated animal deterrents

Human-wildlife conflict is a growing problem in many areas, due to loss of animals' natural habitat through human expansion and a reduction in prey species forcing species to feed on human livestock and crops. This results in local people losing income and retaliatory killing of wildlife which is pushing already threatened species towards the brink.

Deterrents can prevent conflicts from occurring without posing any risk to people, livestock or wildlife. In poorer communities, simple technology is proving effective at scaring off lions and other predators that encroach on people's land. These solutions require LED lights and a power supply to be attached to the outer edge of livestock enclosures. Ready-made solutions are on the market, for example battery-powered Fox Lights http://www.foxlights.com/, which emits frequent pulses of light to scare wildlife away from farmland at night. Solar power can provide a renewable source of electricity. There are more sophisticated solutions which are triggered by external stimuli. Infrared sensors installed in India, when triggered by an approaching elephant, release pre-recorded tiger and leopard growls that scare off the intruding herbivore. Simple SMS-warning systems can be deployed alongside other deterrents; the Nature Conservation Foundation in India texts locations data of elephants that come within 2km of a village. Early-warning systems based on acoustic monitoring are also in development. http://www.tandfonline.com/doi/abs/10.1080/09524622.2014.906321.

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| **Conservation Benefits** | ★★☆☆☆ | It will avoid retaliatory killings of individual animals. |
| **Other benefits** | ★★★★☆ | Helps protect the livelihoods of local communities. |
| **Technology Readiness** | ★★★★☆ | This simple technology is already in existence and able to be implemented. Warning systems and automated triggers to stimuli is less commonly used but again the technology exists. |
| **Ease of Deployment** | ★★★★★ | Quick and simple to set up. Local communities can be trained in their deployment and maintenance. |
| **Cost Effectiveness** | ★★★★★ | Very low-cost technology has already been proven to have an effect. |

**Case study: 'Lion lights' in Nairobi National Park**

11 year-old Richard Turere fitted a series of flashing LED bulbs onto poles around his family's cattle livestock enclosure, situated at the edge of Nairobi National Park, Kenya. The lights were wired to a box with switches and to an old car battery powered by a solar panel. They were designed to flicker on and off intermittently, thus tricking the lions into believing that someone was moving around carrying a flashlight. Since they have been installed, no cattle have been lost to lion attacks.

http://edition.cnn.com/2013/02/26/tech/richard-turere-lion-lights/
https://fonnap.files.wordpress.com/2012/11/lion-lights.pdf

## e) Improving the visitor experience

### Citizen Science Applications

There are now many citizen science applications that help visitors to identify the flora and fauna they are seeing and enable them to take photos of sightings which are geo-located, time stamped, and then automatically uploaded to a shared conservation database for classification and analysis. Such apps both improve the experience of the visitor and can make a useful contribution to the data available to PA ecologists.

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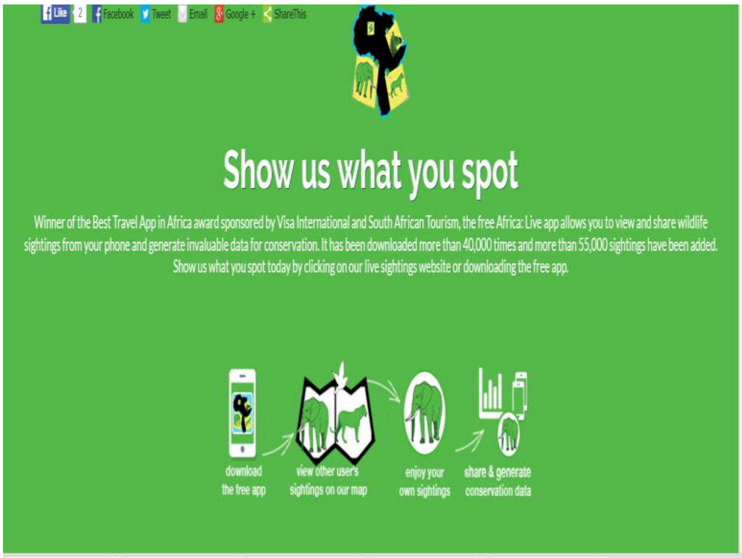
| **Conservation Benefits** | ★★☆☆ | Contributes to the data available to PA ecologists. |
| **Other benefits** | ★★★☆☆ | Can significantly enhance the visitor experience. |
| **Technology Readiness** | ★★★☆☆ | Apps exist which are able to be configured to the needs of an individual park. |
| **Ease of Deployment** | ★★★★☆ | Easy to deploy and use on a smart-phone both by visitors and park staff. |
| **Cost Effectiveness** | ★★★☆☆ | The cost of configuring an app to the needs of a specific PA are low. The benefits in terms of visitor engagement can be significant. |

**Case study: Africa Live app**

The free Africa Live app allows one to view and share wildlife sightings from your phone and generate invaluable data for conservation.

http://wildafricalive.com/site/




## Tourist-focused applications

The growth of the tourism industry in a PA relies on raising awareness of the park's wildlife and features and improving the overall tourist experience so that a positive reputation is nurtured. Some PAs have little publicity and as such potential tourists are unaware of its features and will not consider it as a destination.

In several parks there are specialist smartphone applications available to download. There are a range of applications and features on offer, these include the ability to identify and upload sightings of wildlife, general park information (opening, closing times, accommodation, waterholes) and the ability to track your position through the park using GPS. The maps on these applications can be downloaded before travel and do not require Internet connections to operate, making them suitable for use within the parks.

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| **Conservation Benefits** | ☆☆☆☆☆ | No direct conservation benefit. |
| **Other benefits** | ★★★★☆ | This technology enhances tourist experience and does not have a direct positive impact on wildlife. |
| **Technology Readiness** | ★★☆☆☆ | The technology is existing and is in use in other parks. There is the need for configuration to fit the requirements of PNP. |
| **Ease of Deployment** | ★★★★★ | Very easy to deploy; upload to an app store is straightforward and it requires little maintenance following development. |
| **Cost Effectiveness** | ★★★★☆ | It would be relatively low cost to develop and very inexpensive to maintain. Costs can be recuperated by charging for particular app features. |

**Case study: All-in-one Kruger Park**

This app provides the following:
1. Checklist to record animal sightings
2. Gate opening times and contact details
3. Accommodation information
4. Interactive map
5. Distances and travel time to next destination

It is available for use by tourists visiting the Kruger National Park, South Africa.

The app is available on the Google Play store https://play.google.com/store/apps/details?id=com.janno.krugerparkcheclist&hl=en

## f) Stakeholder collaboration Systems

### Community Collaboration Platforms

Community involvement and benefits can be the key to good relationships with the park that permit it to operate in relative stability. Without this cooperative interaction, the park—and all its delicate systems—are subject to vandalism, poaching and even personal conflict.

Effective PA management requires effective collaboration between a large number of stakeholders including park management and staff, local communities, NGOs, universities, funding partners, and local businesses. This work is hard to administer effectively without on-line tools, and today in many instances the degree of engagement and collaboration is often inadequate.

There are cloud based community collaboration platforms which today enable stakeholders who are subscribed (at no cost) to set up or join groups, participate in discussions, share ideas, ask questions, provide or search for documents, videos and pictures related to best practice experience. The platform can be available through the Internet or, in a more simple form, via SMS, for those who have no access to the Internet. These platforms are simple to establish and the software is inexpensive to purchase. However the platforms do require management and animation if they are to be successful.

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| **Conservation benefits** | ★☆☆☆☆ | The benefits of such platforms tend to be indirect rather than direct. |
| **Other benefits** | ★★★★☆ | Can greatly facilitate communication, collaboration and ultimately trust between the disparate stakeholder groups. |
| **Technology Readiness** | ★★★★★ | There are many providers of community platforms including open source platforms. |
| **Ease of Deployment** | ★★★★☆ | Quick to setup, however driving usage by local communities beyond launch requires active management. |

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| **Cost Effectiveness** | ★★★★★ | Low cost method to engage a large number of people, however resources are required to maintain the content on the platform. |

**Case study: Salesforce partnership with the Black Jaguar Foundation**

Black Jaguar uses Salesforce Community platform to communicate with supporters and partners and raise funds. They recommend the use of Salesforce to any non-profit: '…we needed a tool that could connect … our partners, sponsors and donors wherever they are, and whenever they need to be connected.'

http://www.salesforce.org/stories/black-jaguar-foundation/

BLACK JAGUAR FOUNDATION

**Case study: WeFarm**

An online and SMS-based platform enables African farmers to ask questions and share best practices to improve yields and economic and food security.

http://wefarm.org/

# 6. Appendix: Useful resources

Organisations:

Conservation International's (CI) Metrics aims to measure the impact of policies on conservation. They have also developed tools to measure the impact of human activities such as mining and agriculture on the health of ecosystems. For more information see: http://www.conservation.org/projects/pages/metrics.aspx

Google Earth is a powerful and flexible platform that has provided several conservation organisations with the tools to collect and analyse data on species and habitats remotely. Read about some of their conservation outreach work here: https://www.google.co.uk/earth/outreach/index.html

IUCN: the global authority on nature conservation and the designator of protected areas. https://www.iucn.org/. For Africa specifically visit www.papaco.org.

Mongabay is an excellent resource on the use of technology for conservation, including articles on case studies. https://wildtech.mongabay.com/

Salesforce is the world's leading CRM software and enterprise cloud ecosystem. It offers a range of cloud-based services, including analytics and a community system. http://www.salesforce.com/

Smart Earth Network has a solutions database, covering drones to sensors to database tools. http://www.smartearthnetwork.com/solutions

Terrabella is a Google company building innovative satellites and cameras to look for patterns of change in the physical world to address the world's challenges, including environmental issues such as biodiversity loss. https://terrabella.google.com/

WDPA: United Nations Environment Program (UNEP) together with IUCN has developed the World Database on Protected Areas (WDPA) which provides a picture of the extent, location, name, status and other useful information on the world's protected areas. http://www.unep-wcmc.org/featured-projects/mapping-the-worlds-special-places

Zoological Society of London (ZSL) has a dedicated programme for applying technology to conservation, which includes the 'Whitespaces for Wildlife' project that has tested the use of unused TV channels to provide wireless connectivity. This has been trialled at London Zoo and has the potential to be applied to remote conservation areas. For more information see: https://www.zsl.org/conservation-initiatives/conservation-technology

and https://www.zsl.org/conservation-initiatives/conservation-technology/whitespaces-for-wildlife

Articles:

'What is the Internet of Things?' Guardian, May 2016
https://www.theguardian.com/technology/2015/may/06/what-is-the-internet-of-things-google

'A simple explanation of the Internet of Things' Forbes, May 2014
http://www.forbes.com/sites/jacobmorgan/2014/05/13/simple-explanation-internet-things-that-anyone-can-understand/#25828e7d6828

'Toward an environmental Internet of Things' Hart & Martinez, Earth and Space Science, May 2015
http://onlinelibrary.wiley.com/doi/10.1002/2014EA000044/full

# 7. Appendix: About Smart Earth Network and Eridanis

## Smart Earth Network

Smart Earth Network is a social enterprise founded in June 2015 by Simon Hodgkinson and Sarah LaBrasca with the aim of improving the conservation of the natural world by bringing together conservationists and technologists to innovate and deploy use case applying the latest in IoT and other innovative technologies. SEN'd mission statement is 'reimagining the way we conserve nature'. SEN's purpose is to provide Protected Areas with the tools they need to plan and make technology investments to improve their management effectiveness. SEN has developed its own IoT Maturity Model for Protected Areas describing the strategic phased deployment of technology that enables solutions to be implemented in a scalable and repeatable way. SEN is applying the Maturity Model to PNP with the aim of scaling technological solutions to protected areas worldwide to improve the evidence-base that informs global conservation management and policy decisions. See www.smartearthnetwork.com

## Eridanis

Eridanis is a consultancy that advises organisations on how to take advantage of the IoT revolution. From its Paris and London headquarters, it advises clients on the opportunities available, builds and tests prototypes and provides support throughout the process of digital transformation. Eridanis, with their expertise in IoT technologies and experience of implementing solutions, is helping devise and deliver the strategic deployment of technology into PNP. For more information about their work, see www.eridanis.com/en/our-work/