The Internet of Things for Pendjari National Park:

A Phased Innovative Technology Investment Strategy to Improve Management Effectiveness

Second report of IUCN Mission to Pendjari National Park

Photo credit: Llan Pln Koh, Collage of Orangutan Nests identified by UAVs

Simon Hodgkinson & Daniel Young

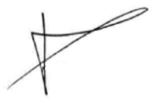
Foreword

The species with which we share the planet, and the ecosystems on which we depend, are being destroyed at an unprecedented rate. Despite decades of conservation effort, species and habitats are still disappearing. Reversing this decline, is one of the biggest challenges of our times. Protected areas cover 15% of the global land surface and represent a significant proportion of the planet's biodiversity. Managing these areas well is a key aspect in preserving species and habitats for future generations. This is one of two reports (the other is titled The Internet of Things for Protected Areas: The Application of Innovative Technologies to Improve Management Effectiveness) commissioned by International Union for the Conservation of Nature (IUCN) showing very practically how a new technology revolution, the Internet of Things (IoT), has the potential to transform the management effectiveness of protected areas in Africa and elsewhere. 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, help build local community involvement and trust through good communication and improve the safety and experience of visitors.

The reports were based on a mission to the Pendjari National Park in Benin undertaken by Smart Earth Network and Eridanis in collaboration with Ministre du Cadre de Vie et du Développement Durable, and Centre National de Gestion des Réserves de Faune (CENAGREF), Fondation des Savanes Ouest Africaines (FSOA), as well as local community groups, NGOs, the Zoological Society of London (ZSL), 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 of the planet's biodiversity.

Signed,



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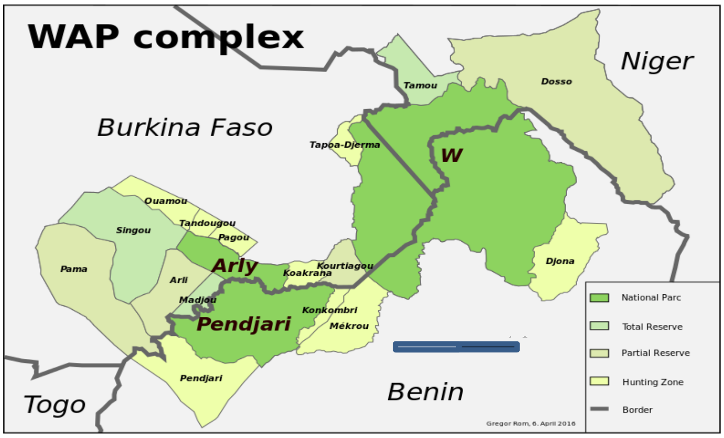
1. Introduction

Background

In early 2016 the International Union for the Conservation of Nature Programme Aires Protégées d'Afrique et Conservation (IUCN-PAPACO) commissioned an evaluation of the opportunities to use innovative technologies (in particular those enabled by the Internet of Things (IoT) to improve conservation management effectiveness and efficiency of the Pendjari National Park in Benin, and other similar Protected Areas (PAs).

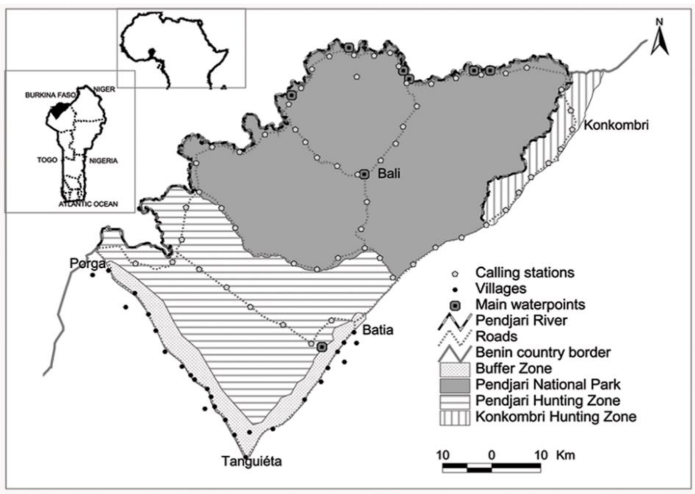
The Pendjari National Park, which covers an area of 2,755 km^2 in north western Benin, is part of the WAP complex of PAs spanning the borders of Benin, Niger, and Burkina Faso. Pendjari is home to some of the last West African populations of elephant, lion, hippopotamus, buffalo and various antelope species. The park is also famous for its richness in bird species.

Fig 1: Pendjari in the context of the WAP complex of Protected Areas in West Africa



Credit: Gregor Rom, Wikimedia Commons

Fig 2: The Pendjari National Park



The IUCN evaluation has had two deliverables:

1. **The Internet of Things for Protected Areas: The Application of Innovative Technologies to Improve Management Effectiveness,** a general report into the management challenges which Pendjari National Park and other similar PAs in Africa face, and a selection of technologies that could be used to help address these challenges.

2. This report which presents a strategy to enable scalable repeatable investments able to drive management effectiveness benefits not just in Pendjari National Park, but across similar PAs in the region and beyond.

The IUCN mission to Benin was undertaken by two consulting companies and took place from the 29th of May until the 6th of June 2016. The companies were:

- Smart Earth Network (SEN), which brings together conservationists and technologists to develop and deploy technological solutions addressing conservation challenges. Its founders Simon Hodgkinson and Sarah Labrasca represented SEN. More information on the company is available at this address: www.smartearthnetwork.com
- Eridanis, an Internet of Things consultancy, advising and supporting organizations to capture the value of emerging technologies. Eridanis has been represented by Daniel Young, UK managing director, and Guillaume Jouffre, consultant. More information on the company is available at this address: www.eridanis.com/en

From IUCN the mission was supported by Geoffroy Mauvais and Béatrice Chataigner, and facilitated by Alfred Allogninouwa of the Fondation des Savanes Ouest Africaines (FSOA).

Why the need for the mission?

Less than a quarter of PAs globally are effectively managed.[1] The majority suffer inadequate resourcing (funding, people, equipment, skills). Most today are not able to say whether their conservation programmes are being effective, nor are many able to identify and react to threats.[2]

The IoT revolution, involving more powerful processors in small remote devices that require lower power, enabled by powerful communications and analytical systems, all at costs that are falling rapidly, is making possible a transformation in PA management effectiveness. The IoT is already making big impacts in the creation of smart cities, and improving effectiveness and efficiency of the health and energy sectors. In PAs however, awareness of the opportunity remains low, investments tend to be piecemeal, and there are important hurdles to overcome to achieve scalable, repeatable and sustainable IoT investments.

This is a critical challenge for PAs anywhere, but especially for African PAs where there is generally no communications infrastructure, where technology investment tends to be disjointed, unsupported and often falls into disuse, and where the ongoing skills needed to support and maintain an IoT integrated solution are not present.

IUCN-PAPACO has chosen the Pendjari National Park in Benin as a case study with a view to developing not just individual business cases, but to evolving a Digital Maturity Model for PAs, enabling phased investments starting from a very low base (if that is the situation). This allows benefits to be achieved from the start, and a full capability to be built up over time on a shared platform which can be deployed across other parks quickly and cost-effectively.

[1] Global Analysis of PA Management Effectiveness; Fiona Leverington, Katia Lemos Costa, Helena Pavese, Allan Lisle, Marc Hockings, Springer Science+Business Media, LLC 2010

[2] 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, 2014.

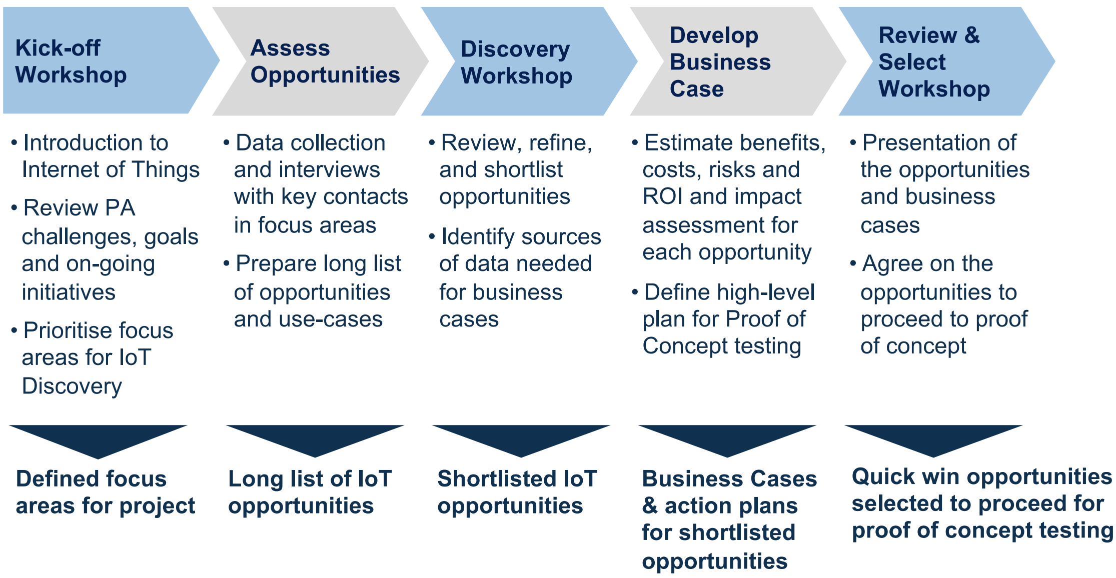
2. Approach

Introduction

The first objective of the IUCN Pendjari mission was to conduct a diagnostic to identify the values to be protected and the management challenges faced by PA managers and rangers, in theory addressable by Internet of Things and other innovative technologies. The objective was not to assess the overall management effectiveness of the park, but to identify technologies from which the park could benefit. A part of this objective has been to provide tangible assessment of the technology use cases possible for management and partners, allowing decisions to be made for funding and development.

Fig 3 below outlines the approach to the diagnostic project. The team performed the first 3 steps while in Benin.

Fig 3: Steps of the diagnostic project



Stakeholders

The first objective of the consultants was to understand Pendjari National Park activities, objectives and key challenges faced. To do so, prior traveling to Benin, the consultants administered a survey, spread among all the stakeholders involved in Pendjari National Park. This intended to identify objectives, challenges faced, on-going initiatives to address them and ideas for new technologies based on the experiences related to the park.

In conducting the mission the team from IUCN, 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)

3. The challenges faced by Pendjari National Park

The diagnostic of the Pendjari National Park identified six major management challenges where advanced technologies could help achieve significant efficiency and effectiveness gains:

Communications

There are today no effective communications within the Park: There is no public mobile phone network, a radio network that was installed is not working, and though staff use walkie-talkies, these have limited range and are not secure. For Park staff this creates difficulty in coordinating collaboration, and for staff and visitors it is a security risk, as it is impossible to summon help when emergencies arise (e.g. vehicles break down, or accidents occur). A cost-effective communications system is a required foundation both for basic voice and text, and for scalable and repeatable IoT enabled investments. A variety of technologies are now available, ranging from satellite telecoms, to VHF radio, private 4G and Wi-Fi systems that enable voice, text and data communications which, combined with GPS, can resolve these issues and enable connected devices to be deployed effectively. The challenge is to select the right technologies to meet the needs of the Park over the long term, given the problems of scale, bandwidth needs, security challenges, etc.

Collection of ecological data to establish trends, threats and causality to support the planning of conservation programmes:

Today this work in Pendjari is labour-intensive, expensive, and ineffective:

1. A manual transect study, for instance, takes many people trekking across the park on foot weeks to complete, is undertaken infrequently (every 2-3 years) and may still produce only partial data that is insufficient to demonstrate biodiversity threats, their causality, and programme impacts.
2. 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.
3. Surveys of big mammals are undertaken using fixed wing aircraft. These are expensive and conducted too infrequently (every ten years) for effective conservation planning.

Networks of sensors, camera traps and UAVs 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 and management.

Surveillance of the park to identify threats from poaching, logging, and transhumance:

Today scarce ranger resources, the sheer scale of the park and limited road access, all make comprehensive and effective 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, loggers and pastoral farmers during these months are often able to operate with impunity. New technology has the potential to transform this challenge by enabling 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.

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.

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 often work in isolation, not discussing issues, nor sharing information, at times duplicating efforts. Lack of participative tools is preventing effective collaboration, leading to misunderstanding and mistrust, and 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 mobile phone access. Over time, if the political will and leadership are there, these platforms can help transform a culture of non-collaboration into one of effective networking, discussion, sharing, and engagement.

The experience of tourists before 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.

4. Existing Technology Initiatives in Pendjari

During our diagnosis, the team identified several on-going initiatives using technologies in the park;

1. Camera Traps: Camera traps have been used since 2012 in the Park for species monitoring. These have been deployed by different organisations including Pendjari Park agency, Cotonou University and Zoological Society of London. As far as we understand the data derived is not shared between these organisations.
2. GPS Devices: Rangers rely on GPS devices for navigation when they leave the designated tracks within the park.
3. Spatial Monitoring and Reporting Tool (SMART): Currently being trialled by Zoological Society of London.
4. ZSL are about to trial Instant Detect (ID) which provides real-time monitoring of threats using camera traps and sensors via satellite.
5. Rotor UAVs: A demonstration was given of drone technologies in 2015 but use cases were not defined, and the work has to our knowledge not progressed.
6. Geographic Information Systems (GIS): Exists, however only based on static data sources (maps).
7. Weather monitoring station: A weather monitoring station has been set up in the Park but we were told this was not functional.
8. VHF Radio: A VHF radio system was installed but, for reasons that were not made clear, is non-operational.
9. Walkie-talkies: We understand that park staff use walkie-talkies but that these have limited range.

5. Summary of Innovative Technology Applications

Below is a summary of the technology applications for addressing the key challenges identified in Pendjari National Park. For a more detailed list, see the accompanying report, **The Internet of Things for Protected Areas: The Application of Innovative Technologies to Improve Management Effectiveness**

Automated collection of ecological data

- *Connected Camera Traps and Security Cameras*: Network of camera traps and security cameras with wireless connectivity that can automatically upload their images centrally for processing, or in the case of security cameras, to alert patrol staff to potential illegal activity.
- *Acoustic Sensor Networks:* A network of acoustic sensors whose audio recordings 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.
- *Bio-tracking:* Tracking movements of individual animals remotely using GPS trackers that can record location history for later retrieval or can relay data using embedded cellular, radio or satellite modem.
- *Habitat Change Detection Software:* Visibility of habitat changes can be improved by using advanced Geographic Information Systems (GIS), to change detection and prediction algorithms, and results in the increased quality and types of remote sensing data available.
- *UAVs for Monitoring Wildlife Populations:* Monitoring trends in wildlife populations using automated UAVs to conduct surveys on a more frequent basis (i.e. monthly, quarterly) than is possible through current methods such as manual transect surveys.
- *UAVs for Monitoring Habitat Changes:* Automated UAVs 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.
- *UAVs for Invasive Species Monitoring:* Multispectral cameras capture the reflectance of plants across different wavelengths, which allows individual 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.
- *Automated Species Identification Software:* Image recognition software can be applied to images and videos of wildlife to automate the identification of species.
- *Automatic Weather Stations:* Automatic Weather Stations can report in near real time via either 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.

Automated surveillance of the park

- *Anti-poaching/illegal logging sensor networks:* A variety of connect 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.
- *Mapping and reporting tools:* Software that enables rangers to record poaching incidents and make effective management decisions. Data is stored on a central database which can be queried and produces maps, both of which enable intelligent allocation of resources to better combat the poaching threat.
- *UAVs for Surveillance:* Fixed wing UAVs 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.

Security of staff and tourists

- *Satellite Emergency Messaging Devices:* Until VHF radio and/or LTE networks are in place satellite devices can allow SOS alerting and 2-way messaging that allow PA operations and emergency services to respond rapidly and collaborate.

Security of local communities

- *Automated animal deterrents:* Range of devices that use sound and light to prevent human-wildlife conflict.

Improving the visitor experience

- *Citizen Science Applications:* Website and mobile apps that allow visitors to identify and submit photos of the flora and fauna they are seeing for classification and analysis.
- *Tourist-focused applications:* Mobile apps that provide Park-specific content to improve the visitors' experience.

Stakeholder collaboration Systems

- *Community Collaboration Platforms:* Web and SMS based tools to improve the collaboration and engagement of Park stakeholders.

6. Outline of a Digital Maturity Model for Pendjari

Introduction

IUCN-PAPACO has chosen the Pendjari National Park in Benin as a case study, with a view to developing not just individual business cases, but also evolving a Digital Maturity Model for PAs. This will enable phased investments which achieve benefits from the start, and full capability to be built up over time on a shared platform which can be deployed across other parks quickly and cost-effectively. Given this, it is important to be clear at the outset on:

1. The end vision for an enhanced management effectiveness capability that is sought
2. The outline target technology architecture for achieving the vision
3. The principles which should be used when selecting the technology to achieve this vision
4. The phased deployment approach based on the Digital Maturity Model which allows the capability to be built over time, delivering value at each stage, piloting solutions before fully rolling them out

Below we set out our proposition for each of these four elements for comment and discussion. Please note that these elements need to be considered by and discussed with Pendjari management before they are finalized.

Vision for Pendjari's technology-enabled enhanced management effectiveness

Fig 4 below summarises the potential of a well-designed technology programme to transform the key challenges of PA management described in section 2, and technology options identified in section 3.

Fig 4: Vision for the transformation of the key PA management challenges using technology

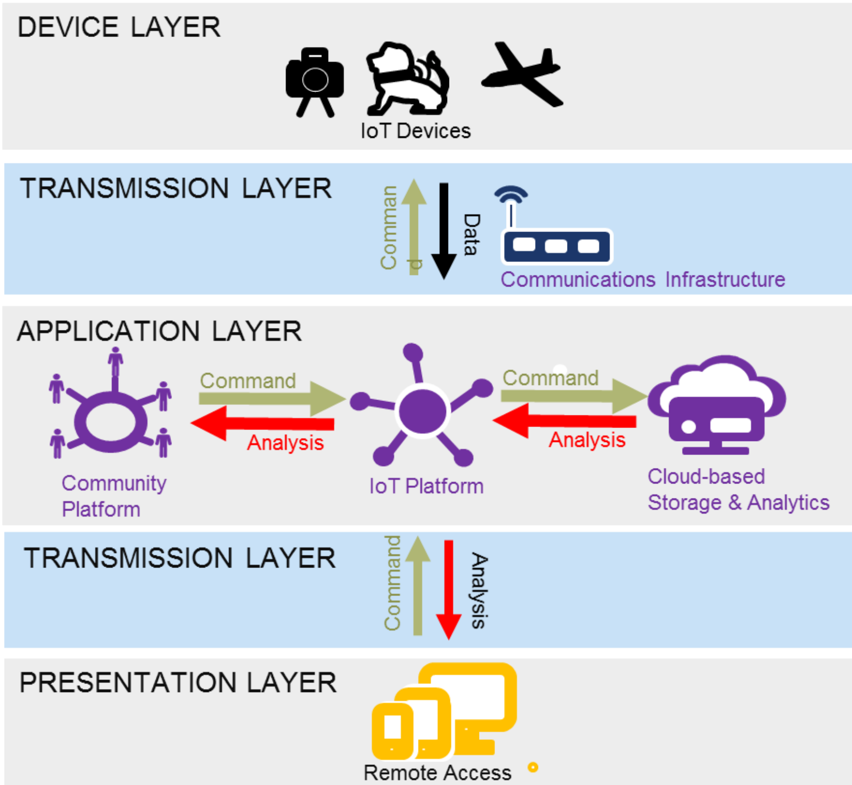
	As-Is	To-Be
Voice and data communications	Lack of in-Park electronic communications, hampering effective co-ordination of work, causing security risks for staff and visitors, and impeding the deployment of connected devices.	Park-wide (GPS-enabled) voice and data network which allow staff and visitors to communicate and access the Internet, and IoT-enabled tools to be deployed effectively. GPS will allow geolocation capabilities, increasing security.
Monitoring, Evaluation & Programme Design	Manually intensive data collection but poor evidence base for impacts evaluation, rendering confident programme design difficult.	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 limit effectiveness of conservation activity.	Use of technology to automate alerts and activate remedial actions reduces burden on resources, increasing capacity.
Collaboration and Governance	Stakeholder engagement at multiple levels creates significant administrative overhead.	Use of advanced stakeholder management and comms tools streamline work.
Visitors	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.

Local Communities	Local community lose livestock and crops dues to predation and trampling.		Notifications enabled by IoT devices allow deterrent action to be taken.

The technology architecture required to achieve the vision

The architecture of a repeatable scalable solution for digital protection of Pendjari National Park will need to comprise the five layers illustrated below in Fig 5. Physical devices will be placed remotely in the field (sensors, cameras, UAVs, etc.) which must use a transmission layer to capture the data and to transmit it to an application layer which manages the data, stores and processes it. The results need to be presented to users via a range of devices (phones, smartphones, computers, tablets, etc.).

Fig 5: The five layers of a digital architecture for a Protected Area



The selection of technology and the deployment plan for this architecture needs to be guided by nine core principles:

1. All core technology should be robust, proven, simple, and, as far as possible, locally maintainable.
2. PAs lack resources today and the aim must be to increase capacity. Technology should not be used to supplant human resources, but be deployed in a way that supports and enriches current work processes, replacing low-value manual work, with higher-value work for which staff may need to be up-skilled.
3. A phased deployment should be planned which delivers value at each stage (such as ecological monitoring and poacher alerts), while building infrastructure upon which later phases can be scaled (such as connectivity, generic storage and analytics).
4. Use cases must be rigorously piloted on the ground before they are rolled out.

5. An equipment control, management, maintenance, & training strategy should be put in place from the outset.
6. All costs (capital and ongoing) must be well understood, and the budgets required to support them must be in place.
7. Digital and physical security requirements must be considered from the outset.
8. The horizon of emerging technologies should be scanned to avoid as far as possible investing in solutions that will rapidly become obsolete.
9. Where the necessary Internet access is in place, cloud-based services should be considered to reduce upfront costs and allow remote technical support.

A four phase plan to transform Pendjari's management effectiveness

Applying the above principles the Smart Earth Network, working with technologists at Salesforce, Eridanis and Day Systems have developed an approach illustrated below to transform Pendjari's management effectiveness through the use of IoT enabled technology at an affordable cost. The approach proposed is scalable and repeatable.

All core technology proposed is robust, proven, simple (though some of the software is evolving), and locally or remotely maintainable.

Fig 6: The technology types and the benefits they can provide to the management effectiveness of Pendjari National Park

Area	Technologies and benefits
Communications	Radio/text/GPS + private 4G together provide communications for staff and visitors, improves work coordination, and enables IoT data transmission
Monitoring, Evaluation & Programme Design	Remote sensor network & UAVs supported by powerful analytics to improve evidence base, and facilitate effective programme design
Surveillance and response to threats to wildlife	Use of security cameras, UAVs, and acoustic sensors greatly improve detection and provide alerts enabling rapid response
Visitor and staff safety and security	Satellite and GPS enabled security devices to provide safety alerts until VHF radio is in place
Local communities	Notifications enabled by IoT devices allow deterrent action to be taken.
Tourism	Mobile apps with GPS enable visitors to plan in advance and to effectively navigate the PA and interpret what they see
Governance and collaboration	Use of advanced stakeholder management and comms tools streamline work

The phased deployment approach illustrated below proposes an equipment control, management, maintenance, and training strategy is in place from day 1. The level 1 investment phase includes infrastructure upon which later phases can be scaled (masts, transmission layer, applications layer), as well as early use cases which deliver immediate value (such as security and voice communications, ecological monitoring and poacher alerts). The approach proposes the rigorous piloting of use cases on the ground before full rollout. The speed at which Pendjari moves between these phases is a matter of choice and will depend on resourcing, the success of pilots and organisational capacity.

Fig 7: A Phased Approach to IoT-enabled investment in Pendjari National Park

As-is
- Piecemeal technology investments, no comms, poor ability to scale

Phase 1
- Construct 4 masts. Pilot 2-way radio enabling communications (voice, text, GPS), security, and low bandwidth (9.6kb) data transfer for sensor alerts

Phase 2
- Build out of radio & pilot 4G/LTE, add additional mast, build out security sensor network, piloting of drones for monitoring and surveillance

Phase 3
- Roll out LTE, roll out full drone capability enabling annual ecological surveying & daily patrolling of sensitive areas of part

Phase 4
- Connect LTE backbone to Internet, applications layer for collaboration between stakeholders, sharing of data & analytical capabilities, conducting cloud based research

Benefits of the proposed programme

The proposed programme will enable better conservation in Pendjari, saving manpower resources, enabling effort to be refocused from low-value activities to more critical activities. In particular it will:

- Improve communications and security within the park for both staff and visitors
- Collate accurate and timely impacts data, enabling better reporting to the authorities, increasing confidence in the value of conservation programmes
- Rapidly identify threats from poachers and loggers, enabling a timely response
- Improve stakeholder communications, management and collaboration

7. Business cases for selected solutions

Introduction

Eight technology applications have been selected for business case development and is based on:

1. the expectations/needs of stakeholders
2. their contribution to the end-vision set out in the last section
3. their potential contribution to conservation management effectiveness of Pendjari National Park
4. the readiness of Pendjari management, within the framework of the proposed phased deployment plan, to manage the successful roll-out of the technologies

The chosen applications are:

1. Communications infrastructure comprising VHF and LTE technologies
2. Unmanned Aerial Vehicles (UAVs) for ecological monitoring
3. Unmanned Aerial Vehicles (UAVs) and connected cameras for surveillance
4. Connected camera traps for ecological monitoring
5. Acoustic monitoring devices
6. Geographical Information Systems for habitat monitoring
7. Emergency satellite devices
8. Application layer comprising collaboration platform, connectivity, storage and analytics

Please note that the costs provided within the business cases are indicative and based on a rapid search of technology vendors against high level requirements. A pre-requisite to proceed with any of the business cases is a detailed requirements analysis and solution sourcing to define exact requirements, technology solution, and competitive suppliers. Where annual costs are given, it is assumed that a single phase is equal in length to one calendar year.

Communications infrastructure

THE CHALLENGE

Pendjari National Park is virtually lacking in all communications modalities. There is no Internet or mobile phone network service. The existing radio system is currently in disuse (if it is still functional, an evaluation of its suitability should be undertaken before investing in a new system). The park has a number of staff who patrol on foot to conduct ecological surveys and manage threats against the wildlife population. The staff need improved communication so that they are better able to coordinate their work. They and park visitors also need a communication system with geolocation capabilities in the event that a rescue effort or call for backup is needed. In addition, ecological monitoring that informs conservation efforts is limited by the lack of communications infrastructure currently available. The camera traps in the field require manual retrieval of photo data, which is a time-consuming effort. The lack of communications is preventing the deployment of other technology solutions, such as connected acoustic sensors and UAVs.

OPTIONS CONSIDERED

Option	Description	Pros	Cons
No change	Continue to manage without communications	• No additional investment needed	• Impossible to make significant improvements in capability without comms • Continued risk to park staff, visitors and assets
FM radio broadcasts	One-way broadcast communications to provide information/alerts to visitors and staff	• Cheap • Easy to deploy	• One-way only • Broadcasts are only heard if radios are kept on • Does not solve security issues
Build up a mast based communications systems	Masts to be deployed across Pendjari, at a height that is sufficient to provide near universal signal coverage. Once built, any communication modality can be added (LTE, VHF, Sigfox, etc)	• Low usage costsTransmission costs for private comms systems are low • Flexible: Many comms technologies can use the masts	• There are significant set-up costs (see Costs) • Masts may become target for vandalism • May be blackspots in coverage where there are obstructions • Need for specialist skills
Satellite based communications where speed is important (voice, alerts)	Threat detection systems and security alerts use satellite, others systems (e.g. camera traps) use manual processes	• No up-front construction costs • Low dependency on skills • Low maintenance • 'Plug and play' – ready to be used immediately • Immune to vandalism • Can be used as a backup to terrestrial radio	• High usage costs • Unable to rely on satellite for all needs
Solar powered UAVs (Google, Facebook)	UAVs or balloons fly high over the site provide low cost internet connectivity	• Will be provided as a service. No up-front construction costs • Low dependency on skills • Could be cost-effective (costs no known yet) • Should avoid problems of black spots	• Early days yet. The details of the service have not yet been made clear by Facebook • No specific date for when might be used in Pendjari

RECOMMENDED SOLUTION

The recommended approach is to implement a series of masts that will facilitate the use of a range of technologies and communication modalities. It is proposed to have four deployment phases, each phase building on the capability laid down in the previous phase. The benefit of this is that set-up costs are staggered to meet any budget constraints, and early capabilities can be continually assessed and improved upon. The early phase will test and implement a 2-way radio system (DMR) to which LTE capabilities will be added, following a testing phase. We are working with two suppliers, Baicells and Motorola, both of which are able to supply the technology at the costs indicated.

Baicells LTE basestation for rural broadband

The phased deployment is summarised below:

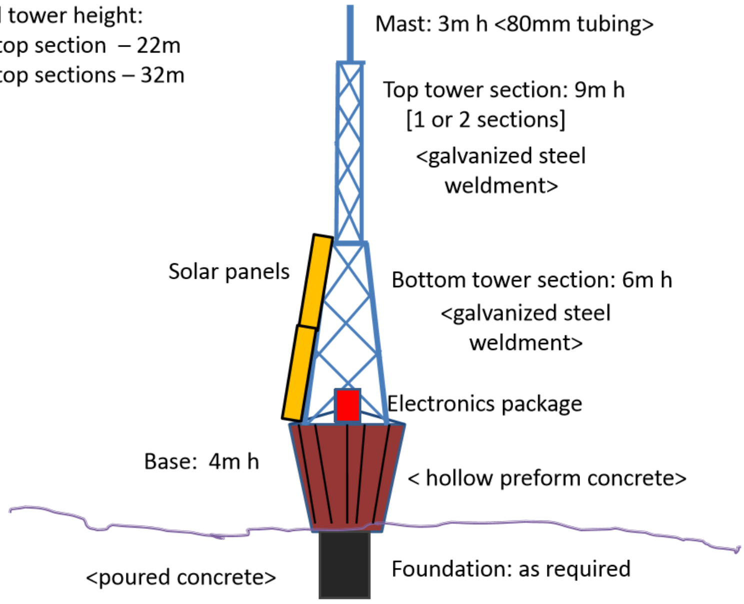
Phase 1: Four communications masts to be constructed, each with solar power systems and digital mobile 2-way radio (DMR) base stations that are linked via microwave point-to-point links. There will be a master control server for the DMR array. The staff will receive hand-held radios, mobile/vehicle radios and fixed point radios. Training and spare equipment will be provided. Simple text message and possibly geolocation capabilities of the radios to be enabled. Visitors can also be rented such radio for alerts. The signal will cover all visitor areas of the park, and around four fifths of the total area.

Phase 2: An additional mast is added, which should be sufficient for near universal coverage of radio signal across Pendjari. In addition, the first private mobile telephone (LTE) node is installed on a northern mast in the park giving coverage over a 25 km diameter. This will enable the testing of smartphone applications in the park, as well as data uploads from camera traps and acoustic sensors.

Phase 3: LTE service is extended with the addition of two more LTE nodes on existing masts. A master control server for telephone and messaging services to be provided. Serves multiple Android mobile phones (‘smartphones’). LTE services will be available for ecological monitoring and management purposes, such as surveillance and wildlife cameras, movement and intruder detection, and acoustic sensors amongst others.

Phase 4: LTE system extended to final two masts. A long-distance microwave link to the nearest population centre to be constructed and the public Internet and telephone service. These services to be integrated into the LTE array for both fixed and smartphone access. Internet service and support to be added to LTE network. Add LTE hotspots or modems for fixed-service use at camps and other high-use areas which will provide access to shared messaging, telephony and databases. Computer equipment will be provided at fixed locations with applications for monitoring and management. Mobile and fixed computing devices to be integrated into a shared application matrix.

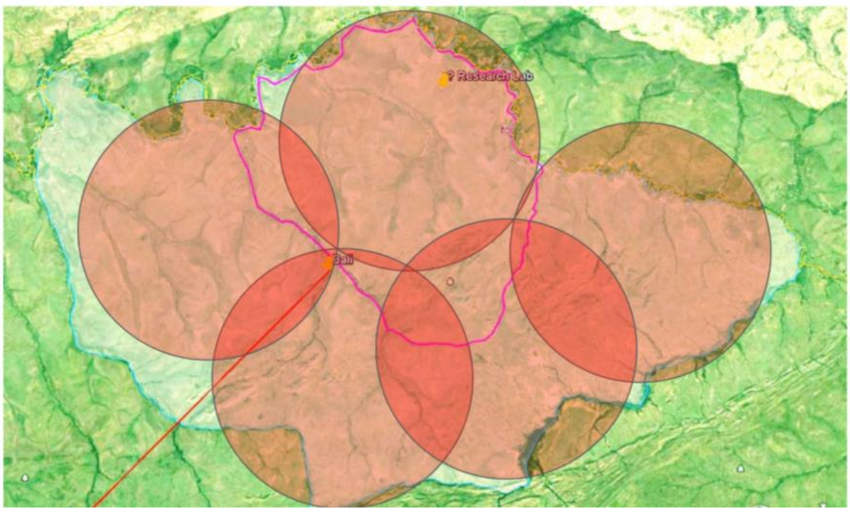
Fig 8: Indicative design of the tower structure



A concrete foundation with an inverted preformed concrete cone provides a level of security against vandals seeking to climb the structure, against low gunfire and other tampering attempts. It also provides a level of protection against damage from wildlife. The electronics package is secured at the base of the tower, on top of the concrete base, which will shield it from gunfire and prevent access by intruders. Satellite back-up mitigates some of the associated risk of masts becoming damaged.

Each individual tower provides an LTE range of 25km in diameter, which means that an arrangement of five towers will provide coverage of the majority of the park (see Fig 9)

Fig 9: Proposed layout of the five towers within Pendjari National Park



Surveillance

24 hour security cameras could be connected via LTE technology, which would enable them to be continually monitored from the control centre and to send out alerts to park staff if they are triggered by movement or sound. Text alerts via radio are available within the first phase, and within the third phase this can be extended to smartphone-based alerts via LTE.

Security

The ability to contact members of staff, to call for help, relay accurate location details and request backup would improve the safety of park staff dealing with incidents. In addition, the location of visitors can be communicated wirelessly, so that in the event of people getting lost or into difficulty, rescue efforts can be initiated immediately and effectively. The security of the visitors will therefore be improved and will lead to an increase of confidence amongst tourists, building Pendjari's reputation as a travel destination and generating more income for the park.

Ecological Monitoring

The collection of ecological data can be automated as data can be sent from sensors to a central device via LTE. Manual retrieval of data will not be required, freeing up staff's time to focus on more important roles. This will be especially useful for remotely deployed camera traps and acoustic sensors.

OUTCOMES AND CRITICAL SUCCESS FACTORS

Outcomes:

- Communications network implemented within PNP
- Automated alerts and rapid responses to incidents
- Security situations dealt with rapidly and effectively
- Sharing of data and information amongst staff and scientists helps decision-making
- Automated collection of ecological data remotely improves knowledge and informs conservation
- Tourism increase as park facilities improved and park gains positive reputation for guest security

Critical success factors:

- Government of Benin must authorize frequencies for VHF radio and for 700MHz LTE
- Towers are successfully maintained and protected from threats
- Tower location is chosen carefully to minimise threats from intruders or wildlife
- Coverage is close to universal and is not affected by obstructions that would create network blackspots
- Data upload speed is large enough for real-time surveillance, immediate communications and automatic collection of data

COSTS AND RISKS

Costs

	US$			
	Phase 1	**Phase 2**	**Phase 3**	**Phase 4**
Masts construction	48000	12000	-	-
Solar power	20000	30000	10000	10000
Links	8000	8000	-	28000
Base radios	10000	4000	-	-
Mobile/portable	8000	4000	-	-
LTE nodes	-	36000	72000	72000
Comms servers	-	-	-	50000
Smartphones	-	-	20000	5000
Fixed LTE	-	-	3000	10000

Design	**20000**	**10000**	**10000**	**10000**
Integration	**10000**	**10000**	**20000**	**20000**
Applications	**5000**	**5000**	**10000**	**20000**
Totals	**129000**	**119000**	**145000**	**225000**

Risks

Risks	**Potential impact**	**Mitigation**
Poachers, intruders and others may damage the tower infrastructure. Gunfire poses a significant risk.	Communications network becomes unusable. Alerts cannot be sent, incidents cannot be responded to.	The mast design provides a degree of protection. The comms should provide value to all stakeholders motivating the stakeholders to protect it. Cameras should provide deterrence. Satellite system can act as a back-up in emergency.
Signal may not reach a sufficient amount of Pendjari National Park, due to obstructions.	Creates blackspots where no signal coverage reaches, meaning no alerts or comms in that area.	This is low risk due to the fact that much of Pendjari is flat grassland but it is something to be aware of when positioning the towers.
Maintenance support may not be provided	Towers and communications system falling into disrepair.	Ongoing maintenance support guaranteed and included in budget.
Training is not provided in the use and maintenance of equipment.	Towers and communications system falls into disrepair.	Training given to park staff and costs included in budget.

Unmanned Aerial Vehicles for Ecological Monitoring

THE CHALLENGE

Wildlife inventories are conducted in PNP every 1 or 2 years and take a number of staff 2 to 4 weeks to complete. The inventories focus on 20-30 species. Big mammal (elephant, hippo, lion, buffalo) inventories are conducted every 2 to 3 years using multiple 3 person teams, and are occasionally supported by survey planes if funding is available. Carnivore focused inventories are conducted every 5 years. The data from the surveys is collated into reports by the park management. Habitat changes and invasive species are currently not monitored on a regular basis.

The problem of infrequent and unreliable manual surveys and resulting limited ecological monitoring affects PNP management and stakeholders, who are unable to make informed conservation decisions.

The need is to provide PNP management and stakeholders with regular visibility of changes to wildlife populations, habitats and invasive species, to allow them to make informed conservation decisions in a timely manner.

OPTIONS CONSIDERED

Option	Description	Pros	Cons
Take no action now	Continue with manual surveys.	- Manual transect surveys using local communities increase commitment to conservation. - Current surveys are high labour but low cost to conduct.	- Manual surveys are only conducted every 2-3 years. - Accuracy of results is considered inadequate.
Manned Aircraft Surveys	Conducting surveys with manned planes, helicopters.	- Established and proven service. - Surveys can be conducted more quickly than with UAVs.	- Expensive to undertake – can only be conducted infrequently.
Low Cost UAVs	Utilising low cost UAVs (like HBS Skywalker) instead of professional UAVs.	- Less investment required (total investment over 3 years is less than $300k).	- Requires more technical capability to operate and maintain the UAV operations than is expected to be available. - Payloads are lower, limiting the sensing equipment that can be used.
Mid-range UAV	Conduct surveys with fixed winged UAVs able to fly for 1.5 hours at a time supported by software.	- Able to conduct surveys with less manpower on a more frequent basis. - Software enables results to be analysed automatically. - Accuracy of results may be better than with manual transect surveys.	- The set up and operation of an effective UAV capability requires skilled resources, and careful governance if it is to be made sustainable.
Long Range UAVs	Conducting the survey with long range UAVs that can stay in the air for 6+ hours at a time.	- Less manpower and operations are required as the UAVs can be launched from fixed location in the park. - Fewer UAVs are required.	- Cost of UAVs is significantly higher (€ 250,000 each) making them unaffordable for this application.

Option	Description	Pros	Cons
Outsourcing UAV based Ecological Monitoring Operations to a 3rd Party provider	Instead of being operated the PA management, the UAV operations, image processing and analysis would be conducted by a 3rd party company.	Expected to improve quality and reliability of operations.	- Costly. - Limits local skills development.

RECOMMENDED SOLUTION

Solution Overview

The recommended solution is to utilize automated mid-range Unmanned Area Vehicles (UAVs) operated by the Pendjari Park agency to survey the whole Protected Area and use software to determine the changes in populations, habitats and invasive species spread.

The solution consists of the following elements:

1. **Acquire:** UAV missions, flown by autopilot, are conducted to systematically capture images of the whole PA.
2. **Consolidate**: The high-resolution photographic and multispectral images are consolidated by photogrammetry software into orthomosaic geo-referenced image maps.
3. **Analyse**: Key wildlife populations are then counted manually or with assistance from pattern recognition software. Habitat distributions are mapped and change detection algorithms are used to highlight changes in habitats and land usage over time. The distribution of invasive species are mapped if the multispectral signature is known, otherwise the location can be shared for visual classification.
4. **Report**: The trends for the populations, habitat and invasive species are then made available on a web platform for the park management and stakeholders.

Solution Detail

1. **Acquire**

The foundation of this solution is the capture of quality images of the whole park through UAV surveys. To effectively identify key wildlife and habitats it is estimated that the image resolution required is 2-3 cm/pixel. To achieve this resolution with standard camera sensors the UAVs need to fly at an altitude of approximately 100m. The images are taken using downward facing camera sensors to take both photographic and multispectral images at regular intervals. To allow images to be scaled correctly and consolidated into an orthomosaic geo-referenced image map it is important that there is sufficient overlap between subsequent images and the lateral images taken on other passes.

To conduct a single survey of the whole park it is necessary to conduct multiple UAV flights each with a unique flight path to capture a section of the park. The UAVs fly by auto-pilot along a pre-defined flight path which means that skilled UAV pilots are not required.

Example of single UAV flight path for mapping

The aim is to minimise the number of flights needed to cover the area, so as to reduce the number of take-offs, landings and collections. Fixed wing UAVs are the most suitable as they provide the greatest endurance. Fixed wing UAV with wingspans of 1.5m to 3m can currently achieve flight times of about 1.5 to 2 hours and survey in the range of 2.5 to 4 km^2 per flight at sufficient resolution and overlap.

Examples of UAVs with 2 hours+ flight time include:

Cumulus
(Sky-Watch)
1.65m wing span
http://sky-watch.dk/products/cumulus/

Nomad
(Novadrone)
3m wing span
https://novadrone.com/

HBS Skywalker
(Hornbill Surveys)
1.8m wing span
https://hornbillsurveys.com/equipment/

For this business case we have selected the Cumulus UAV from Sky-Watch. This is a professional mapping drone that can be launched by hand, can fly on autopilot for 2 hours, and can automatically land with a deep stall at designated location. The reason for choosing this UAV is that it is rugged, reliable (allowing quick turnaround), requires minimal skill to operate and maintain, and is small enough be easily transported.

By flying at an altitude of 100m, the Cumulus can capture images at a resolution of 2.32 cm/pixel across an area of 2.75 km^2 within a 2 hour flight.

Assumptions:

Total Area to be covered	2,755	km2
	275,500	Hectares
Image Coverage per UAV Flight	275	hectares
Duration of UAV Flight	2	Hours
Av. Turnaround time	0.5	Hours
Daylight hours	8	Hours

Flights per day per UAV	3	Flights
Average Flying days per Month	20	Days
UAVs per Launch Team	2	UAVs

Calculations:

25% of the PNP	688.75	Km2
	68875	Hectares
Area covered by one UAV in one month	16500	hectares
Number of UAVs to cover ~25% in one month	4	UAVs

Survey Period	**Flying days available**	**No. of UAVs required**	**Teams required**
4 months	80	4	2

For an annual survey frequency conducted within a 4 month period (25% of the park area per month), the setup would be 4 UAVs operated by 2 drone teams. Each team would consist of 2 staff, with a vehicle and 2 UAVs. Each team would be provided schedule of where to launch the UAVs and would launch each drone 3 times a day (6 launches a day in total per team). The UAVs would be setup to fly on autopilot according to a flight plan that is loaded into the drone before launch. The teams would go to the assigned GPS location of the landing to retrieve the drone and swap out the battery and memory card before proceeding to the next launch. At the end of the day the teams would return to base and the full memory cards would loaded onto a computer.

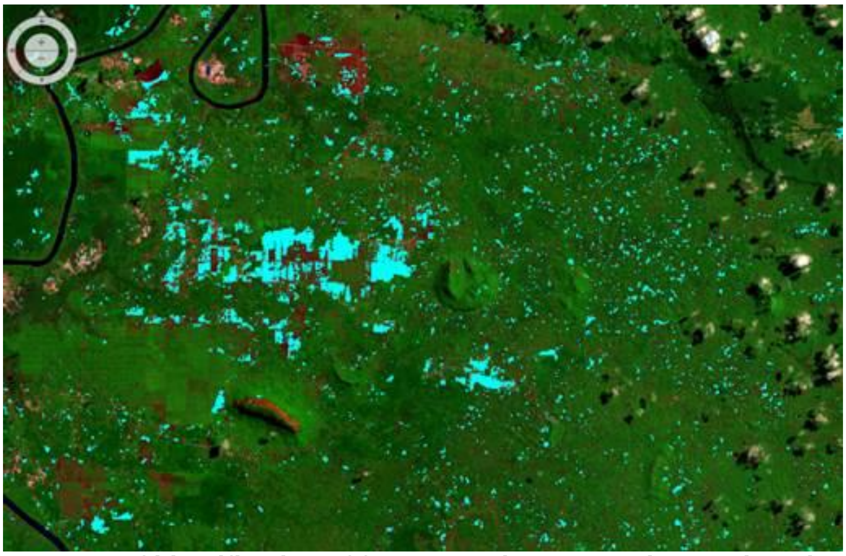
2. Consolidate:

An automatic workflow would process the captured images using photogrammetry software into an orthomosaic geo-referenced image map of the Park. There are multiple photogrammetry software packages available. Examples include Pix4Dmapper (https://pix4d.com/), AgiSoft Photoscan (http://www.agisoft.com/) and ERDAS IMAGINE UAV (www.hexagongeospatial.com). For this business case ERDAS IMAGINE UAV has been selected as it is integrated with ERDAS Imagine, the Geographic Information System (GIS) selected. Each day, as an additional section of the park is surveyed, the images would be processed automatically and added to the GIS where an updated view of the Park can be viewed and compared with previous surveys.

3. Analyse:

Manual and automated analysis of the image maps would be conducted within the GIS software, ERDAS Imagine (www.hexagongeospatial.com);

- Monitoring Wildlife Populations: Within the GIS, ERDAS IMAGINE, the spatial modeller tool, or an image recognition module called Objective, would be used to automate the identification of wildlife species. Initially the wildlife species would have to be manually classified to train the model, and then subsequently the workflow can identify them automatically. The end result is the identification of the individual animals on the map by species (and potentially sex and age), from which counts, distributions, population estimates and trends (compared to previous periods) can be automatically generated.
- Monitoring Habitat Changes: Within the GIS, ERDAS IMAGINE, the spatial modeller tool, would be used to automate the identification of the different types of vegetation, roads, logging and habitat types. Initially the different features would be classified, and then subsequently the workflow can identify them automatically. Specific workflows would be configured to visually identify changes between images on different days and calculate change statistics. For instance a deforestation workflow would be used to visually identify regions of forest loss and calculate the % loss and rate.



Example of identification of forest loss between 2 dates, where blue areas are regions of forest loss.

Monitoring Invasive Species: Within the GIS, ERDAS IMAGINE, the spatial modeller tool would be used to process the multispectral image map to identify automatically the classified invasive species, and the unknown species (potential new invasive species). Specific workflows would be configured to visually identify changes between images on different days and calculate change statistics. The locations of unknown species would be automatically reported for on the ground investigation and classification.

4. **Report:**

To maximise the value of the analysed data for decision making the GIS would be integrated with a web based analytics platform called Smart M. Apps (www.hexagongeospatial.com). This would allow park management and stakeholders the ability to review the latest trends for populations, habitat and invasive species from any computer, tablet or phone that has an internet connection. In addition recent and historical maps of the park can be dynamically viewed and compared.

OUTCOMES AND CRITICAL SUCCESS FACTORS

Anticipated Outcomes

- Predicted to provide increased accuracy in animal counts.
- Provides increased visibility of trends in animal populations and potentially allows an increased number of species to be tracked.
- Allows the number of species monitored to be increased retrospectively.
- Provides increased visibility of habitat changes.
- Provides visibility of the trends in the distribution of invasive species, and enables new invasive species to be identified earlier.
- The increased frequency of the surveys enables threats to be identified and conservation decisions to be taken more quickly.
- The increased standardisation and reproducibility of the surveys enables detailed analysis and independent verification.
- Allows the impact of conservation programmes can be objectively assessed.
- Provides summary data on trends to park management and stakeholders in an accessible way.

Critical Success Factors

- The selection of drone equipment that is durable, and comparatively easy to maintain and operate, yet is viable and cost-effective in the context of the finances of PNP.

- UAVs. The purchase of spare UAVs and a full kit of spare parts enabling the service to be reinstated as quickly as possible in the event of UAVs being lost or damaged.
- The availability of technical support to undertake remote software configuration and resolve issues that cannot be resolved by the PNP staff on the ground.
- The selection of software that meets the requirements of PNP, is cost-effective and able to be maintained.
- The training of PNP staff in the operation and maintenance of the UAVs and in the use of the software.
- Governance arrangements that ensure that the service is available not just to the PNP staff but also to others (e.g. NGOs) wishing to make use of it or a prescheduled (and perhaps fee paying) basis.
- Survey data and results need to be promptly shared with all key stakeholders.

COSTS & RISKS

Costs

These costs are based on the assumption of conducting ecological monitoring of the whole of PNP once a year (during a 4 month period).

Project Costs	Details	Frequency	Amount
UAV Purchase	6 x Cumulus UAV systems ($20,000 each) – 2 in phase 2, an additional 4 in phase 3	One-time	$ 120,000
UAV Annual Maintenance	6 x UAV Service/Repair ($2,500/per UAV/year)	Annually	$ 15,000
UAV/GIS Software Purchase	1 x Non-Profit License of ERDAS IMAGINE, IMAGINE UAV & IMAGINE Objective software ($11,200 per licence)	One-time	$ 11,200
UAV/GIS Software Maintenance	1 x Non-Profit Software Maintenance/Updates for IMAGINE software ($1900 per year/licence)	Annually	$ 1,900
Web Platform Setup and Licence	License, configuration and hosting for Smart M. Apps web platform ($11,900 per year/licence)	Annually	$ 11,900
IT Equipment Purchase	1 x Desktop Computers (~$2,500 each) 3 x Laptops (~$500 each) 2 x Data storage devices (~$1000 each)	One-time	$ 6,000
Labour	5 x Staff (1 Manager/Operator, 1 Analyst, 3 UAV operators) at average of $13.5/day and 240 working days/year	Annually	$ 16,200
Operating Expenses	2 x Teams Travel Expenses at average of $12/day and 240 working days/year	Annually	$ 5,760

Costs for sourcing and implementing the solution are not included.

Risks

Risk	Potential Impact	Mitigation
Unable to repair/maintain UAVs	Capability falls into disuse	Ensure that sustainable capability to maintain UAVs is built into the proposal from day 1
Staff unable to operate UAVs and/or software	Capability falls into disuse	Ensure training of staff and or hire of skilled staff is built into proposal
Software unable to perform as required	Capability falls into disuse	Ensure that software is able to meet requirements
Annual costs are unaffordable	Capability falls into disuse	Ensure up front that costs are affordable & sustainable

UAVs lost in operation	Need to purchase new drone	Ensure contingency built into budget. Ensure model selected is as reliable as possible, and that spares are available.

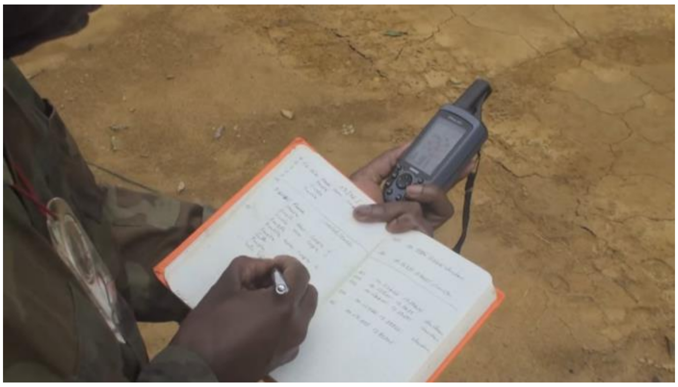
Unmanned Aerial Vehicles for Surveillance

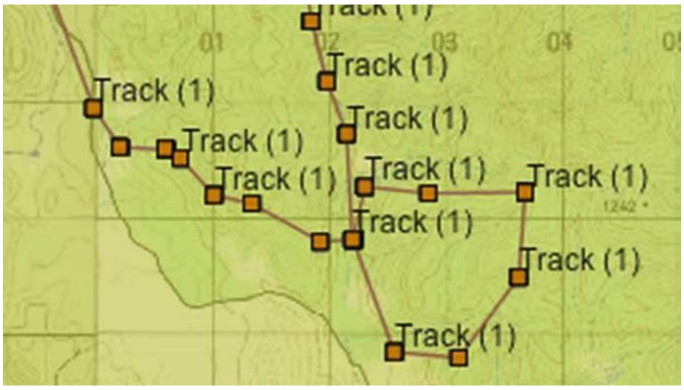
THE CHALLENGE

It is understood that biodiversity in PNP is threatened by the activities of poachers, illegal loggers and herders. Detection of these threats via random vehicle and foot patrols has had limited success due to the large geographic area and limited resources available to conduct patrols. The problem is particularly acute during the rainy season when the animals are dispersed and patrolling becomes more difficult.

To help solve these issues, Zoological Society of London (ZSL) have an existing initiative in PNP to deploy:

- SMART, which is a reporting, database and mapping tool which enables rangers to locate poaching hotspots and take effective decisions as a result. Webpage: http://www.smartconservationsoftware.org/materials





- Instant Detect, which comprises cameras and sensors that detect incidents and send near real-time alerts via satellite. Webpage: https://www.zsl.org/conservation-initiatives/conservation-technology/instant-detect

We believe that there is potential for Unmanned Aerial Vehicles (UAVs) to complement both these technologies and solve the challenges of:

- Conducting effective day and night surveillance of high risk areas in the park considering limited patrol resources.
- Directing the patrols to the current location of park intruders during day or night, and providing live intelligence to enable their apprehension.

OPTIONS CONSIDERED

Option	Description	Pros	Cons
Take no action now	Continue with random patrols supported by SMART reporting and satellite cameras.	- No further investment required	- Low effectiveness in detection of threats especially in rainy season, and limited ability to apprehend intruders at night or away from the satellite camera locations.

Option	Description	Pros	Cons
Long range UAV (Persistent Surveillance)	Use of UAVs with long endurance (6-12 hours) to provide strategic surveillance of high-risk areas of the park during the day or night.	- Able to provide patrols or rapid response teams with actionable live video surveillance of large areas of the park for extended periods during the day or night. - Allows the rangers to optimise where limited resources are deployed. - Able to provide patrols on the ground with aerial 'backup' during apprehensions. - Able to provide surveillance even when no patrols are active in the park.	- Investment for long endurance UAVs is significant ($200,000+). - Local capability is needed to operate and maintain the UAV operations. - A ranger is required to monitor the live-video feed and determine if action is required.
Short range UAV (Tactical Surveillance)	Use of UAVs with short endurance (20-40mins) to provide patrols with tactical surveillance of their immediate vicinity during the day or night.	- Less investment and expertise required than for long range UAVs. - Rangers are able to improve the effectiveness and safety of their patrols as they are able to see beyond their line of sight and see intruders during the night.	- Surveillance is limited to the vicinity (few km) of a ranger patrol and only for short durations during the patrol. - Needs to be operated by a patrol (when there is no patrol active there is no benefit).

RECOMMENDED SOLUTION

Solution Overview

The recommended solution is to utilise short-range Unmanned Aerial Vehicles (UAVs) to increase the chance of detecting illegal activity in the park, and enable the rangers to locate and apprehend the intruders during the day or night.

Based on intelligence provided by SMART the Ranger patrols would focus on the high-risk areas of the park or respond to specific alerts from the satellite-connected cameras by travelling to the location. The patrol would carry a UAV in a rucksack, and when aerial surveillance is required they would launch the UAV. The UAV would include thermal and high definition (HD) video cameras and radio transmitter to stream the live video to a handheld controller operated by a member of the Ranger patrol. The thermal cameras allow intruders to be identified at night by their body heat, or the heat from a vehicle or fire. When the intruder is located, the UAV would be set to track the intruder automatically, and the Ranger patrol would then move to intercept and apprehend. When the intruder is apprehended or when the batter level drops below a certain level, the UAV would return to the Rangers and land automatically for retrieval.

Examples of commercially available autonomous UAVs that are ruggedized and proven for surveillance include:

Short Range

Huginn X1
(Sky-Watch)
25 minute endurance
2km live-video range
http://sky-watch.dk/products/huginn-x1/

Medium Range

Heidrun V1
(Sky-Watch)
2 hour endurance
25km live-video range
http://sky-watch.dk/products/heidrun-v1/

Long Range

Superbat DA 50
(Martin UAV)
10 hour endurance
50km+ live-video range
http://martinuav.com/uav-products/super-bat-da-50/

OUTCOMES AND CRITICAL SUCCESS FACTORS

Anticipated Outcomes

- Rangers will be able to extend the scope of their patrols and get visibility of areas that are inaccessible.
- Rangers will be able to identify the live location of unauthorized individuals during the day or night, enabling them to take action to apprehend.
- Potential to provide visual evidence to support prosecution.

Critical Success Factors

- The Rangers are trained in the effective operation and maintenance of the Surveillance drone.
- Rangers are clear on the actions to take following an alert from a satellite camera and have the capability to respond.
- The selection of drone and camera equipment that is durable, and comparatively easy to maintain and operate, yet is viable and cost-effective in the context of the finances of PNP.
- The drones and cameras may get damaged. The purchase of spare drones and cameras and a full kit of spare parts enabling the service to be reinstated as quickly as possible.

- The availability of technical support to undertake software configuration and resolve issues that cannot be resolved by the PNP staff on the ground.

COSTS & RISKS

Costs

Project Costs	Details	Frequency	Amount
UAV purchase	1 x short range surveillance UAV, controller, extra batteries and training. e.g. Huginn X1 from Sky-Watch (est. $ 50,000)	One-time	$ 50,000
UAV Annual Maintenance	1 x UAV Service/Repair ($3,000/per UAV/year)	Annually	$ 1,000

Risks

Risk	Potential Impact	Mitigation
Unable to maintain the surveillance drone	Capability falls into disuse	Select a drone that requires minimal maintenance. Conduct training on maintenance.
Staff unable to operate drones and/or software	Capability falls into disuse	Ensure staff are trained on the use of the drones
Annual costs are unaffordable	Capability falls into disuse.	Ensure up front that costs are affordable & sustainable
Drones lost in operation/shot down by poachers	Need to purchase new drone	Ensure contingency built into budget. Ensure drone model selected is as reliable as possible and that sufficient parts are purchased to enable service to be re-established quickly.
The rangers are unable/do not respond to alerts	Investment is ineffective	Ensure that planning includes the development of an effective rapid reaction capability

Connected Camera Traps for Ecological Monitoring

THE CHALLENGE

Camera traps have been utilised in PNP since 2012 and are used to monitor 20-30 species. There are currently 30 camera traps setup by the park and around 200 set up by other organisations (universities and NGOs) and the data is collected manually on a monthly basis by 2 staff over a period of 6 days. The photos (around 250 per camera per month) are then manually processed by a member of staff over a period of 2 weeks. Once the images have been processed, a member of staff prepares an analysis report for the park management, to inform their conservation decisions.

The current process of collecting, processing and reporting on the camera traps is time consuming, and there is inconsistent collaboration between the stakeholders. This reduces the effectiveness of research and ecological monitoring. In addition currently a large proportion of traps breakdown in the field – this is not detected until the camera is visited.

The need is to reduce the effort in reporting observations of species, increase the quality and breadth of monitoring, and increase the collaboration between the stakeholders. It is also necessary to reduce the proportion of cameras that are out of operation at any one time.

OPTIONS CONSIDERED

Option	Description	Pros	Cons
Take no action now	Continue with manual collection and manual processing of camera traps	- No additional costs.	- Continued high manual effort. - Less than optimal collaboration between all stakeholders. - Continued high redundancy from duplicate work and non-working cameras.
Private cellular network enabled camera traps	Camera traps enabled to transmit by GSM/3G. The increased bandwidth available with 3G would allows more and higher quality images to be collected automatically.	- Cellular enabled camera traps are readily available. - If based on a private cellular network the ongoing costs would be small. - Images are sent in near real-time, reducing the time between observation and analysis.	- Would require investment and setup of private cellular network.
Drone enabled camera traps	Traditional camera traps with Wi-Fi-enabled memory cards. A Wi-Fi-enabled drone is used to periodically fly over the cameras to gather the images taken.	- No cellular or satellite network would be required to collect the data from the camera traps. This would reduce data costs.	- Technology not proven. - Would require significant levels of drone operations to cover all of the cameras.
Radio network enable camera traps	Camera traps with radio transmitters.	- Could piggy back on network of radio based voice communications.	- Bandwidth for sending the images maybe insufficient. - Cameras with radio compatible transmitters do not exist – would have to be added on.

RECOMMENDED SOLUTION

Solution Overview

The recommended solution is to replace the existing camera traps with a scalable network of cellular connected camera traps that wirelessly transfer the images taken to a shared cloud platform that streamlines, and where possible automates, the image processing and reporting.

The solution consists of the following elements:

1. Acquisition

Cellular enabled camera traps operate in a similar way to a traditional camera traps, taking photos during day or night when triggered by infrared motion. However once a photo is taken, instead of waiting to be collected manually, the photo is transferred by a near real-time data transfer using a cellular connection to a server in the cloud. To be able to stay operational without maintenance for long periods each camera would be connected to a solar panel unit. As the images are transmitted as they are captured, damaged or misdirected cameras can be quickly identified and resolved. An example of a professional grade cellular camera trap that is reliable and has a quick trigger time is:

PC900C HyperFire Cellular Professional Covert Camera Trap (Reconyx)
http://www.reconyx.com/product/PC900C-Cellular-HyperFire-Professional-Covert-IR

2. Processing

The raw images then need to be processed to discard empty images and classify the wildlife species that are captured. It is proposed that images captured are automatically imported into a shared platform where the images can be collaboratively classified. This image classification can be conducted by PNP researchers and also supported by a citizen science crowdsourcing platform like Zooniverse (www.zooniverse.org) and MammalWeb (https://www.mammalweb.org). As the cellular cameras send the photos received on a near real-time basis the number of images to process each day is relatively low (on average about 8 photos per camera per day in PNP). Hence it is feasible for local researchers to process them each day as they are received.

3. Reporting

To maximise the value of the classified images for decision-making it is proposed that the shared platform would include or be integrated with an analytics platform to provide automated reporting. As the images are classified the park management and stakeholders would have the ability to review the latest sightings, and trends from any computer, tablet or phone that has an Internet connection.

By connecting all camera traps in the park to a single shared platform, individual researchers and stakeholders will gain access to wider data sets and with reduced manual effort to collect and process data.

OUTCOMES AND CRITICAL SUCCESS FACTORS

Anticipated Outcomes

- Reduce the delay between when wildlife is observed by the cameras and is reported.
- Reduce the manual effort required for camera data collection and retrieval.
- An increase in the number of species that are able to be identified.
- An increase in the sharing of camera trap imagery between stakeholders.
- Problems with the cameras can be identified immediately.

- Provides a scalable platform for adding additional cameras.
- Potential increased engagement with wider citizen population through a citizen science platform.

Critical Success Factors

- Camera traps are deployed correctly (in correct and secure locations, with right settings, etc) so that they do not require unscheduled visits.
- The creation of an effective collaboration between organisations who need to use camera traps.
- The communications capability must be able to upload images at a sustainable cost.

COSTS & RISKS

Costs

The costs below are estimations based on supplier quotations and assumptions of usage.

Project Costs	Details	Frequency	Amount
Camera purchase	30 x Cellular cameras (est. $1000 each) and 30 x solar panels (est. $250 each).	One-time	$ 37,500
Camera Installation	Installation of the cameras and testing - 10 days for 2 staff including transport (av. $40/day)	One-time	$ 400
Camera Maintenance	Maintenance of cameras, required 2 times per year, each requiring 6 days for 2 staff including transport (av. $40/day)	Annual	$ 240
Shared Platform	Cost to be determined.	One-time	-

Note the cost breakdown assumes a cellular network available and excludes any network data costs.

Risks

Risk	Potential Impact	Mitigation
Only partial participation in the scheme by the relevant stakeholders.	Continued duplication of effort.	Make working in the park dependent on sharing of data.
Costs of cellular data is unaffordable.	Scheme falls into disuse.	Ensure that the deal is properly calculated up front and affordable.
Sharing platform does not meet user needs.	Scheme falls into disuse.	Ensure user needs are well understood up front and select correct platform.

Geographic Information Systems for Habitat Change Monitoring

THE CHALLENGE

Habitats, and the biodiversity they sustain, is impacted by logging and cattle herding. Due to the large area of the park and limited resources it is challenging to identify habitat changes across PNP and make informed conservation and management decisions in a timely manner.

OPTIONS CONSIDERED

Option	Description	Pros	Cons
Take no action now	Continue current approach to habitat monitoring.	No investment required.	Limited visibility of habitat changes.
Use data from UAVs	Use higher resolution imagery collected by UAVs instead of using satellite data.	Higher resolution data allows more analysis and insight.	UAVs operations to cover the entire park on regular basis requires significant operations and management.
Use satellite data	Use imagery available from satellite constellations.	Low resolution satellite data is freely available and is frequent and comprehensive.	Resolution is low and limited by cloud cover.

RECOMMENDED SOLUTION

Solution Overview

The recommended solution is to use free and/or commercial satellite imagery together with a Geographic Information System (GIS) to automatically highlight the changes to habitat within the PA.

By using regular satellite data feeds, this solution will enable PA management and stakeholders to get regular updates on the habitat changes. This analysis and the underlying imagery would then shared with the Park management and stakeholders via an accessible web interface.

The solution consists of the following elements:

1. Acquisition: Satellite Imagery

There are many different imagery satellite constellations depending on requirements. It is proposed to initially use freely available satellite imagery and setup a software program to download it as it becomes available. The main freely available satellite imagery is:

a. Landsat: 30m resolution imagery with a 16 day refresh rate
http://landsat.usgs.gov/Landsat_Search_and_Download.php

b. Sentinel: 10m-60m resolution imagery (multiple spectral bands) with 10 day refresh rate
https://sentinel.esa.int/web/sentinel/sentinel-data-access/access-to-sentinel-data

A key advantage of satellite imagery data is that historical data is available and can be analysed for trends. The key challenge with satellite imagery is cloud cover. PNP is particularly cloudy and it is estimated that only imagery from October/November to March each year is clear. Higher resolution data is available.

2. Processing: Geographic Information System

It is proposed to use a Geographic Information System (GIS) software like ERDAS Imagine (www.hexagongeospatial.com). The GIS will be configured to automatically import and process the downloaded satellite imagery as it becomes available. The satellite imagery will then be available for analysis, and change detection workflows will highlight the habitat changes (vegetation, forest cover, land usage) over time. This is the same GIS system that would be used to support the Ecological monitoring using UAVs.

3. Reporting

To maximise the value of the analysed data for decision making the GIS would be integrated with a web based analytics platform like Smart M. Apps (www.hexagongeospatial.com). This would allow park management and stakeholders the ability to review the latest habitat trends from any computer, tablet or phone that has an internet connection. In addition the latest and historical maps of the park can be dynamically viewed and compared.

OUTCOMES AND CRITICAL SUCCESS FACTORS

Anticipated Outcomes

- Provides high level visibility of habitat changes and status to Park management and stakeholders on a regular basis.
- Once setup, the change analysis and reporting is automated, minimising the on-going need for specialists.

Critical Success Factors

- Key ecological monitoring questions are clarified early so that the correct satellite data feeds and change monitoring workflows can be setup.
- Non-profit/NGO/environmental conservation status is leveraged effectively to obtain higher quality satellite feeds at low/no cost.
- Appropriate resources on the ground are trained in the use of the chosen GIS system.
- Park Management and Stakeholders are trained in how to access and interpret the data.

COSTS & RISKS

Costs

Please note these costs are also included within the UAVs for Ecological Monitoring business case.

Project Costs	Details	Frequency	Amount
GIS Software Purchase	1 x Non-Profit License of ERDAS IMAGINE, IMAGINE UAV & IMAGINE Objective software ($11,200 per licence)	One-time	$ 11,200
UAV/GIS Software Maintenance	1 x Non-Profit Software Maintenance/Updates for IMAGINE software ($1900 per year/licence)	Annually	$ 1,900
Web Platform Setup and Licence	License, configuration and hosting for Smart M. Apps web platform ($11,900 per year/licence)	Annually	$ 11,900
IT Equipment Purchase	1 x Desktop Computers (~$2,500 each) 1 x Data storage devices (~$1000 each)	One-time	$ 3,500

Risks

Risk	Potential Impact	Mitigation
System is not maintained.	Change monitoring will not be available.	Ensure that procedure for maintaining the system is in place. Processing conducted by a 3rd party or out of country.
Stakeholders don’t use system.	Systems falls into disuse, and no benefit is gained.	Ensure that stakeholders are engaged during project and provided guidance on how to use it.
System doesn’t take advantage of newly available satellite imagery (when additional satellites are launched).	Full benefit of system will not be realised.	Ensure that procedure in place for integrating newly available satellite data.

Satellite Emergency Messaging Devices

THE CHALLENGE

Currently there is no cellular coverage in PNP. Radios for staff communication have been previously trialled in PNP but are not utilised as they do not work. We understand that walkie-talkies are used by park rangers, but that these have limited range. There is therefore today no effective way for visitors or staff to communicate or send emergency alerts whilst in the middle of park. This severely limits the operational effectiveness of staff and increases the safety risk to visitors and staff. Incidents like vehicle breakdown, accidents, and aggressive poachers cannot be reported, and may become endangering or even life threatening in the absence of assistance. The intent of this business case is to outline a sustainable method of emergency alerting, location reporting and communications.

Note that this would be a short-term solution only if the recommended deployment of a communications network set out previously is undertaken. In this instance smartphones or 2 way VHF radios can perform the same function.

OPTIONS CONSIDERED

Option	Description	Pros	Cons
Take no action	Continue with no communication method within PNP for visitors and simple walkie-talkies for staff.	- No further investment required.	- Poor staff communications. - Unable to respond effectively to threats. - Safety risk to staff and visitors.
Radio Transceivers & repeaters	Install radio repeater units throughout park, and using radio transceivers for communication.	- Enables full voice & text comms. - No pay per use charges. - Enables low bandwidth data in short-term. - Relatively inexpensive.	- Complex to deploy, maintain and use. - May not be sustainable considering previous experience with radio in PNP. - Masts can be vandalized.
GSM/3G Network	Install a GSM/3G network covering the park	- Would enable use of smartphones with all attendant advantages.	- Not viable for the public network operator. - A private network is possible but the investment is high.
Satellite Phones	Utilize satellite phones	- Simple to deploy – plug and play. - Robust technology.	- High device cost and monthly cost. - Does not provide tracking.

RECOMMENDED SOLUTION

The proposed solution is to provide a **Satellite Emergency Notification Device (SEND)** for each vehicle entering the park. For emergencies, the user can click an SOS button to send an emergency alert that includes their location. For tracking, the devices provide regular location updates that can be monitored by park management. For communication, some devices also allow text messages to be sent and received to other SEND devices or normal mobile phones (if they are connected to a mobile network outside the park).

The Satellite Emergency Notification Devices (SEND) are handheld devices which include GPS and communicate via one of the commercial satellite networks. SOS alerts and messages, including details of current location, are transmitted via the satellite network and are delivered via email or SMS. The devices run off rechargeable batteries and can be supplied with lighter socket chargers for recharging from vehicles.

It is proposed that, when visitors enter the park, they are provided with a satellite messaging device, and guidance on how to use it, in exchange for a deposit or fee. In the case of a problem in the park, the visitors can press the alert button to request assistance. An acknowledgement can be sent, and the visitor can be rescued. Before leaving, the visitor would return the device to the park.

There are a number of Satellite Emergency Notification Devices available which will provide SOS alerting and tracking:

SPOT Gen3
(Globalstar Satellite network)

DeLorme InReach SE
(Iridium Satellite Network)

Briartek Cerberus
(Iridium Satellite Network)

The recommended solution at this time is the DeLorme InReach SE (http://www.inreachdelorme.com/product-info/inreachse.php), as, in addition to SOS alerting, it allows 2-way text messaging. The 2-way text messaging enables communication during an emergency to confirm what is required, and enables staff to coordinate operations anywhere in the Park and to mobile phones outside the park.

SOS alerts could be configured to be received by SMS and/or email in Tanguiéta. SEND devices would be provided to staff in Batia and Porga who would also receive the alerts. Once the emergency alert is received, appropriate action needs to be taken to respond. During the deployment of the SEND devices the emergency alert response process would be defined.

OUTCOMES AND CRITICAL SUCCESS FACTORS

Anticipated Outcomes:

- Visitors and staff can raise an emergency alert for assistance throughout PNP.
- Visitors and staff can be located and communicated with throughout PNP.
- PNP rangers and management can communicate with short text messaging throughout PNP.

Critical Success Factors

- Messaging devices must be regularly recharged (by connecting them to vehicle lighter socket).
- Visitors and staff must be provided with guidance on how to operate the devices.
- System is required for providing visitors with SENDs and retrieving them when they leave.
- Responsibilities for taking action when receiving an emergency alert must be allocated.

COSTS & RISKS

Costs are indicative and based on initial quotations from suppliers.

Project Costs	Details	Frequency	Amount
Device purchase	20 devices (DeLorme InReach SE**)** at $380 each (shipment, activation & lighter charger inclusive); - 10 for visitor vehicles (estimated peak per day) - 2 for fixed locations (Batia, Porja) - 8 for PNP vehicles/teams	One-time	$ 7,600

Connection subscription	10 x $270/year Recreation Plan (for Visitors) - inc. 40 messages/month & unlimited tracking/location pings 10 x $540/year Expedition Plan (for PNP Staff) - inc. unlimited messages/tracking/location pings	Annually	$ 8,100

Risks	Potential Impact	Mitigation
Loss or theft of device	Need to replace device which adds to costs.	Attach devices to vehicles.
Annual costs are unaffordable	System falls into disuse.	Ensure up front that tariffs are affordable & payment can be sustained. Charge visitors for usage of devices.

Acoustic sensor networks

THE CHALLENGE

There is a need for large-scale and long-term ecological monitoring in order to establish effective conservation strategies. Surveys of mammals are infrequent and for many species non-existent. This severely hampers the reliability of estimates of population numbers and trends. There is also a need for real-time monitoring of several threats, namely logging, poaching and habitat encroachment by farmers. Many species communicate acoustically and can be identified by their species-specific calls. A network of acoustic sensors can be deployed and animal call data remotely collected. The sound file analysis can be automated for efficient identification of species present.

The same technology can detect the sound signatures of several human activities, such as gunshots, chainsaws and vehicle movement. Identification of human threats could produce real-time alerts to be communicated to the rangers and park staff for decisive and rapid responses.

ALTERNATIVE SOLUTIONS

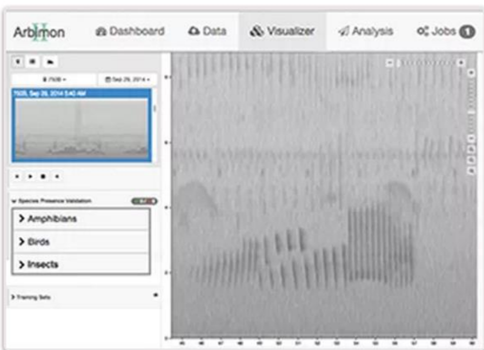
Option	Description	Pros	Cons
Take no action	Continue with no established acoustic sensor network.	- No further investment required.	- Not collecting potentially huge data resource on species and threats. - No large-scale and continuous remote sensing capabilities.
Microphone array + data manually collected	Install microphone arrays across the park and manually collect SD cards on a regular basis.	- Easy to deploy. - Requires no existing communication infrastructure. - Relatively inexpensive. - Long battery life relative to cameras. - Less visible than camera traps – less prone to vandalism.	- Requires retrieval of data which could be time-consuming. - No real-time alerts so not effective for detection and response to threats.
Microphone array + data transmitted via wireless network	Install microphone arrays that are connected to a wireless network.	- Enable real-time monitoring. - Can also be used to detect threats (e.g. gunshots, chain saw sounds) and send alerts.	- More expensive. - Requires existing wireless infrastructure.

Option	Description	Pros	Cons
Automated classification of species	Use of software that enables automatic species identification from sound files.	- Faster processing of data. - Can be applied to any species (mammal, insect, bird).	- Requires pre-configuration with sample sound files. - Error rates can vary depending on habitat type and background noise.
Manual classification of species	Manual processing of sound data and human-based identification of species.	- Cheap. - Requires no pre-programming. - Requires no specialist software.	- Extremely time-consuming. - Requires high level of expertise. - High error rate. - Delayed identification meaning no real-time monitoring.

RECOMMENDED SOLUTION

There are several fully integrated and supported acoustic sensor devices and analytical software packages on the market. Microphone devices with supported accompanying analytics is recommended to ensure the data is processed correctly and can be translated into useful information for management decisions.

The recommended solution is to use the Automated Remote Biodiversity Monitoring Network (ARBIMON) acoustic sensors and analytical software solutions.



The sensors are relatively inexpensive, long-lasting and can be joined to an existing wireless network. They are powered by solar (and has an accompanying solar panel on each device). They have already been tested in a range of environments and for a number of different species.

The analytical software package is flexible and can be configured to suit any chosen sample species. The cloud-computing platform includes an intuitive interface for using species-specific identification using algorithms. The package allows the easy set-up of the species-specific identification algorithms that are used to automatically identify species from their calls.

OUTCOMES AND CRITICAL SUCCESS FACTORS

Anticipated Outcomes:

- Remote monitoring of a variety of species can be achieved.
- Automation of analysis will generate useful information from large volumes of data quickly.
- Threats can be detected in real-time for quick responses.

Critical Success Factors

- The microphones and analytics software must be calibrated correctly.
- Existing wireless networks must be in place to facilitate transmission of acoustic data.
- Analytics software must have adequately low error rates for accurate assessments.

COSTS & RISKS

Costs are indicative and based on initial quotations from suppliers.

Project Costs	Details	Frequency	Amount
Acoustic sensor devices	10 devices @ $2000 each	One-time	$20,000
Analysis platform	$0.03 per 1 minute recording for 1 year (1 hour per device per day = 60x10x365x0.03=6,570)	Annually	$6,570

Risks	Potential Impact	Mitigation
Loss or theft of microphone	Need to replace device – added costs.	Devices are well hidden and secured.
Annual costs are unaffordable	System falls into disuse.	Ensure up front that tariffs are affordable & payment can be sustained. Agree on data limits beforehand.
No pre-configuration or training given in use of analytics software	No analysis of data.	Ensure proper configuration of algorithms and provide adequate training for the use of the analytics. .

Application layer

THE CHALLENGE

Many protected areas contain ad-hoc and unconnected technology solutions, which may be maintained by a variety of organisations and stakeholders with little to no collaboration between them.

Today the lack of connectivity and collaboration hampers research efforts by limiting the data available to researchers and the limited communications slows decision-making and responses to incidents. The data collected from devices in the field requires manual upload for it to be analysed, and so there is a significant delay between data collection and analysis. The limited analytical capabilities can cause a backlog of data and reduce the usefulness of the data.

The solution is to implement a system which:

- provides connectivity to devices in the field
- provides storage of data and analytics in the cloud
- enables communications and collaboration between stakeholders of protected area and between those people and others outside the protected area.

OPTIONS CONSIDERED

Option	Description	Pros	Cons
Take no action	Continue with no connectivity between devices, no collaboration platform between staff and stakeholders, and no integrated analytics.	• No further investment required.	• Duplication of work. • Collaboration is limited by lack of connectivity. • No real-time alerts. • Decision-making hampered. • No alignment in strategy. • Data limited in its usefulness.
IoT, Storage and Analytics without collaboration platform	Devices in field are connected to platform, and can be monitored and receive alerts and instant data. Data can be stored and analysed.	• Enable real-time monitoring and production of alerts if needed. • Data can be automatically stored in common database. • Shared analytical tools.	• Requires external specialist support from developers– can be remotely provided. • Lack of collaboration tool constrains sharing, engagement, collaboration.
IoT + Analytics + Community platform	The above analytical and monitoring capabilities. In addition a platform where stakeholders can share ideas, knowledge and best practice.	• Above benefits. • In addition, governance will be improved, decisions will be more clearly communicated to all stakeholders. • Strategies of stakeholders better aligned.	• The most expensive option. • Requires the most specialist support, though all can be provided remotely.

RECOMMENDED SOLUTION

The application layer is the third layer in the IoT architecture illustrated in Section 6 and is designed to address several challenges, both technical and non-technical:

- **The IoT 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.
- **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 but these can be remotely based.
- **Collaboration platform:** As previously stated, park management is being 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 often work in isolation, not discussing issues, not sharing information, at times duplicating efforts. Lack of participative tools is preventing effective collaboration, leading to misunderstanding and mistrust, and 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 a simple mobile phone. Over time, if the political will and leadership are there, these platforms can help

transform a culture of non-collaboration into one of effective networking, discussion, sharing, joint research and effective engagement.

This 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.

The proposed solution is to implement an integrated platform provided by cloud software provider Salesforce with three main integrated capabilities (IoT platform (Heroku), Wave Analytics Platform, Community Cloud).

1. **Heroku,** the recommended IoT platform, allows one to build applications in several languages that can be scaled with ease. With flexible app-building capabilities through 'buildpacks', there can be a tailored platform for monitoring data collected by the devices deployed in the field.

2. **Wave Analytics** is a powerful cloud-based analytical tool. Its connectivity with the Community Cloud means that trends and outcomes of analysis can be delivered to contacts quickly. Wave apps can be built and customised to deliver the type of analysis needed for each data source.

3. **Community Cloud** can be easily configured to provide an online and SMS platform that can be accessed from any device, even a 2G phone, and used by Pendjari stakeholders to join or form specialist interest groups, engage in the discussions that interest them, ask questions, share files and access best practice information. Once established the platform can be easily scaled to encompass stakeholders from other WAP parks or even further afield.

OUTCOMES AND CRITICAL SUCCESS FACTORS

Anticipated outcomes:

- Stakeholders can start to collaborate in ways not previously possible, and to build trust.
- Connected devices will provide real-time alerts.
- Devices can be continually monitored.
- Information can be easily shared.
- Unprecedented amounts of data can be analysed.
- A greater number of questions can be asked of the data which increases understanding.

Critical success factors:

- A governance framework that sets conditions for participation within the platform and community and requires participants to use the platform.
- Adequate training and ongoing support is provided to prevent disuse of platform.

COSTS & RISKS

Project Costs	Details	Frequency	Amount
Community cloud	100 users: £588/month ($766) 50 users: 383*12 = 4596	Annual	$4,596
Wave Analytics	To be provided	Annual	TBD

IoT platform (Heroku)	Standard 1x: $25per dyno/month	Annual	$4000

Risks	Potential Impact	Mitigation
• Adoption is slow	• Users will consider the platform not useful. Platform requires critical mass to succeed	• Requirement for park staff and stakeholders to become members, and to put data onto system
• Costs become prohibitively high	• Platform falls into disuse or is cancelled	• Incorporating pre-paid plans into a budget will ensure costs are anticipated and agreed upon beforehand
• Lack of development expertise	• Platform cannot deliver the required outcomes and therefore falls into disuse	• Agreement with the Platform providers for the provision of technical support and training. Obtain support through Power of Us global network
• Lack of ongoing support	• Platform may not be able to be grown, or customised or scaled. It restricts the connection of devices, the level of analysis that can be conducted and the number of members on the community	• Agreement with Platform providers for ongoing support. Salesforce's Power of Us offers continuing advice to non-profits.

8. Estimated costs by deployment phase

The phased deployment strategy is summarised below. Based on this strategy the worksheet beneath provides the estimated cost breakdown by technology type and deployment phase. No timescales are given as no assumptions have been made about the length of each phase of deployment. However, for cost purposes we have assumed the length of each phase to be one year.

As-is
- Piecemeal technology investments, no comms, poor ability to scale

Phase 1
- Construct 4 masts. Pilot 2-way radio enabling communications (voice, text, GPS), security, and low bandwidth (9.6kb) data transfer for sensor alerts

Phase 2
- Build out of radio & pilot 4G/LTE, add additional mast, build out security sensor network, piloting of drones for monitoring and surveillance

Phase 3
- Roll out LTE, roll out full drone capability enabling annual ecological surveying & daily patrolling of sensitive areas of park

Phase 4
- Connect LTE backbone to Internet, applications layer for collaboration between stakeholders, sharing of data & analytical capabilities, conducting cloud based research

Costs summary

	$US				
	Phase 1	Phase 2	Phase 3	Phase 4	Ongoing operations and maintenance
COMMUNICATIONS INFRASTRUCTURE					
Mast construction	48000	12000	0	0	12000
Solar power	20000	30000	10000	10000	0
Links	8000	8000	0	28000	0
Base radios	10000	4000	0	0	0
Mobile/portable	8000	4000	0	0	0
LTE nodes	0	36000	72000	72000	0
Comm servers	0	0	0	50000	0
Smartphones	0	0	20000	5000	0
Fixed LTE	0	0	3000	10000	0
Design	20000	10000	10000	10000	0
Integration	10000	10000	20000	20000	0
Applications	5000	5000	10000	20000	0
Subtotal	**129000**	**119000**	**145000**	**225000**	**12000**
DRONES FOR ECOLOGICAL MONITORING					
Drones Cumulus	0	40000	80000	0	0
Maintenance	0	5000	15000	15000	15000
Software	0	22000	0	0	0
Software Maintenance	0	1900	1900	1900	1900
Web platform	0	11900	11900	11900	11900
Itequipment	0	6000	0	0	0
Labour	0	5,832	16200	16200	16200
Operating	0	2880	5760	5760	5760
Subtotal	**0**	**95512**	**130760**	**50760**	**50760**
CAMERAS FOR ECOLOGICAL MONITORING					
Camera traps	0	37500	37500	37500	0
Camera installation	0	400	400	400	0
Camera maintenance	0	480	960	1440	1440
Analytical software	0	2000	2000	2000	2000
Subtotal	**0**	**40380**	**40860**	**41340**	**3440**
SECURITY AND SURVEILLANCE					
UAV purchase	0	8000	0	0	0
UAV maintenance	0	1000	1000	1000	1000
Subtotal	**0**	**9000**	**1000**	**1000**	**1000**
GIS					
GIS Software Purchase	0	11200	0	0	0
UAV/GIS Software Maintenance	0	1900	1900	1900	1900
Web Platform Setup and Licence	0	11900	11900	11900	11900
IT Equipment Purchase	0	14700	0	0	0
Subtotal	**0**	**39700**	**13800**	**13800**	**13800**
ACOUSTIC SENSORS					
Acoustic sensors	4000	16000	20000	0	0
Sensor analysis	1314	6570	13140	13,140	13,140
Subtotal	**5314**	**22570**	**33140**	**13140**	**13140**
Total	**134314**	**326162**	**364560**	**345040**	**94140**
4 phase total				**1170076**	0