Law Enforcement Monitoring

Lessons learned over Fifteen Years in the Albertine Rift Region of Africa

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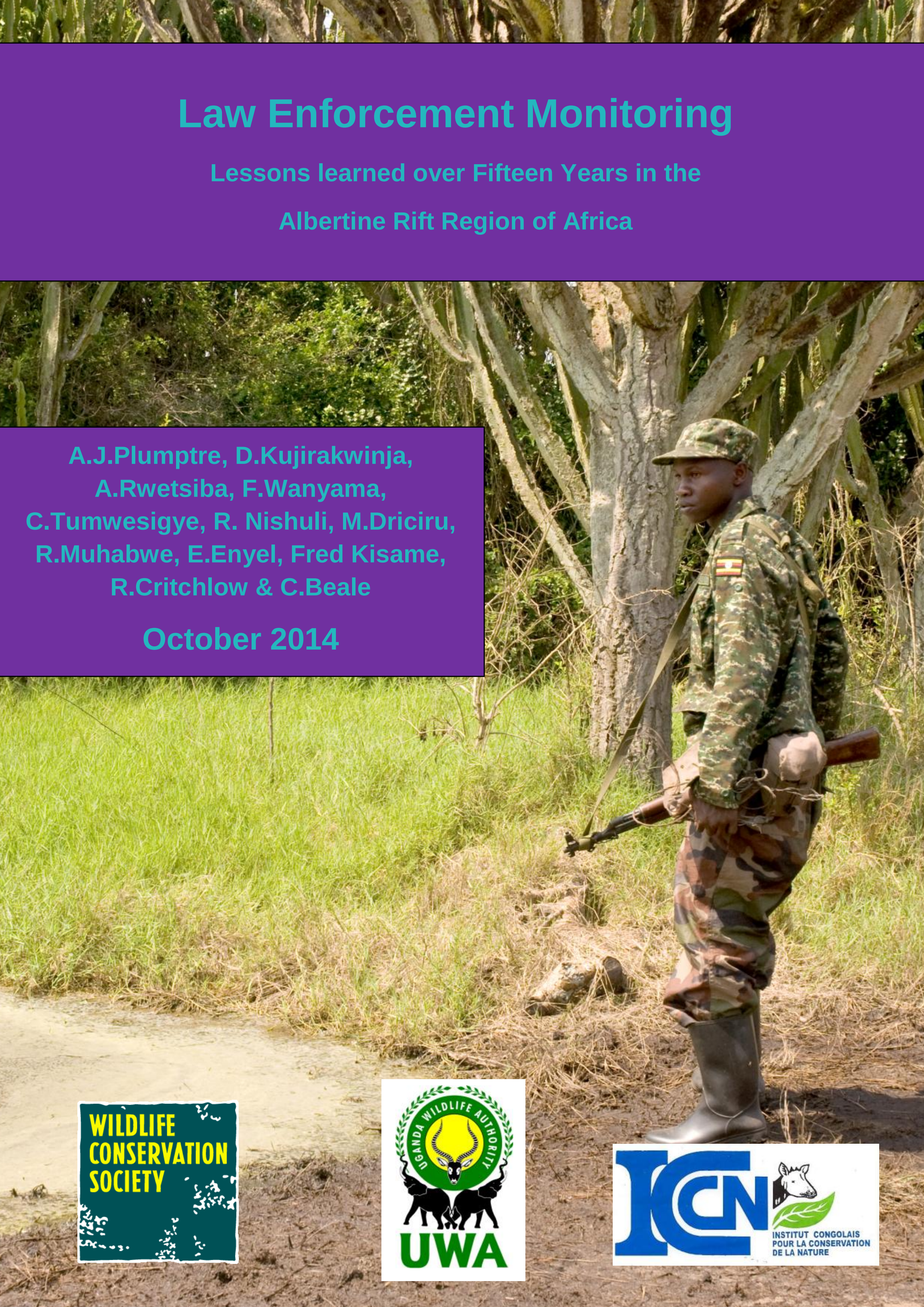

The Wildlife Conservation Society (WCS) saves wildlife and wild places worldwide through science, conservation action, education, and inspiring people to value nature. WCS envisions a world where wildlife thrives in healthy lands and seas, valued by societies that embrace and benefit from the diversity and integrity of life on earth.

In the Albertine Rift region of Africa WCS has been supporting conservation since 1957 and is the oldest International Conservation NGO working here. Our focus has been on building the capacity of the protected area authorities in the region to be able to better manage their protected areas as well as providing results of scientific research to better understand the importance of the Albertine Rift and how best to conserve the incredibly rich biodiversity to be found here. Find more at www.albertinerift.org; www.wcsuganda.org; and www.wcs.org

The Uganda Wildlife Authority (UWA) has a mission to conserve, economically develop and sustainably manage the wildlife and protected areas of Uganda in partnership with neighboring communities and other stakeholders for the benefit of the people of Uganda and the global community. It also aims to be the leading, self-sustaining wildlife conservation agency that transforms Uganda into one of the best ecotourism destinations in Africa. Find out more at: http://www.ugandawildlife.org/

The Institut Congolais pour la Conservation de la Nature (ICCN) has a mission to assure the protection of the fauna and flora in the collection of protected areas of the Democratic Republic of Congo, to encourage research and tourism and to manage stations for capture and domestication of wild animals. ICCN manages five World Heritage sites including the Virunga National Park, Africa’s oldest park, and the Kahuzi Biega National Park which conserves a large proposrtion of the endangered Grauer’s gorilla. For more information: www.iccn.cd

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Executive Summary

Law enforcement activities in protected areas in Africa form a significant proportion of the protected area budgets of a site. Yet there has been little research into measuring the effectiveness of ranger patrols and whether their deployment can be made more efficient. In 1998 the Uganda Wildlife Authority (UWA) worked with a company, Ecological Software Solutions, to develop a software, MIST, that would enable them to monitor their ranger patrols and to record where illegal activities were occurring in Uganda's protected areas. In 2001 the Wildlife Conservation Society (WCS) supported UWA to roll out MIST from Murchison Falls National Park, where it had been piloted under a GTZ project of support to the park, to all the other protected areas managed by UWA in Uganda. WCS then took MIST to Rwanda , eastern Democratic Republic of Congo (DRC) and then further afield including to South East Asia and Latin America. MIST is now used at most CITES/MIKE sites where elephant populations and poaching are monitored.

This report summarises how MIST and the more recently developed software SMART have been used to monitor the impacts of law enforcement activities in the Albertine Rift region of Africa (particularly Uganda and eastern DRC) and how this information has been used to improve management and make ranger patrolling more effective. The report also summarises some of the latest developments in the analysis of ranger-collected data which by the nature in which it is collected is biased and clumped in nature.

Monitoring information can be collected easily on almost anything but unless it is embedded within a monitoring framework or monitoring plan which specifically links the information collected to how it should be used then it is unlikely that the data collected will be analysed or provide the type of information protected area managers need. In each country in the Albertine Rift where WCS supported the establishment of MIST a process was used to develop such a monitoring framework to help decide what information should be collected, how it should be analysed and who was responsible for each step of the process. This approach is described first here before the results of how MIST data have been used because the authors believe it is critical.

Subsequent sections of the report look at ways in which analyses that can be made in MIST and new developments in SMART can be used to improve management of protected areas. There is then a section on ways in which MIST/SMART data can be exported and analysed more fully to provide more statistically robust methods of data analysis.

A final section summarises some of the lessons that have been learned over the 15 years of law enforcement monitoring in the region and some of the ways forward that could be adopted in the future.

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Law Enforcement in Protected Areas

Law enforcement of protected areas often forms significant portions of the protected area management budgets. This is particularly true in tropical countries where labour is relatively cheap so that many rangers can be employed at a site, but also because the poverty of people adjacent to the protected areas is often linked to higher frequencies of illegal activities taking place within the protected areas. For instance, in Uganda during 2009-2010 the Uganda Wildlife Authority (UWA) spent on average 65% (min:44% - max: 92%) of its protected area operating budgets on staff salaries, benefits and food rations for patrols across its 10 National parks and 14 Wildlife Reserves. Studies have shown that law enforcement at a site is critical for ensuring the long term conservation and viability of specific conservation targets (Pfeifer et al. 2012; Tranquilli et al. 2011; Craigie et al. 2010; Hillborn et al. 2006; Bruner et al. 2001) and where poor law enforcement exists there is often a marked degradation in biodiversity (Laurance *et al.* 2012; Peres and Terborgh, 1995). As a result, effective law enforcement is paramount for effective conservation, particularly in countries where poverty is high amongst rural populations and there is potential to increase income through illegal activities (Jachmann 1998).

Research on law enforcement has primarily focused on monitoring law enforcement effort and its relation to the levels of illegal activities (Jachmann 1998, Jachmann & Billiouw, 1997, Leader-Williams *et al.* 1990), measuring the impacts of increasing patrol effort or penalties (Leader-Williams & Albon 1988; Leader-Williams *et al.* 1990; Milner-Gulland & Leader Williams 1992; Hofer *et al.* 2000) and assessing the numbers of rangers per unit area or budget needed to minimize illegal activities, at least to a level where conservation objectives are not greatly impacted (Jachmann 1998; Jachmann, 2008; Jachmann & Billiouw, 1997; Leader-Williams *et al.* 1990). More recently law enforcement research has begun to be used to assess the management effectiveness of protected areas (Jachmann 2008) and the links between protected area performance and tourism (Jachmann *et al.* 2011). Other studies have looked at the incentives that can be used to encourage compliance with wildlife laws (Keane *et al.* 2008). These studies, taken together, generally show that the best way to improve law enforcement is to increase the probability of detecting illegal activities, particularly identifying the people involved and penalising them (Milner-Gulland & Leader Williams 1992; Arcese *et al.* 1995). While ‘catching the crook’ is an intuitive way to overcome illegal activities, rarely has the spatial nature of illegal activities been assessed and how this affects law enforcement strategies in conservation. One study from the Serengeti concluded that mapping where poaching activity is likely to occur was an effective way of proactively identifying where enforcement activities should be targeted (Campbell and Hofer, 1995; Hofer *et al.* 2000).

The focus of protected area management on law enforcement by ranger patrols in the tropics has often been criticized as a neo-colonialist intervention or ‘fortress conservation’ that negatively impacts the livelihoods of poor communities living adjacent to protected areas (Hulme & Murphree, 2001). The aim of this report is to learn lessons from monitoring of law enforcement in protected areas while recognizing the importance of engaging local communities in the management of protected areas. UWA has been actively engaged with communities around its protected areas for over 20 years now, trialing new approaches with the aim of building relationships and sharing benefits from tourism revenues. Studies of the impacts of this approach have shown that it has led to greatly improved relations between UWA and local communities and also improved livelihoods (Blomley *et al.* 2010; Infield & Namara 2001). However, the research also shows little impact on the level of illegal activities taking place within the protected areas where community conservation interventions have been focused (Blomley *et al.* 2010), and in some cases it created jealousies in households that did not benefit greatly and led to increased illegal activity (Twinamatsiko *et al.* 2014). It therefore is still necessary to employ law enforcement methods to prevent illegal activities in Uganda’s protected areas, despite the fact that UWA could share more of its revenues if it wasn’t investing so much of its budget in deploying ranger patrols.

The Albertine Rift is a Global-200 priority Ecoregion (Olson & Dinerstein, 1998; Burgess *et al.* 2004), part of the Eastern Afromontane Biodiversity Hotspot (Brooks *et al.* 2004) and an Endemic

Bird Area (Stattersfield *et al*. 1998). Extending from the northern tip of Lake Albert and Murchison Falls National Park down to the southern tip of Lake Tanganyika and encompassing the mountains on either flank of the rift valley, the Albertine Rift covers about 313,000 km^2 and is the richest area in Africa for vertebrates with more endemic vertebrates than any other region also (Plumptre *et al*. 2003; 2007). The Wildlife Conservation Society (WCS) has been supporting conservation in this region since the late 1950s but has had a program dedicated to its conservation since 2000. One of the initial activities of this program was to support UWA to develop a national monitoring plan for its protected area estate. Given limited resources, it was necessary to make this plan feasible but at the same time give it the potential to expand should more resources become available. As a result a large part of the plan relied on ranger-based data collection methods to monitor threats to conservation of species and habitats within the protected areas. It built upon a project that supported the conservation of Murchison Falls National Park in the late 1990s, with the support of German Development through GTZ, and which had supported the development of a database for ranger-collected data by Ecological Software Solutions. Called Management Information System (MIST) it allowed such data to be spatially mapped, to map where patrols had been, where illegal activities or sightings of key species had been made and to assess encounter rates of sightings per unit effort of patrol. The ability to assess the number of encounters of illegal activities per patrol day or per kilometer of ranger patrol made MIST unique among such databases that existed and WCS staff recognized its value for monitoring.

WCS supported the rolling out of MIST to all of UWA's protected area estate and also took the software to other protected areas in the Albertine Rift region, initially in Rwanda and Eastern Democratic Republic of Congo (DRC) and then, through its global network of conservation projects, to other parts of the World (Stokes, 2010). MIST data have been collected in some of UWA's protected areas since 1999 and in Eastern DRC since 2003 and they are still used today. This report assesses lessons learned from the use of MIST to monitor law enforcement effectiveness at a time when MIST is becoming superseded by new conservation software, SMART (Spatial Monitoring and Reporting Tool) which takes much of the good aspects of MIST but incorporates it with many other options for monitoring Law Enforcement.

Establishing a monitoring framework for a protected area

Monitoring is a process, which aims to detect changes, establish their direction and measure their extent or intensity. It checks whether the prevailing conditions match the previously defined standards or norms. There are different reasons for monitoring and these are largely informed by the objective of management. Some of the purposes of monitoring are as follows:

a) To assess the effectiveness of any management actions carried out to protect or enhance any special features, habitats or particular species

b) To detect changes that may occur in any part or form of the natural system that is of interest to management

c) To facilitate state-dependent decision making (Lyons *et al.,* 2008) where managers need to know the prevailing state of the ecosystem components before taking appropriate action

d) To 'provide a feedback loop for learning about the system to reduce critical uncertainties in models of a managed system' (ibid).

The protocols presented here can be used for any of the above functions provided the objectives are specified before any protocols are implemented. The key point to note here is that monitoring efforts should be concentrated on collecting information needed to make conservation decisions rather than monitoring with hope that some useful trends will emerge to inform future actions. Data collection is an expensive undertaking and it is important that careful thought goes into what information is needed, how it will be analyzed, who collects it and reports on the analyses and how it will be used. It is also very easy to collect vast amounts of data that then are never analyzed and interpreted because of the volume of information or because their analysis wasn't planned for.

The other fault is that the data are analyzed and reported in complex reports and scientific papers and the information is never used because it is not communicated to the protected area managers in a way that is easily understood.

In the case of protected area management we are most interested in information that can help a protected area manager monitor the impacts of their interventions and management strategies and to monitor the outcomes that result from these. A manager needs to know if their strategy is working or not, and if not they need to adapt their strategies to try and develop something that does work. This is the most critical information a park manager needs and should be the minimum data requirement of any monitoring program in the park. In general this means that such a program needs to monitor the state of the conservation targets in the park (species and habitats) as well as the state of the threats to these targets and to the integrity of the park.

There is a need to establish a framework within which the monitoring data are collected so that it is very clear why the data are being collected, who is responsible, how it will be used and when it will be interpreted and used to inform management strategies. We developed such a framework for the protected areas in the Albertine Rift which identified the types of information that should be collected and when they should be interpreted and used. For each protected area we worked with existing management plans that had identified the following (or if these were not identified we identified them during the development of the monitoring plans):

- Conservation targets for the site (species and habitats)
- A conceptual model with the threats to these targets as well as the strategies that will be used to address the threats
- Goals and objectives for the targets and threats

We aimed to develop a framework that would enable adaptive management to occur within a regular project management cycle (figure 1).

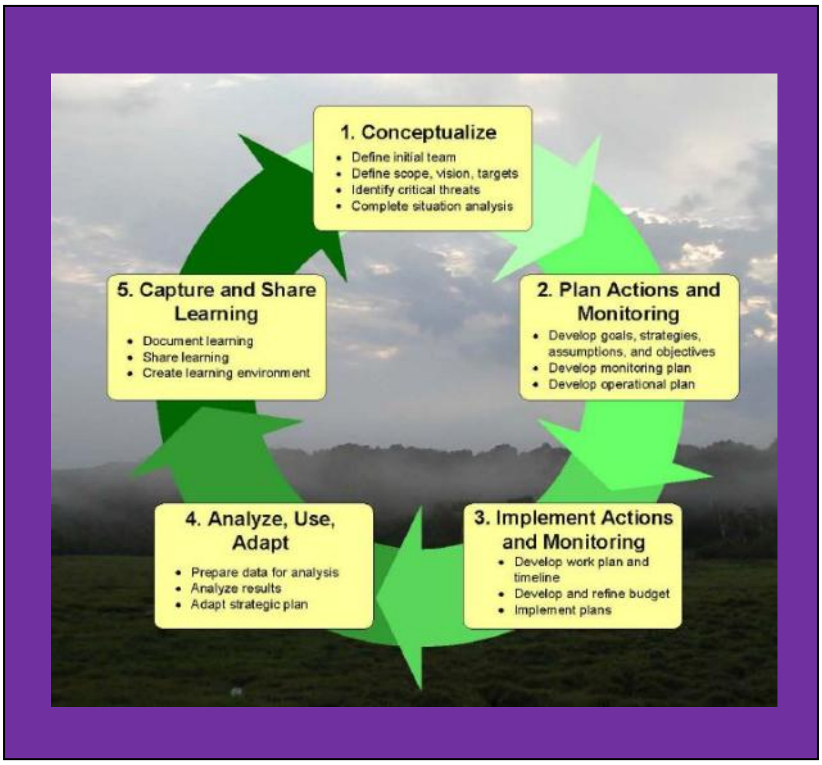


Figure 1. The Project management cycle from the Conservation Measures Partnership (Salafsky & Margolius, 1998).

The following method was used for establishing a framework for monitoring across the Albertine Rift by WCS. The process led to the development of a national monitoring plan for Uganda and Rwanda and also was used at individual parks and wildlife reserves, in the Democratic Republic of Congo, to develop monitoring plans specific to those protected areas also. It follows an eight step process that can be undertaken in a 3 day workshop to develop the framework of a monitoring and research plan for a landscape or protected area. The workshop included senior protected area management staff from all disciplines (not just monitoring and research wardens) that are needed to ensure that the data are collected for the monitoring plan.

I. *Identify why the protected area is important globally and nationally – what are the conservation targets*

At the beginning of the process the conservation targets for the site are re-visited. Hopefully if these have already been identified for the conceptual model then this process shouldn't take long but it should remind everyone what has been agreed upon.

II. *Identify threats to these conservation targets*

Here again the main direct and indirect threats are re-visited in a conceptual model or threats tree. The key threats that are most impacting the conservation targets and where strategies have been developed to tackle them are then agreed upon. In the Albertine Rift the threats ranking process used by Salafsky and Margolius (1998) that rank by area, intensity and urgency was used to identify the priority threats.

III. *What strategies are currently used to address these threats*

The key strategies that are being used by the protected area authority to address the selected threats are listed so that the link between the threats and the strategies is made very clear and will encourage an assessment of the strategies in any review process of trends in the threats.

IV. *What can be monitored to tell us whether we are reducing the threats*

For each threat a set of monitoring parameters were identified that could be measured to assess whether a manager was succeeding in reducing the threat or not. If the parameter could not be directly measured (eg. frequency of poaching of conservation targets) then indicators need to be identified that will help contribute to the assessment of the parameter (eg. a. numbers of snares per km of patrol, b.number of poachers arrested per patrol day, c.numbers of elephant carcasses per km of patrol, and d. population of target species can all be used as indicators of poaching frequency). The indicators or parameters have to be measured per unit of effort and as part of this process it was important to decide what measures of effort would be used. Generally number/patrol day or number per km of patrol are the usual units of effort, although some indicators were measured much less frequently such as species surveys which were made every 2-5 years. These parameters and indicators were identified as measures that would be analyzed and reported upon annually to assess whether the threat was increasing, stable or decreasing so it was important to spend time on them and get them right.

V. *What data are collected, by who and when*

The data that needs to be collected for each indicator/parameter were then identified and the method that would be used (eg. Law enforcement monitoring (LEM), Line transects, etc). The person responsible for ensuring the data were collected needed to be identified and noted and the frequency of data collection also needed to be decided upon.

Analysis and reporting frequency - examples

The frequency of data analysis and reporting depended on what data were being collected and how they needed to be used. We suggest a list of basic reporting needs for a park manager here with when they need to be reported upon so that a manager can receive it in a timely manner.

Daily reporting from ranger patrol post to park HQ –this would be by radio and would be for urgent incidences by Senior rangers at patrol posts

i. Fresh carcasses
ii. Gunshots heard or encounters with poachers
iii. Arrests made
iv. Intelligence gathered when urgent to act on it

Monthly level reporting – reported at park level to chief park warden by M&R team

i. Patrol coverage mapped
ii. Location of different threats mapped
iii. Arrests made
iv. Items confiscated
v. Carcasses
vi. Intelligence gathered which is less urgent to act on but is important
vii. Crop raiding/livestock killing events

Quarterly reporting – reported to HQ level in capital city by M&R team

i. Patrol coverage
ii. Location of different threats mapped
iii. Arrests
iv. Items confiscated
v. Carcasses
vi. Intelligence for issues of national importance eg. elephant poaching

Annual reporting – reported to HQ level by M&R team

i. Patrol coverage
ii. Locations of threats mapped
iii. Locations of key species mapped
iv. Trends in monitoring parameters and indicators
v. Assessment of park management strategies based on trends
vi. Identify where strategies need to be changed/augmented

Multi-annual reporting

i. Species surveys
ii. Other surveys not made on an annual basis – eg governance and livelihoods

VI. Who is responsible and how often does he/she report

The person responsible for analyzing the data and reporting on the results was also identified and decisions made about when reports need to be produced for various recipients, particularly protected area wardens and protected area authority headquarters. Identifying the people responsible helped make sure these plans were implemented.

VII. When are results assessed and decisions made on the strategy

As well as the analysis and reporting there is a need to identify when managers will act on the data. This necessarily depends on the type of information with some information requiring immediate attention and some being much longer term in nature. We aimed to institute an annual assessment of the trends in threats just prior to the preparation of annual operations plans to ensure that the results were used in the planning for the subsequent year.

These first seven steps are written up in a table form for the monitoring plan so that it can be quickly reviewed (figure 2).

Figure 2. Example Monitoring plan tackling the threat of poaching

Part of the monitoring plan for a park where the threat was poaching. RBDC – ranger based data collection, WLE – Warden law enforcement, WCS – Warden Community Conservation, CBDC – Community based data collection. Note that it is clear that the monitoring data to be collected are not just collected by ranger patrols or specific monitoring rangers but that all aspects of park management had a role to play.

(a) Threats common to most or all protected areas

Threat	Strategy to address threat	What is measured		Data collection and analysis				Review of t
		Parameter	Indicator	Method of data collection	Frequency of Collection	Method of analysis	Who is responsible	When Reported on
Poaching	• Patrols • Arrests and prosecution • Sensitization • Benefit sharing • Intelligence gathering	• Frequency of poaching incidences	• No. poachers arrested/month • No. prosecutions /month • No. of snares and carcasses /km walked/ month/ sector of PA • No. armed exchanges with poachers/month • No. reports of poaching activities by local	• RBDC • Reports by WLE • RBDC • Reports by WLE • CBDC	• Routine • Monthly • Routine • Monthly • 1/week • Every 2-5	• MIST • Summary • MIST • Summary • MIST	• WLE • WLE • WLE • WLE • WCC	• Monthly at PA level • Quarterly to HQ

VIII. Identify Research projects that will better understand threats and improve management strategies to tackle them

Finally it was useful to identify some key research areas where additional research could help a manager tackle particular threats. Establishing a monitoring program using a process as described above helps a protected area system analyze trends in various threats and assess whether they are being controlled or not. However, if a threat is increasing, it may not always be clear why this is so and research may need to be focused on explaining the reasons for the increasing trend. Ensuring that the research was carried out in a targeted manner may involve working with Universities or NGOs to ensure it was undertaken quickly if the warden for monitoring and research did not have enough time.

Using monitoring information for adaptive management

As we stated at the beginning of this section the collection, analysis and reporting of the data are not the end point but they must be used to affect management decisions. It is useful to build into the monitoring framework a mechanism of review of monitoring information to ensure that it is used. We suggest that a review of all monitoring information should be made on an annual basis with a monitoring report evaluating trends in the threats and highlighting which strategies are not working at reducing threats. This review would ideally happen just prior to the preparation of annual operations plans. A summary should be presented at park level to all senior and junior wardens as well as senior rangers. A second presentation should be made at the headquarters of the national parks agency in the capital city. It is the presentation of the trends AND their interpretation which should be presented and discussed. We also recommend a ‘threats reduction assessment’ be made by the parks staff comparing previous rankings of the threats with the current situation as described by Salafsky and Margolius (1998). This process has been used by UWA and the Institut Congolais pour la Conservation de la Nature (ICCN) in DRC at their sites.

Initially there can be resistance to this process and framework because it involves more work. There are several ways to encourage the framework to be adopted so that it eventually becomes normal procedure. Encouraging presentations on the data by all parks at headquarters at the same time can be useful in building peer pressure between park wardens, particularly if a prize/incentive can be given for the best presentations. Similarly supporting chief park wardens and senior staff at headquarters to present the monitoring information at international fora, such as IUCN congresses, can engender pride in their achievements. Where monitoring information is used to adapt management these occasions should be recorded so that examples can be used in such presentations. Similarly there should be recognition for protected area wardens who can demonstrate that they have increasing wildlife populations and have been able to tackle and reduce threats in their parks/reserves.

Developing and using such a monitoring framework doesn’t preclude decisions to collect additional data as an when new threats arise. However it does aim to focus the activities of the Monitoring and Research team in a protected area to produce information that is likely to be useful for the managers in a format that directly links conservation targets to their threats and the strategies being used to tackle the threats.

Ranger-based data collection

Ranger-based data collection involves the collection of routine information by ranger teams while they are on patrols in a protected area (Gray & Kalpers, 2005). Rangers aim to patrol over most of the protected area and as such access more of the protected area than most managers or any other person. As such their ability to record what they see can be very useful for both management and for planning. Patrols can be both routine patrolling from ranger posts to sites where rangers believe they will find illegal activities (or to ensure they deter any potential incursions to undertake illegal activities), or they can be based upon intelligence and are determined by were the intelligence information suggests illegal activities are taking place (Stokes, 2010). Rangers are not trained researchers, however, and therefore cannot be expected to make complicated measurements or to collect data with any particular sampling strategy. They are also not employed to collect data but rather to deter illegal activities. Therefore they should not be burdened with too much additional information gathering and there is a tradeoff between the value of additional information and the need to perform their primary role.

In each site we have established MIST we have designed a simple data sheet that rangers use in the field to record sightings of illegal activities and also key species. The list of illegal activities and species is determined during the development of the monitoring plan and it is important that the list of options is kept short. It can be very tempting to want to collect data on all species but when rangers have to stop too regularly our experience suggests that they stop recording the information making the analyses impossible. In our experience it is valuable to record such sightings, not for monitoring trends in numbers (we believe that separate surveys are needed to achieve this) but more to build up a picture of where these species occur within the protected area. Such point location data for a species can also be used to develop species models for their use of the protected area. Most illegal activities are rare or at least uncommon so this is not usually a problem when recording illegal activities.

A problem of too much data

In the initial data collection that UWA rangers made they recorded sightings of all large mammal species. However, species such as the Uganda kob (*Kobus kob thomasi*) are very numerous in three of the parks that are patrolled and it became clear that the trends in sightings of this species declined over time while aerial surveys were not showing such a decline. When this was discussed with some rangers it became clear that it was too time consuming to collect this information. Key species that should be focused upon should be those that are rarely sighted such as large carnivores or that won't require that the rangers halt too regularly.

If a ranger patrol has not sighted anything within a 30 minute period they also collected a waypoint to indicate where they patrolled. MIST is able to link up the various points to create a tracklog that can be used to estimate the distance a patrol has walked and so it was important that points were collected regularly to ensure this track was relatively accurate. With the advent of SMART it is possible to download tracklogs from a GPS unit directly into the database and the accuracy of the distance walked is greatly enhanced. Similarly the whole process of data collection will be speeded up with the advent of smart phone hand held devices that are capable of recording data which can be downloaded directly to the SMART database or even sent by cell phone network (where there is coverage) to a cloud storage from where it can be downloaded to the database.

Given the way in which rangers patrol, actively looking for illegal activities, their data collection sampling strategy is heavily biased to areas where they believe illegal activities are likely. This makes the analyses of such data complicated but not impossible. However care must be taken when analysing the data because of this. The simple outputs generated by MIST primarily map the areas where illegal activities have taken place, however the trend analyses that are possible in MIST are affected by this bias (see below).

Analysing Law Enforcement Monitoring Data in MIST

There are various ways in which ranger-collected data have been analysed and we here summarise some of the most common methods employed in MIST and how these results have been used by protected area managers.

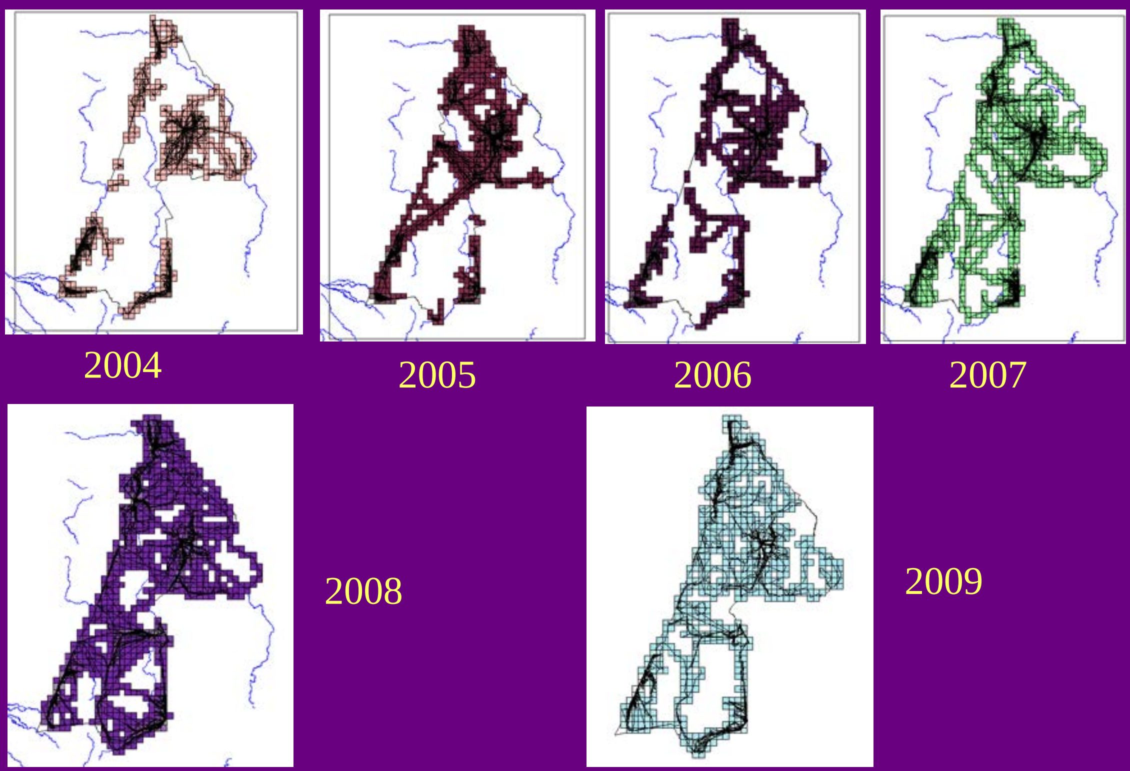
Maps of patrol coverage

At all sites where LEM was established with MIST the monitoring warden would generate maps of patrol coverage on a monthly basis to help orient patrols in subsequent months. Prior to the establishment of MIST most wardens did not really know where their rangers were patrolling and they relied on simple reports which described where patrols had taken place, sometimes with a simple map, but this was not compiled over time into a total patrol coverage map. Initially at many sites rangers were resistant to the LEM system because it showed where they had been and how far they had walked and they believed it was a system to check on their work rather than to monitor species and threats. Of course the system does both and in MIST and SMART it is possible to track how far individual rangers have patrolled over time provided that the patrol membership is recorded and entered in the database for each patrol. In some protected areas this has been used as a basis for a bonus or prizes for the ranger who has walked the furthest in a year.

In comparing annual patrol coverage over time it was clear that the MIST database led to increased patrol coverage of most protected areas as the system became established and used (figure 3).

Figure 3. Changing patrol coverage in Kibale National Park, Uganda

LEM was implemented in Kibale National Park in 2004 and as patrol coverage maps were produced wardens started to orient patrols to areas that had been rarely patrolled if at all.



Maps of sightings of key species

Maps of the locations of where certain key species occur has been useful to identify where certain species are present and where they appear to be absent within a protected area. Species such as the large carnivores (lions, spotted hyaenas, cheetahs and leopards) and apes (gorillas and chimpanzees) which are not observed frequently can be mapped as data build up over the years (figure 4). We have used such location data to develop species distribution models for these and other species within the protected areas of the Greater Virunga Landscape (figure 5) using the software

Figure 4. Sightings of large carnivores in Murchison Falls Conservation Area, Uganda

LEM results of sightings of large carnivores in Murchison Falls Conservation Area between 2000 and 2009. Lions – yellow circles; spotted hyaenas – pink circles; leopards – turquoise circles.

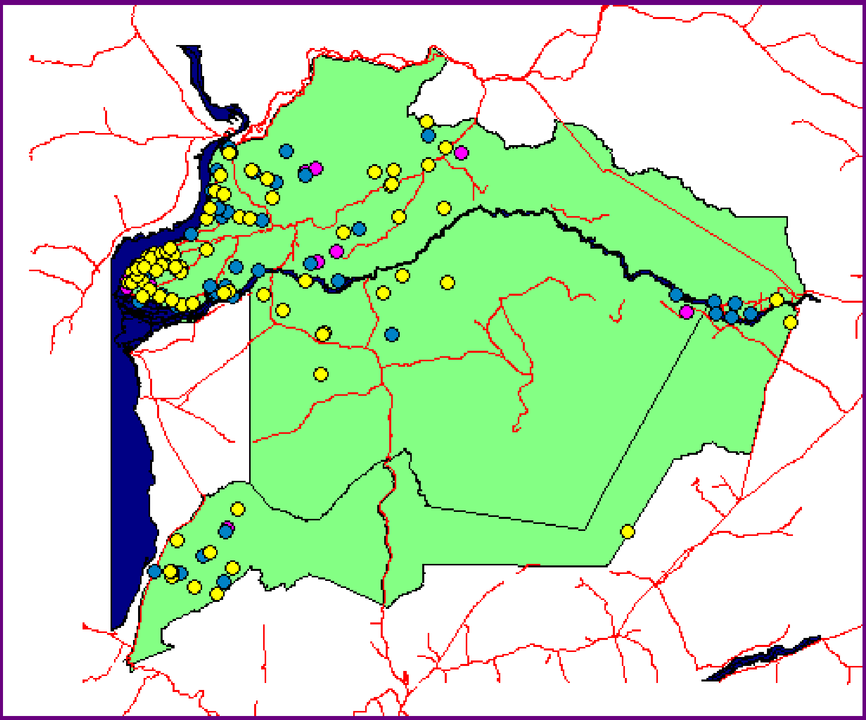
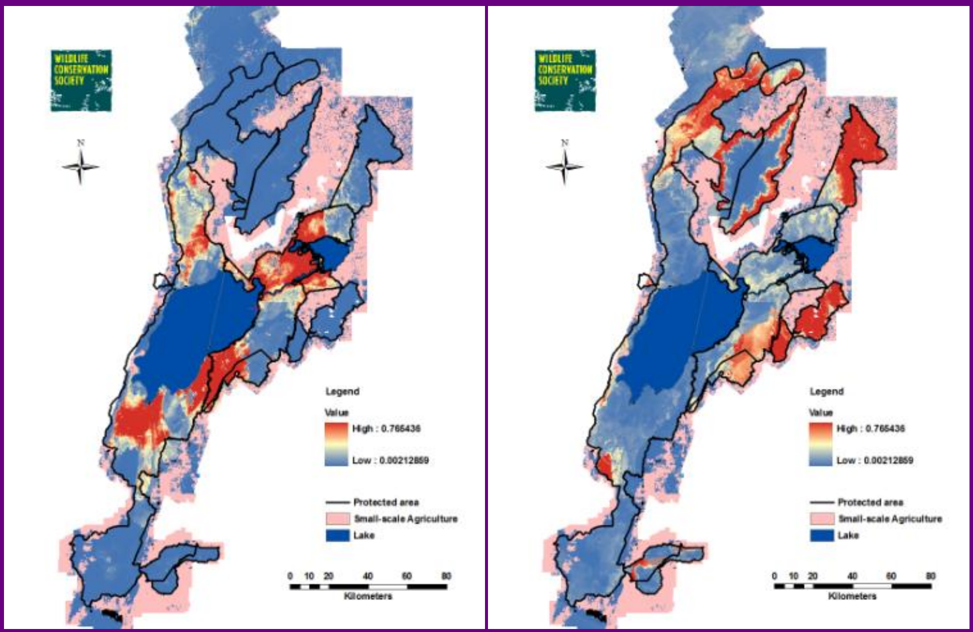


Figure 5. Modeling species distributions within the Greater Virunga Landscape

MAXENT model of lion (left) and chimpanzee (right) distribution within the Greater Virunga Landscape which is comprised of protected areas in Uganda, Rwanda and DRC.



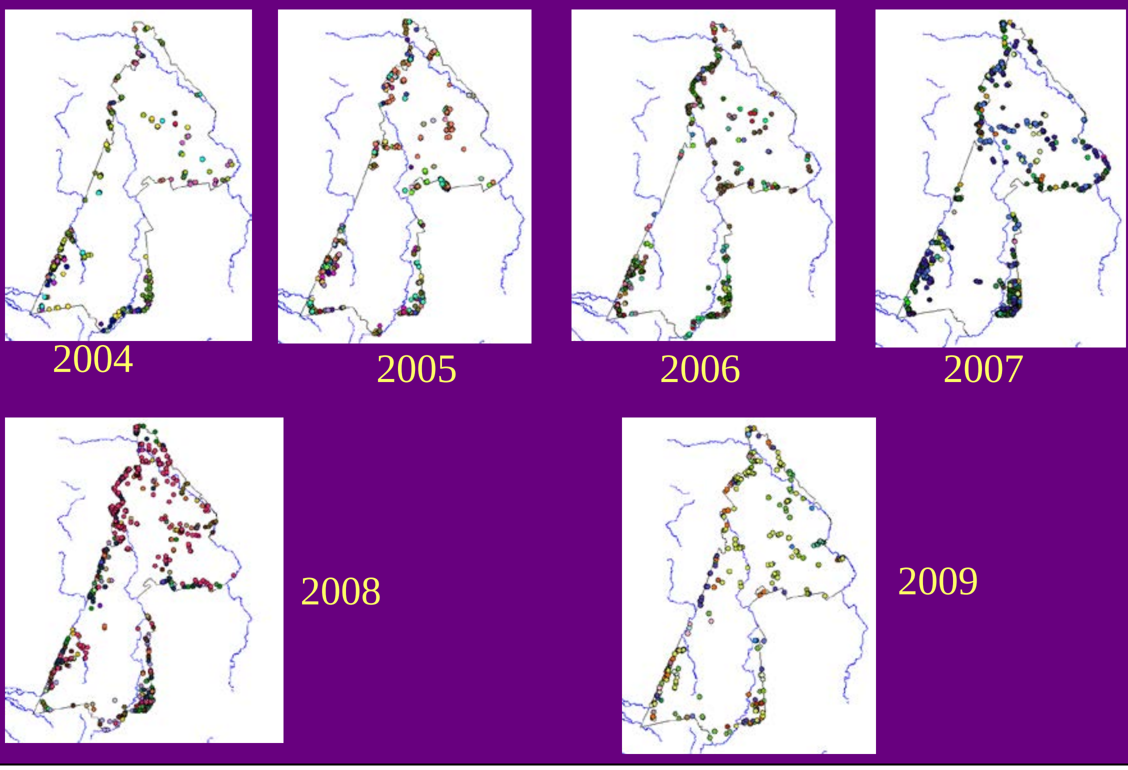
MAXENT (Plumptre *et al*. 2012). These species distribution models have subsequently been used to develop conservation plans and improve ranger patrolling by assessing where patrols need to be active to ensure that target species are best protected at minimal cost (Plumptre *et al*. 2014).

Maps of illegal activities

Of particular value is the ability to map where illegal activities occur across the protected area. Over time this builds up a picture of where each illegal activity occurs (figure 6). These maps can be used to orient patrols to better target illegal activities but care must be taken when analyzing the data. All maps must be compared with where patrols have been (figure 3). The International Gorilla Conservation Programme (AWF, FFI and WWF) set up a similar Microsoft Access database to capture LEM data for the Virunga Volcanoes that straddle Rwanda, Uganda and DRC in the Greater Virunga Landscape (Gray & Kalpers, 2005) but they failed to collect data on patrol effort, particularly on where ranger patrols had traveled. As a result their results only show a concentration of illegal activities at the boundary of the protected areas (where most patrols occur) which cannot be converted into relative frequencies of illegal activities.

Figure 6. Sightings of illegal activities in Kibale National Park, Uganda

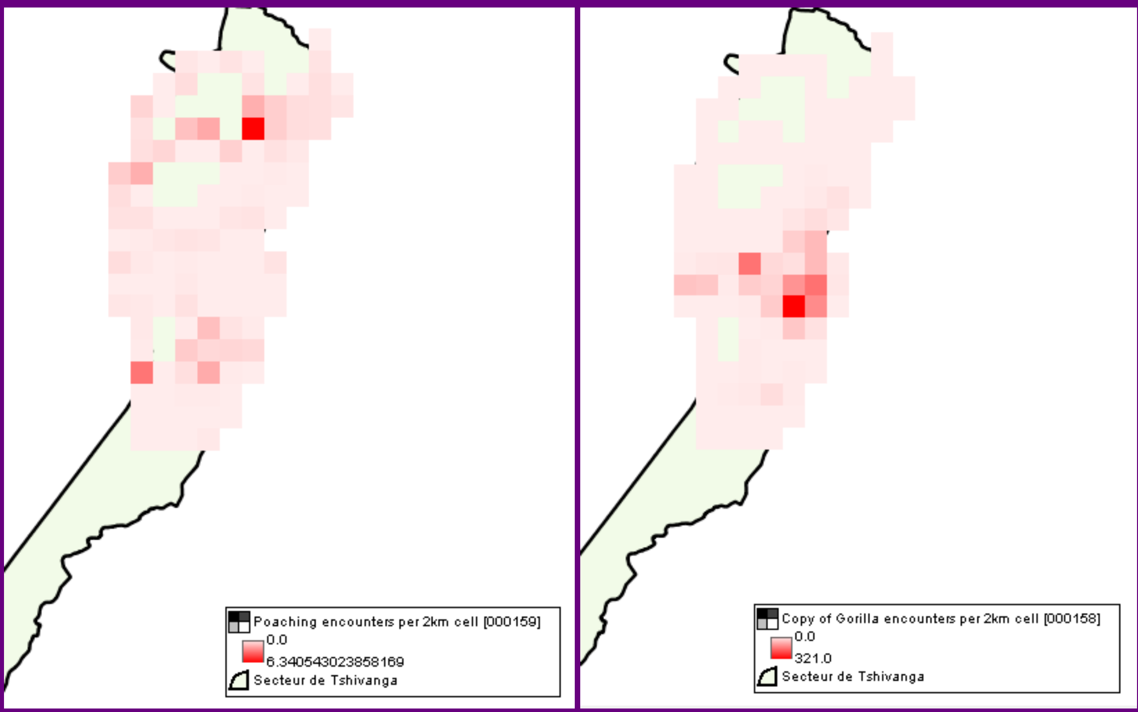
LEM results of sightings of illegal activities in each year between 2004 and 2009 in Kibale National Park. Note how there is an expansion of locations of illegal activities over time, mainly because patrol coverage increased (compare with figure 3).



MIST cannot convert the data into relative frequencies directly but the data can be exported and analysed in a GIS package provided the locations where patrols visited were collected. SMART, however can make these calculations directly and give relative abundances of illegal activities within grid cells of a specified size. This means that the real encounter rates of illegal activities or other signs can be mapped within the areas patrols have visited (figure 7).

Figure 7. Map of the encounter rates of snares in the Kahuzi Biega National Park, DRC

Encounter rates of snares (left) and gorilla sign (right) per km walked by ranger patrols in the highland sector of Kahuzi Biega National Park. This map produced in SMART calculates the encounter rate per grid cell and allows the user to specify the cell size.



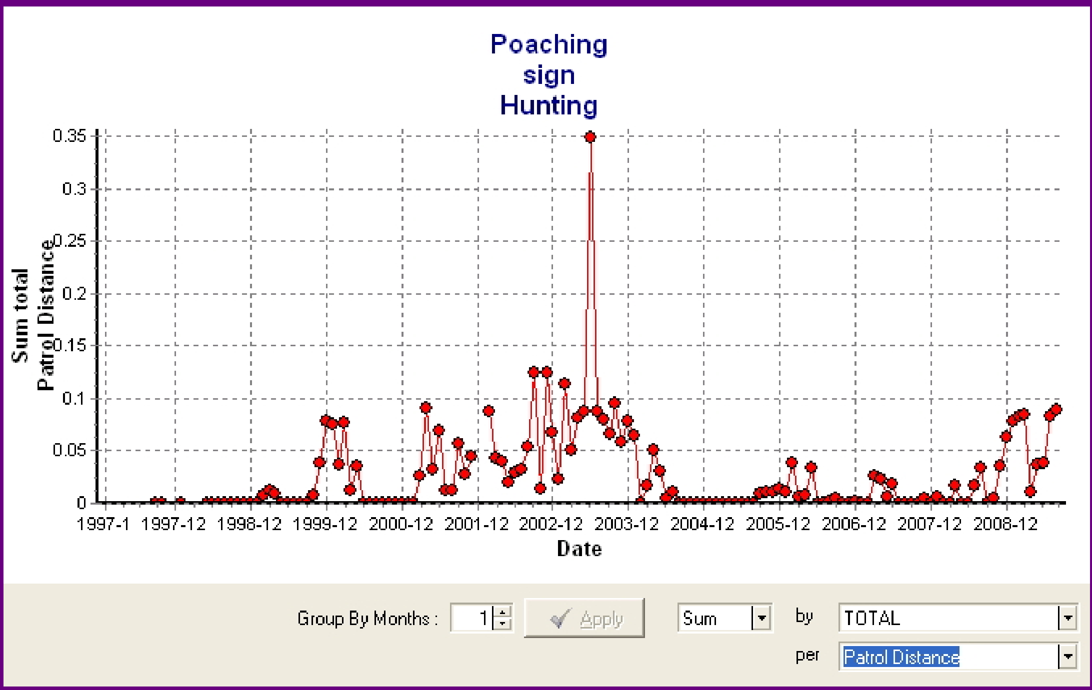
These maps have not only been used to orient patrols to sites where illegal activities are commonly found, but also have been of use when engaging local politicians and cultural leaders in dialogue over the extent and abundance of illegal activities. Having a map with data showing where the key illegal activities occur has proven to be much more powerful than simply explaining this verbally.

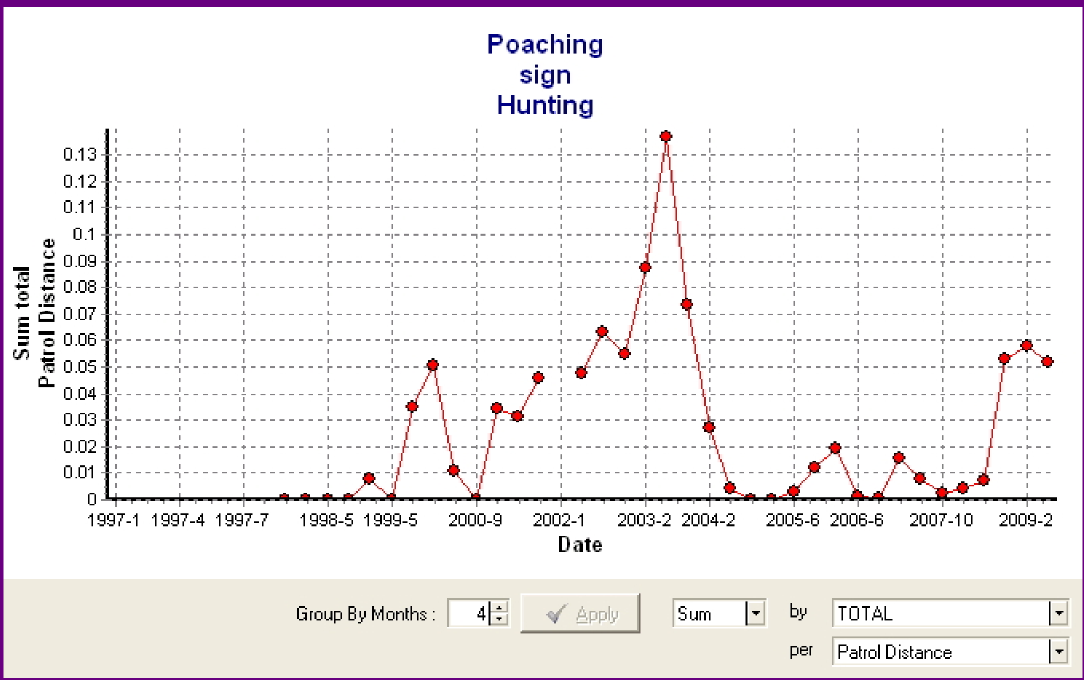
Trends in observations over time

One of the main aims of a monitoring program is to assess changes in both the numbers of illegal activities as well as the key species over time. MIST has the ability to assess trends over time in the number of observations per unit effort (Number per patrol, number per day, number per km walked etc) and also has the ability to smooth the trends across months where sightings are few in each month (figure 8). These figures provide a picture of changes that are occurring throughout the protected area and give a general idea of the patterns but are affected by several factors that need to be understood. Firstly the trend can only be calculated for the protected area as a whole rather than part of it. This is an issue as it assumes that the whole park is patrolled in the same way each month to enable the comparisons between time periods. A better method to analyse the trends would be to focus on those parts of the park that are patrolled every month and measure trends in these areas only. However, recently a better method still has been developed by Rob Critchlow *et al.* (2014a) which is summarized in the next section.

Figure 8. Trend calculations for hunting sign in Murchison Falls National Park, Uganda

Plots of the total number of hunting sign per km walked by patrols (top) and the same figure smoothed over four-month periods (below) for the Murchison Falls National Park in Uganda between 1997 and 2009 .





Analysing Law Enforcement Monitoring Data outside of MIST/SMART

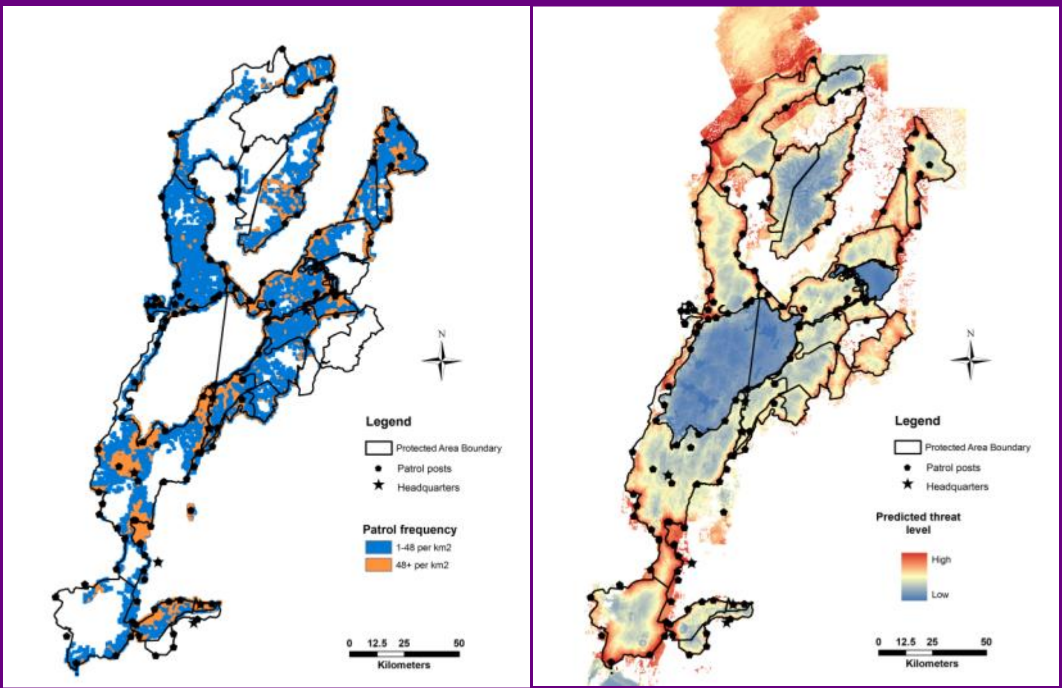
While MIST has been designed to make some simple queries to produce the types of results presented above, the data collected by rangers can be analysed in greater detail outside of MIST to provide useful information for protected area management. We here give some examples of how MIST data have been analysed in other packages to help guide management and planning.

Assessing Ranger Patrol effectiveness

Rangers are mostly based at patrol posts from where they patrol on foot on a daily basis in most parts of Africa. Mobile patrols from a park headquarters where a vehicle takes a patrol out and then drops them to make a foot patrol in more remote areas also occurs. In some sites there are also water-borne patrols by boat. While maps of patrol coverage can be made in MIST it is not possible to assess how patrols are related to patrol post locations and the effort made in relation to distance from the patrol post. Plumptre *et al.* (2014) made such an assessment for ranger patrols in the Greater Virunga Landscape which is comprised five parks and two wildlife reserves in Uganda, and one park in Rwanda and DRC respectively. These analyses were made in ArcGIS 9.3.1. (ESRI 2008). An initial analysis indicated that only 60% of the landscape had been visited over a 5-9 year period (length of time varied depending on the protected area). However one visit in 9 years is very different to one visit each day in terms of the likelihood that a patrol will deter illegal activities. A separate analysis was therefore made and selected to identify those areas that were visited at least for 2 hours every month (i.e. had 4 ranger points collected every 30 minutes for twelve months = 48 points). The results showed that only 23% of the area was patrolled with this level of effort (figure 9). It is unlikely that patrols made more infrequently than once per month will provide a great deterrence to illegal activities.

Figure 9. Map of the patrol coverage of the Greater Virunga Landscape

The figure on the left shows the total coverage of patrols between 2000 and 2010 (blue) with those areas visited for 2 hours each month (orange). This is compared with the predicted likelihood of illegal activities from Maxent models on the right.

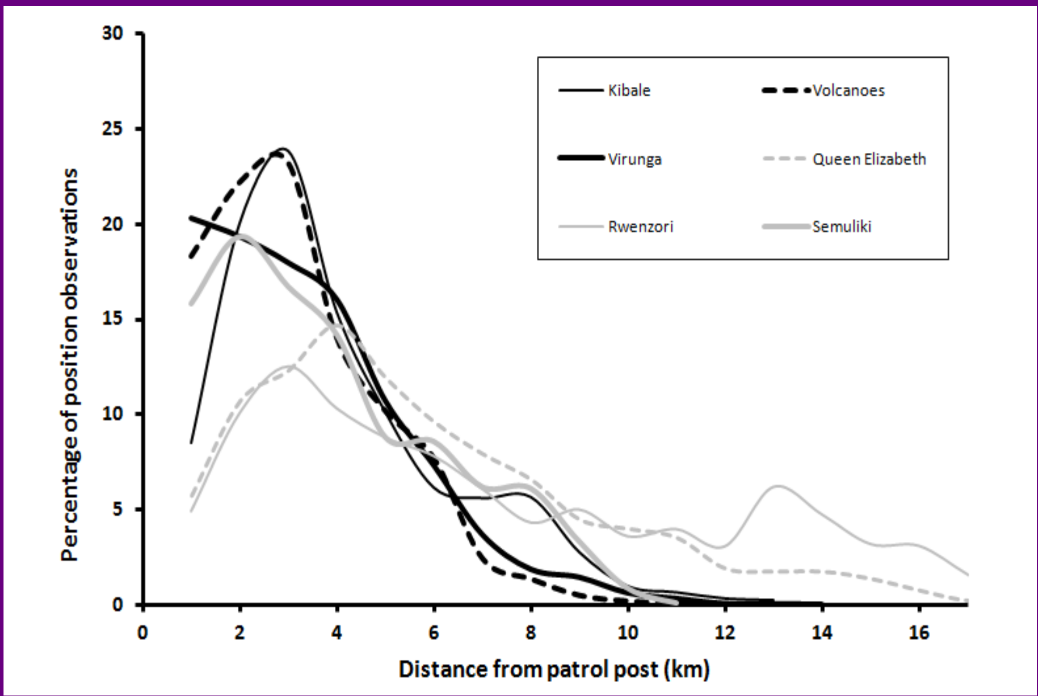


Plumptre *et al.* (2012; 2014) also mapped the likelihood of illegal activities by modeling specific threats data from MIST in relation to likely predictors of the illegal activities, such as distance from protected area boundaries and from human settlements. These likelihood values were summed across each threat to estimate where most illegal activities are concentrated in the landscape (figure 9). The results show that most illegal activities are concentrated around the boundaries of the landscape closest to human habitation.

A further analysis looked at the intensity of ranger patrols with distance from the patrol posts in the landscape and found that much of the patrol effort is made within the first 3-4 km of a patrol post (figure 10). In some protected areas such as Rwenzori Mountains National Park patrols tended to be longer as multi-day patrols are made with camps at night in order to access the mountainous interior of the park. In Queen Elizabeth National Park mobile patrols form vehicles are also used which helps improve access to more remote areas.

Figure 10. Patrol effort in relation to distance from patrol post

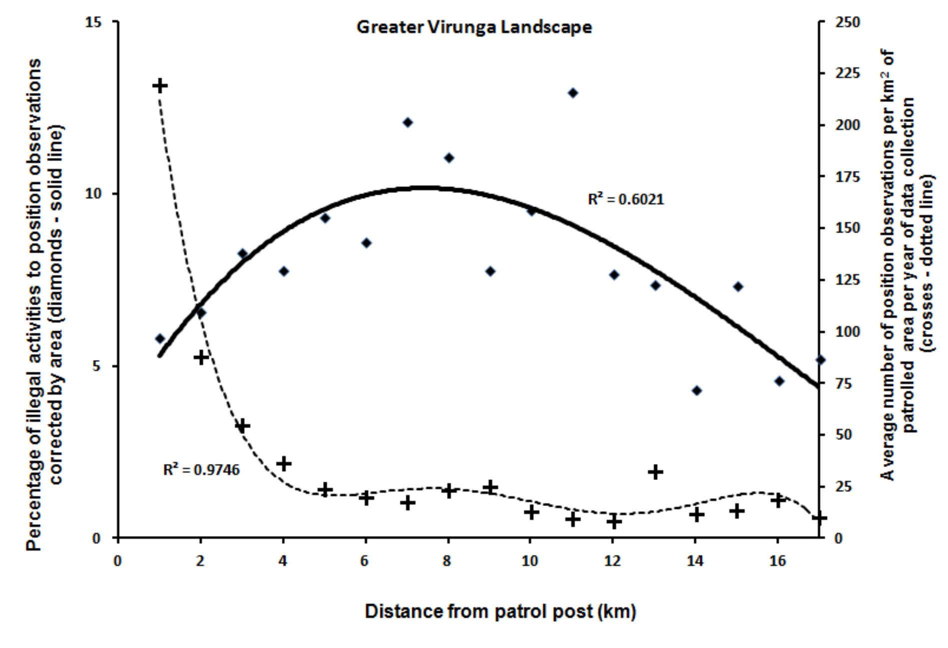
The percentage of locations from MIST patrol observations in relation to distance from a patrol post in six of the main protected areas in the Greater Virunga Landscape.



In order to assess the effectiveness of patrols though the frequency of patrolling has to be related to the frequency of illegal activities in the landscape. As patrols move away from a patrol post the area patrolled potentially increases because of the circular nature when measuring distance from a point. There is therefore a need to correct patrol location data frequency by the area patrolled to estimate patrol effort per unit area at different distances from the patrol post. When this is made the effort per square kilometer is much greater within 2 km of a patrol post (figure 11- dotted line). When this effort is related to the frequency of illegal activities it shows that there is a decline in the frequency of illegal activities per km^2 up to about 3-4 km from a ranger patrol post indicating that there is a likely deterrence effect up to this distance. The decline beyond 10km from the post is likely because many of the areas at this distance are in remote parts of the park and are more effort for a poacher to access.

Figure 11. Frequency of illegal activity sightings in relation to patrol effort

The percentage of illegal activity sightings per km^2 in relation to distance from a patrol post (solid line and diamonds) is plotted with the frequency of position observations of patrols per km^2 (dotted line and crosses) showing a decline in illegal activities where patrol frequency is high near the patrol post.



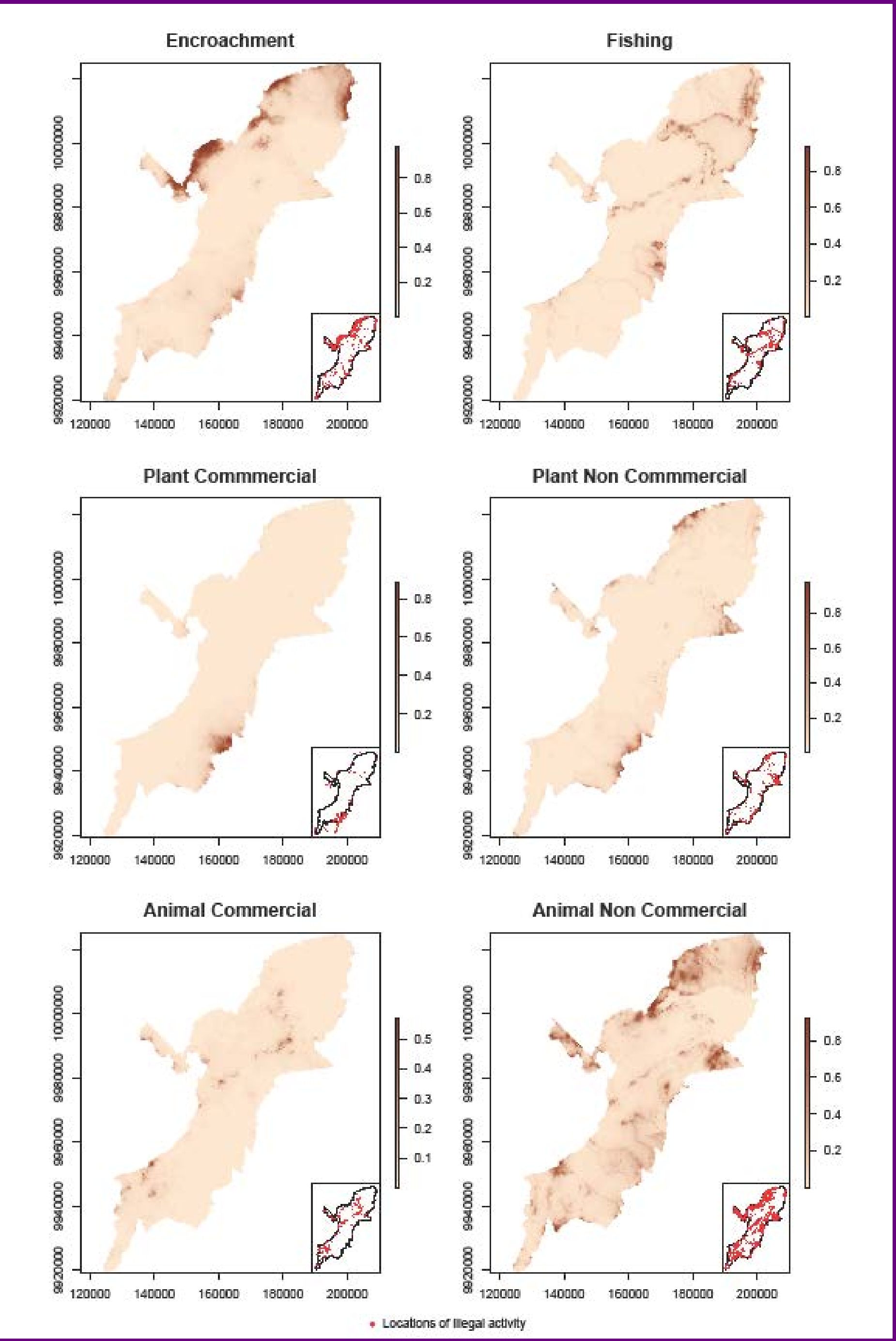
Mapping trends in illegal activities

The biased nature of ranger patrols means that it is difficult to accurately determine trends in illegal activities over time. The crude trend figures generated by MIST (figure 8) are not statistically robust and can be affected by many variables including where patrols have been during the year, variability in the detection probability of observations, and fatigue. In order to develop more robust methods of detecting trends in illegal activities it is necessary to use a Bayesian hierarchical modelling approach to analyse the spatio-temporal distribution of each illegal activity separately. The models have three components: (1) a process model defining the relationship between covariates and illegal activities, (2) a component to account for spatial autocorrelation and (3) a model to explicitly account for temporal and spatial variation in the detection of illegal activities by ranger patrols. Full details are provided in Beale, Brewer & Lennon (2014) and a summary in Critchlow et al. (2014a). These models require information on the spatial patterns of observer effort and covariates likely to influence levels of illegal activity, and allow estimation of the underlying patterns of illegal activities independently of the probability of detecting such activity.

This method was tested with MIST data from Queen Elizabeth National Park. Models were fitted separately to each class of activity across the entire time period as well as for annual and monthly subsets of the data. Covariables used included distance from the park boundary, distance from roads and rivers, wildlife density, habitat, travel cost, slope and net primary productivity. The spatial distribution of illegal resource use differed among six threat categories for the full time period data were collected (Figure 12). Overall, there were differences in the distribution patterns of the six classes of illegal activity.

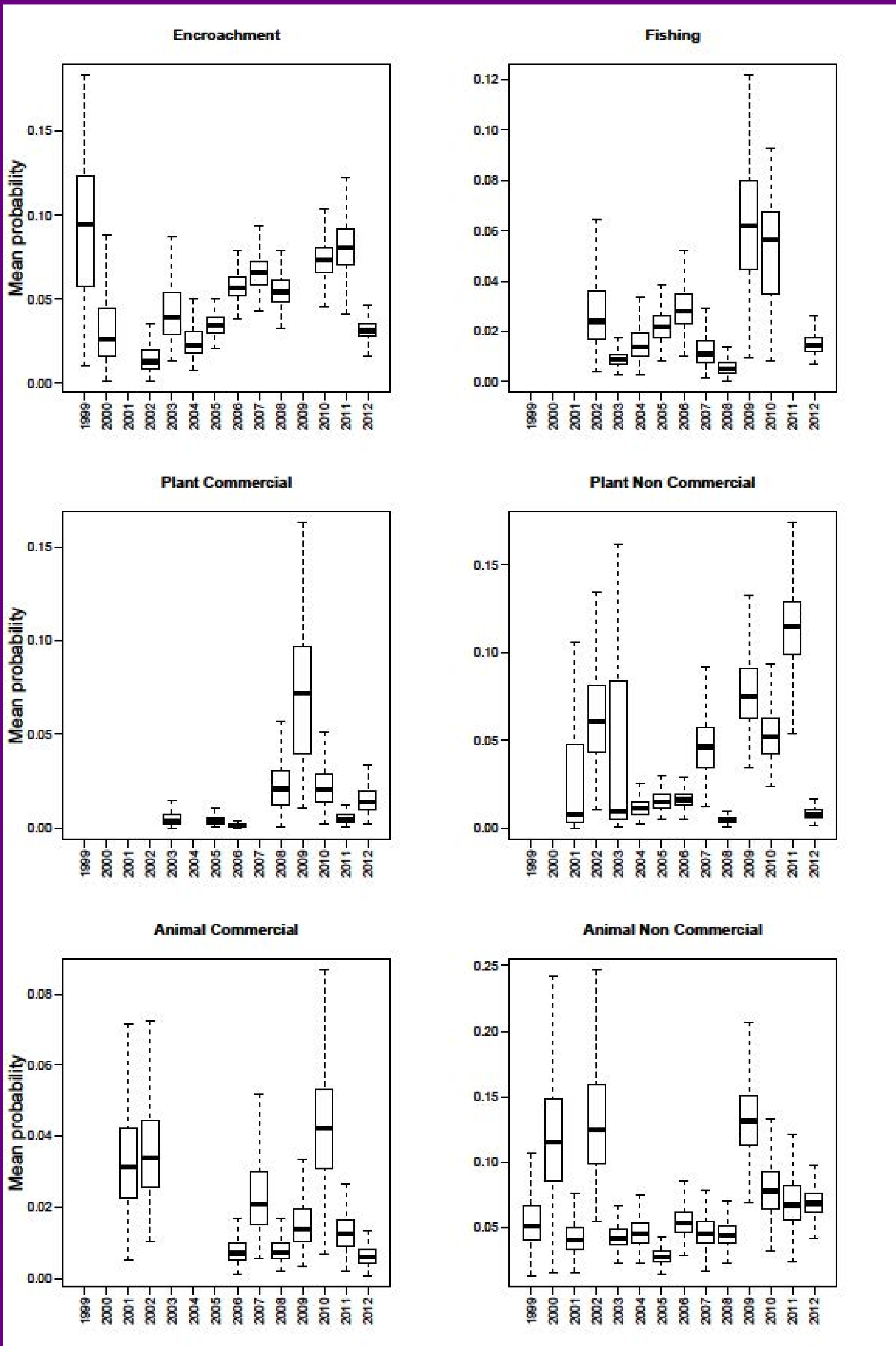
Figure 12. Spatial distribution of six illegal activities in Queen Elizabeth National Park

The results of the Bayesian hierarchical modeling to estimate the probability of an illegal activity occurring within a 500 x500m cell of the park between 2000-2012. Plant commercial included timber harvesting and charcoal; Plant non commercial was harvesting of non-timber forest products; Animal commercial was poaching of elephant, buffalo or hippo; Animal non-commercial was snaring and carcasses of other species



These maps were calculated for each year since 1999 when data collection started in Queen Elizabeth National Park. The mean probability per 500mx500m grid cell across the park of each activity over time was calculated to estimate park-wide trends in each illegal activity (figure 13).

Figure 13. Trends in illegal activities between 1999-2012

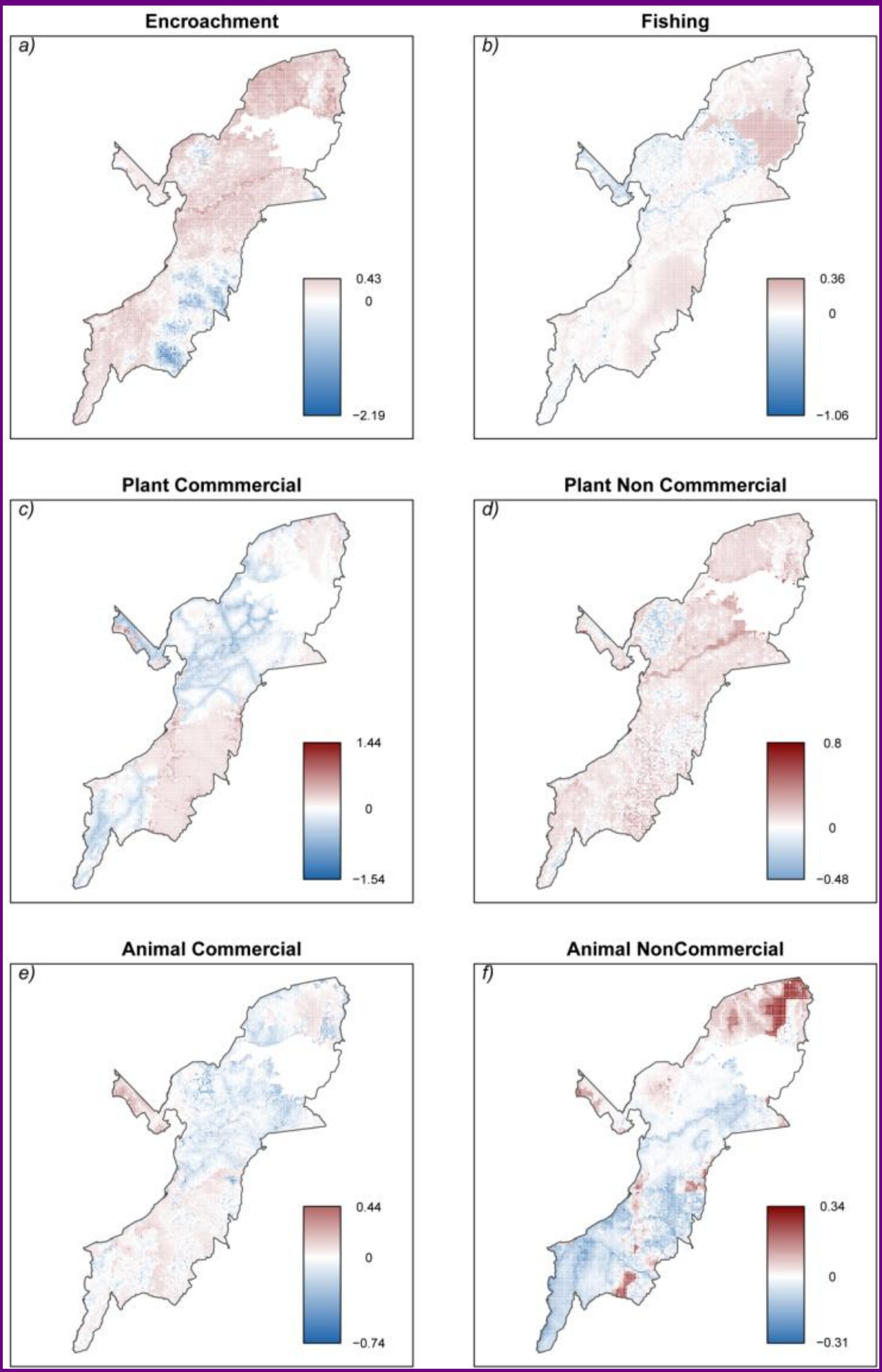


These results show that the probability of illegal activities occurring have fluctuated between years but that encroachment, and plant non-commercial have shown significant increases over time.

Encroachment is mainly dues to pastoralists herding their cattle and goats into the park in the north western and north eastern parts of the park (figure 12). These average trends across the park can also be mapped spatially to assess trends for each grid cell in the park (figure 14).

Figure 14. Spatial trends in illegal activities between 1999-2012

Temporal trends of illegal activities per grid cell (500m) between 1999 and 2012 in the Queen Elizabeth National Park. White indicates no significant change and darker colours indicate more significant trends during the full period (brown=increasing; blue=decreasing)



Improving ranger patrolling effectiveness

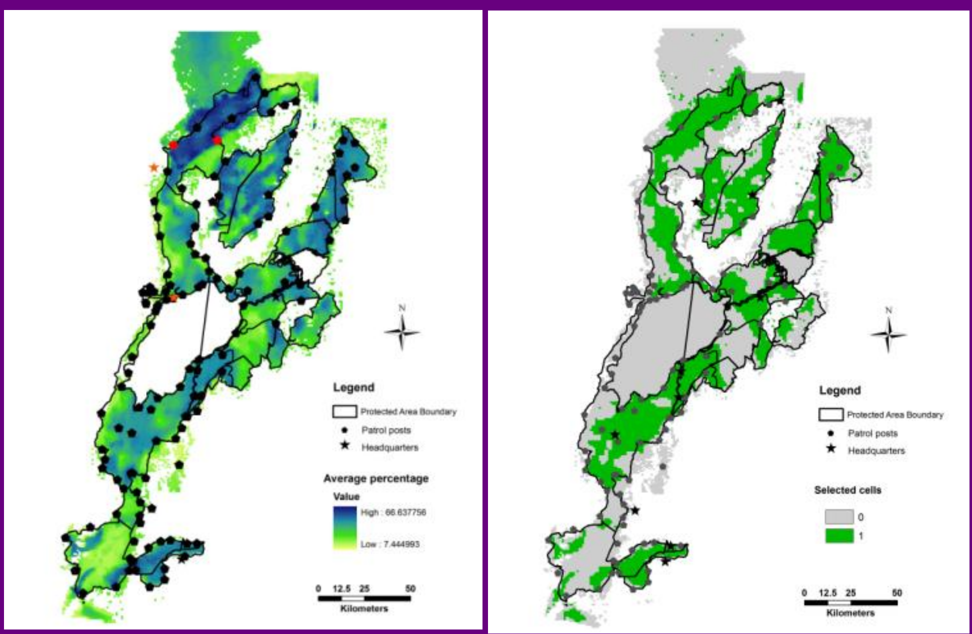
Two methods have been used to investigate how to improve the deployment of ranger patrols using these results to make them more efficient and effective. Plumptre *et al.* (2014) used a conservation planning approach, employing the software Marxan, to maximize the impacts of patrols to ensure the conservation of certain conservation targets (key species and habitats). Critchlow *et al.* (2014b) took an approach building upon the Bayesian hierarchical modeling approach described above to identify where patrols should be deployed to tackle the threats mapped in figure 12. We briefly describe the two approaches here.

a. Marxan approach

The Conservation planning approach with Marxan used data on modeled species distributions for a suite of landscape species and habitats throughout the Greater Virunga Landscape. Marxan aims to minimize the costs of conserving these conservation targets by using a cost layer and target levels for each species that it aims to achieve by selecting cells across the landscape. The analysis was made using 1 km^2 cells and a cost layer that was calculated to measure the cost of patrolling a cell from patrol posts and mobile patrol bases within the landscape. Target population values for the species were set at 1000 individuals or the maximum number if the population was lower than this. An area of each habitat was also identified to ensure that sufficient area was conserved for most plant species and hopefully the smaller species that are confined to these habitats. Marxan uses a simulated annealing algorithm to assess many millions of possible options of cells that can be selected. It would be impossible though to assess all possible combinations as these are too numerous. Therefore Marxan was run 1000 times to estimate the selection frequency of each cell across the landscape to identify areas that are almost always selected. The cost of patrolling these areas was similar or less than current expenditures on patrolling in the landscape, but spending on patrolling in this way is estimated to be more efficient and would ensure the conservation of all target species.

Figure 15. Identifying where to concentrate patrol effort in the Greater Virunga Landscape

The selection frequency for patrol coverage identified using Marxan (left) and the cheapest solution for patrol coverage (right) to ensure the key conservation targets are protected.

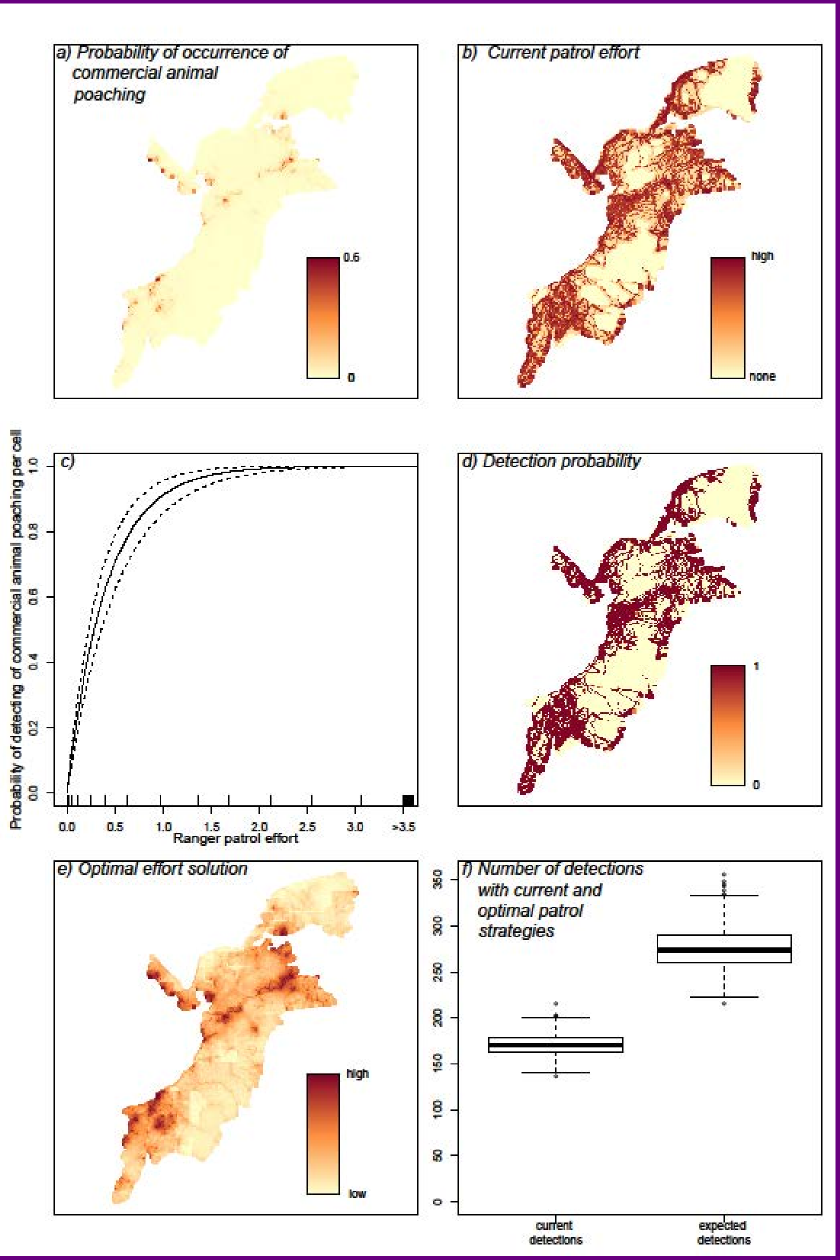


b. Targeting threats approach

The approach employed by Critchlow et al. (2014b) aimed to maximise patrol effort in areas where illegal activities are predicted to be high. In practice, this was implemented by ordering the existing ranger patrol effort in each cell according to the ranked probabilities of each activity occurring per cell, so that the highest probability cells received the greatest amount of effort (figure 16e). By substituting the optimal patrol strategy in place of the spatial pattern of existing ranger effort, the number of detections by the patrols can be estimated (and associated uncertainty) for any given strategy (figure 16f).

Figure 16. Targeting commercial animal poaching in Queen Elizabeth Park

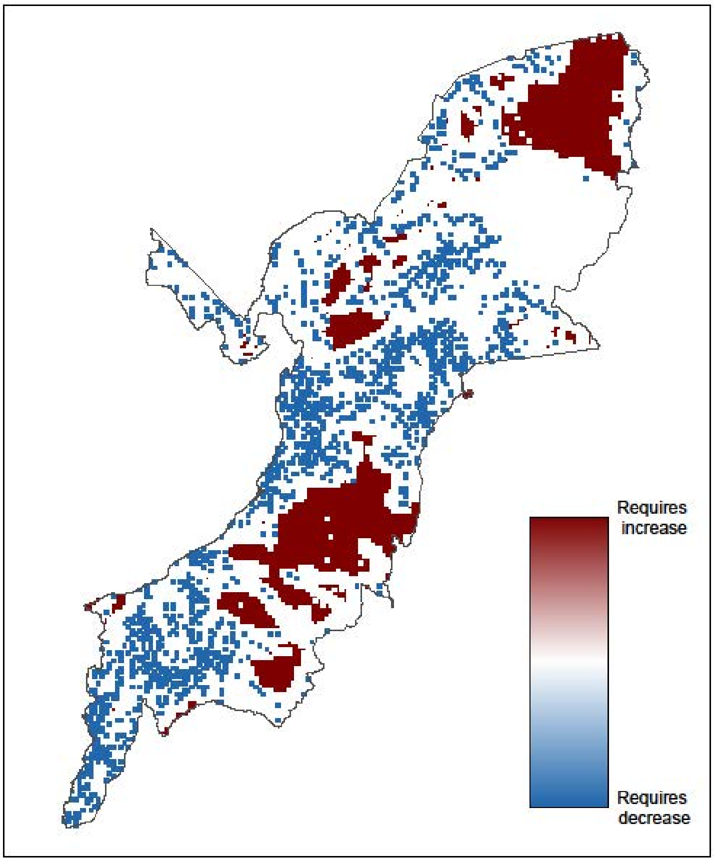
(a) Current estimated probability of occurrence. (b) Current ranger patrol effort. (c) Modeled relationship between probability of detection and patrol effort. (d) Current effective detection probability given (b) and (c). (e) Optimal ranger patrol strategy. (f) Expected detections of animal poaching using current effort and using optimal strategy



The difference between the current and optimal strategies can then simply be compared (subtract one form the other) to assess where there is too little patrolling and where there is too much patrolling taking place (figure 17). This approach needs to be tailored for each threat separately and then weightings given to each threat so that an optimal patrol strategy can be identified as shown here for the six threats in Queen Elizabeth National Park.

Figure 17. Comparison between optimal and existing patrol intensity.

Changes in patrol effort with respect to current patrol strategy that are recommended irrespective of conservation priorities within the Queen Elizabeth National Park, Uganda.



Both of these approaches don't factor in the potential for poachers to change their behavior and where they undertake illegal activities. In the Marxan approach provided the visitation rate per cell in the landscape is sufficient to act as a strong deterrence then the likelihood of poachers changing where they undertake illegal activities won't affect the ability to conserve the conservation targets. The second approach does assume that the main areas of illegal activities do not change greatly. It also assumes that taking patrols away from areas with little illegal activity will not lead to increased activity in these areas. For both methods understanding the patrol frequency that provides an effective deterrence is critical and we are working on how to estimate this using ranger patrol data at the moment.

These more complex analyses at present require a sophisticated understanding of fairly complex statistics and software to generate these types of results. However, we are aiming to make them more widely available for use by developing a plug-in option for SMART that would enable someone to analyse the data for their own protected area in similar ways. SMART, being an open-source software, is being designed to allow additional options to be added onto the basic program so that additional data can be collected or more complex analyses made.

Key lessons learned from Law Enforcement Monitoring in the Albertine Rift

Some lessons that have been learned about the process of establishing and managing LEM in Uganda and DRC that have not been summarised above but yet were critical include the following:

1. Uganda Wildlife Authority with Ecological Software Solutions developed and piloted MIST and worked with WCS to roll it out to all their protected areas. This process was not easy as it involved a fairly lengthy testing phase which included sorting out bugs in the software, issues to do with computer maintenance, problems with a lack of back up procedures and computer viruses causing problems in the software. This led to frustration within UWA staff using it and at a couple of sites they stopped using MIST. Data entry was all manually done initially which also required a dedicated ranger and often a backlog of data sheets resulting in a delay in analyzing the data by about 2-3 months. As more GPS units were purchased this was somewhat alleviated with the ability to send a GPS unit to the park headquarters to download the GPS locations while using a second unit to continue collecting data. With SMART the aim is to move to the ability to collect the data on hand-held devices such as smartphones with databases such as Cybertracker (www.cybertracker.org) which can be designed for data input in the format for the SMART database. This should significantly speed up the process of data entry as data can be saved on SD memory cards and sent to headquarters or in areas with cell phone network the data can be sent by phone to the computer.
2. Given these hurdles one key lesson was that MIST worked well where there was a 'champion' who worked to make it happen at a site. Often the Chief Park Warden or the Warden of Monitoring and Research these individuals made sure that rangers were supplied with GPS units, batteries, datasheets etc and also that data were entered, checked and cleaned. There also needs to be a desire at both park headquarters and in the capital city to see the results from the LEM outputs on a regular basis to ensure that those involved collect and analyse the data but also get feedback and encouragement to continue collecting data. Encouraging a spirit of friendly competition between sites such as providing a prize for the best analysis each year when annual summaries are made can lead to every site improving their data analyses in subsequent years.
3. It was important to generate results such as maps of patrol coverage and give feedback to the rangers collecting the data to motivate them to continue but also at the same time to get their feedback on problems they were facing with the data collection. In some cases this feedback led to a scaling back of key species on the list for parks, as some were too abundant and were causing patrols to stall in order to collect all the data. Keeping the rangers motivated is vital to ensuring that the flow and quality of the data being collected are maintained.

4. The importance of collecting data that allows ranger patrol effort to be quantified needs to be emphasized very strongly. Without it none of the analyses presented above (apart from the basic mapping of sightings) can be made. The protocol used in Uganda and DRC was to collect a position point every 30 minutes if no other sighting had been made in that time. If it had then the patrol would wait 30 minutes from the last sighting. These points are joined to estimate a route where the patrol has traveled. The fact that these points are not collected every 30 minutes does make estimating time spent in grid cells more difficult than if a point was collected every 30 minutes irrespective of whether other sightings had been made. With the ability of GPS units to collect and store longer track log routes these days it is becoming possible to record the tracks more accurately and SMART is being developed to use these to be able to analyse patrol routes.
5. By assigning ranger names to each patrol it was possible to also assess ranger performance throughout the year and identify those that clearly work harder and walk further each year than others. This has been used to reward rangers in Uganda providing a further incentive to collect the data.
6. The mapping of LEM data has been very useful to give senior managers at the central headquarters of a protected area authority a good picture of the current status of illegal activities in a protected area, as they cannot dedicate much time on the ground to understand what is happening during site visits. In situations of insecurity such as in eastern DRC, mapping has been even more critical as it has allowed information to be made available, not only to senior managers, but also to international bodies such as World Heritage Committee in UNESCO and IUCN who are wanting to know about the status of a site but cannot visit because of the insecurity.
7. The collection of sightings of key species was very useful even though MIST is not really a tool to monitor animal numbers. Location data on rarely seen species such as large carnivores or rare ungulates was very useful in identifying where in protected areas these species occurred. It was also useful to then identify potential areas where they might occur using species distribution modeling, particularly in areas where patrolling was rare or impossible such as areas with armed rebel groups in the DRC. These data also act as a baseline for the distribution of these species that can be compared in the future, something that is severely lacking for these species prior to the start of LEM data collection.
8. Results of the analyses above show that UWA rangers are providing an effective deterrence for illegal activities in some areas of Queen Elizabeth National Park and also highlight the need to better understand what level of patrolling provides an effective deterrence for different illegal activities as it is likely to vary depending on various factors including the monetary gain that the poacher expects, distance to a site from the park boundary.
9. It was important to place the LEM within a monitoring framework to understand why the data were needed and to ensure they were used to improve management, through a process of adaptive management. Annual assessments of the threats, strategies to tackle the threats and assessment of LEM data to show if the threats were being reduced, proved to be very important when developing annual operation plans for the following year.
10. Results from LEM in Uganda and DRC have been used to inform regional and global initiatives such as the Monitoring of Illegal Killing of Elephants (MIKE) program of CITES and have been useful to demonstrate to UNESCO's World Heritage Committee the improved management of World Heritage Sites in eastern DRC where site visits have been impossible because of security issues.
11. The use of GPS units by the rangers in the field has led to other spin-off benefits. For instance when sick or snared animals are sighted a GPS location is recorded by UWA rangers and a

veterinary doctor can be taken back to find and rescue the animal. Similarly the collection of GPS locations of carcasses during anthrax outbreaks has been used to map the disease and its spread as well as enable management to relocate and bury carcasses.

12. Another aspect of MIST that has been used by UWA is the ability to put in targets for the annual operations plans within the software and monitor achievements in their implementation over the year. However, while useful there was not a great uptake of the use of this aspect of the software probably because MIST was seen to be a LEM software primarily. While many users initially wanted one tool to monitor everything when MIST was being designed it became clear over time that there are very different needs and that it doesn't make sense to try and create something that can do everything. This has been taken on board with SMART which only focuses on LEM. Using something similar to the monitoring tool for annual operations plans would still be useful but probably would be better as a stand-alone software package.

Future plans and needs to improve LEM

Key areas for future improvement of LEM include some of the following ideas, some of which are already in the process of being developed.

1. SMART will be moving forward with several new features that will both support data collection and analysis. A Cybertracker download plugin has already been created that allows data to be collected on handheld devices using the Cybertracker software and then exported to SMART. In future it will be possible to upload the data to a cloud site from a patrol post if cell phone coverage is present allowing a data manager to download the patrol data without having to physically share the files from each post. This will make sure that results can be generated much more quickly and that assessments of patrol coverage can be made in the month of data collection.
2. Another plug in for SMART which is being developed at present will allow data from ecological surveys using systematic sampling methods such as transects, plots, camera traps etc to be incorporated in SMART and overlaid on data of sightings of key species made by rangers. It will allow joint queries to be made.
3. There is a need to assess the effectiveness of LEM that is based on regular ranger patrols compared with targeted patrols based on intelligence information. SMART has the ability to record a patrol based on intelligence separately and to record the type of intelligence information that led to the patrol. This will in future enable sites to assess the effectiveness of each type of patrol method.
4. There is a need to measure the deterrence effect of patrols at a site and to be able to assess the frequency of ranger patrolling that can effectively deter different illegal activities. While MIST/SMART data can help with such an analysis it is likely that there will be a need to test different patrol frequencies at a site to better understand the nature of this deterrence and how it changes with increasing patrol frequency as well as patrolling at different times of day.
5. Research into the behavior of poachers is also a real need. How often do they move into a protected area each month? How often do they monitor snares they set? What times of day are they most active? How could patrolling behavior be altered to increase the chance of detecting poachers? These are all questions that have not really been addressed to our knowledge but some groups are beginning to work on them, bringing in expertise from both criminology work as well as LEM.
6. The law enforcement world is moving more and more to the use of cameras to monitor sites. The technology is now available to have remote cameras that beam images in real time to a park headquarters and these cameras can have a whole suite of sophisticated devices to reduce the chance of them being stolen or destroyed. As international poaching operations are becoming more sophisticated there is a need to investigate the uses of such methods including fixed cameras as well as mobile ones such as in Unmanned Aerial Vehicles (UAV/drones). This would complement the ranger patrols and enable monitoring to take place at night as well as during the day.

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