Darwin Initiative Project:

"Improving anti-poaching patrol evaluation and design in African rainforests"

Report on Gun Hunting Intensity in Korup National Park 2013-2015 and the Evaluation of Anti-Poaching Patrols' Efficacy

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1. Introduction – Project and Report Rationale

From April 2013 to March 2015 we delivered a Darwin Initiative project (Ref 20-012) with the aim of developing and providing training for a monitoring protocol that could be used to design and assess the efficacy of anti-poaching patrols and other management strategies in tropical forest protected areas. The project was a collaborative partnership with the Government of Cameroon (Ministry of Forests and Wildlife + Korup National Park management) and civil society organizations (University of Oxford, James Madison University, Cornell University, Programme for the Sustainable Management of Natural Resources – Southwest Cameroon (PSMNR), Korup Rainforest Conservation Society, WWF-CFP), and had Korup National Park (KNP) in SW Region of Cameroon as the experimental field site.

Until now poaching pressure has been almost impossible to quantify directly in Central African protected areas (PAs) with law enforcement patrols being typically limited to recording signs (rather than actual events) such as encountered spent cartridges, snares, bush camps, (in the past) carbide dumps, hunting trails, or even foot prints. The issue with such indirect methods of monitoring hunting patterns in an area are multiple. For example, hunting signs are:

- very coarse in the temporal information they provide about when a hunting event took place, (e.g. sign happened sometime since last patrol in the area…)
- difficult to convert to actual hunting incidents, (e.g. how many days did a hunter use a bush hut and how much did he hunt in those days…)
- near impossible to combine for interpretation, (e.g. how do you add 3 spent cartridges + two bush huts from one patrol in one index…)
- challenging to compare across sites, (e.g. different protocols may be used as to what constitutes as sign, or how to age them…)
- susceptible to significant seasonal variations, (e.g. cartridges rust faster in the rainy season or get covered by leaves in the dry season...)
- vulnerable to deception efforts by hunters, (e.g. hunter can collect the spent cartridge, or throw it away from the trail…)
- over-reliant in the consistent application of a strict protocol by tired field personnel, and (e.g. we expect rangers to be equally alert of signs on day 1 and 15 of a patrol…day or night)
- limited in their spatial coverage. (e.g. signs can be observed only where people walk…an issue in understaffed PAs)

In addition to this limitations, hunting sign collection is expensive (field teams cost a lot of money in field per diems), distract the anti-poaching patrol members from their law enforcement tasks (i.e. ambushing and arresting hunters), and are perverse in that they are collected by the same people whose performance in combatting poaching is to be evaluated.

Bushmeat market surveys, a popularly employed method to study hunting pressure in an area, can be informative but are useful for long term monitoring at landscape level given the difficulty of determining the origin of the carcasses (which can be very far from the point of sale, given that bushmeat is smoked and transported distances).

Given the lack of a robust hunting intensity monitoring methods, anti-poaching patrols are in effect designed and executed “blindly” – without field evidence as to their efficacy and therefore without the possibility of meaningfully adapting them to emerging patterns or even to even recognize the fruit of the PA teams’ effort with appropriate, performance based bonuses.

However, in many remote PAs, such as the study site of our project - Cameroon's Korup NP (KNP), most hunting is undertaken with local 12-gauge shotguns (snaring being also ubiquitous but typically limited to areas closer to settlements where snare lines can be frequently checked). With that in mind, we applied in a novel way existing and tested passive acoustic monitoring (PAM) techniques to record continuously gun hunting activity in the southern sector of KNP, developing as far as we aware the first field-based robust anti-poaching patrol evaluation and design protocol for the rainforest zone of Africa (and possibly beyond).

This report presents the unprecedented in spatial and temporal resolution data on gun hunting activity within the PAM grid from June 2013 to May 2015, evaluates the KNP anti-poaching patrols' impact on curbing poaching, discusses the future of the developed PAM protocol as a law enforcement monitoring tool, and presents a series of recommended anti-poaching "next step" strategies for the Korup NP considering the project's findings.

Concurrently, and as a project impact monitoring mechanism, the DI project oversaw the collection of additional survey data - namely:

1. Line transect surveys – we surveyed four line transects in southern KNP monthly to assess gun hunting pressure and primate abundance.
2. Hunter surveys – we interviewed monthly ten hunters in each of three villages surrounding KNP to assess offtake, gun hunting success rate, and hunting frequency.
3. Household surveys – we interviewed ten heads of households (HHs) in each of three villages surrounding KNP to assess food consumption patterns, and especially the role of bushmeat consumption in the local diet.
4. Bushmeat price and availability surveys – we surveyed three bushmeat bulk sellers (midle-women) twice per month (as well as local eateries and general stores) to assess temporal changes in bushmeat prices relative to other protein sources.

The findings of these surveys are presented in more detail in separate reports, but are also referred to as necessary in this report.

2. Methodology

We established a 12-sensor passive acoustic monitoring (PAM) grid within KNPs southern sector (Fig. 1), which continuously recorded forest sounds from June 2013 to the end of the project. In this report we will concentrate on the first two years of data for the gun hunting pattern analysis, and the data from the November – February periods in 2013/4, 2014/5 and 2015/6 for the evaluation of the anti-poaching patrols' efficacy to curb gun hunting.

The Wildlife Acoustics SM2+ autonomous recording units (ARUs) were placed in plastic containers to protect them from the forest elements and tampering from wildlife and connected to 6*6V lantern batteries that allowed them to operate for 3 months (Fig. 2). The ARUs were placed ~8m above the ground on trees and away from trails and visible hunting paths to reduce risk of vandalism. We also avoided sites near streams to reduce background noise and away from very large trees or rock outcrops so as to ensure that sounds were recorded all around the sensor. The ARUs digitally stored on memory SD cards all forest sounds of 4 KHz frequency. The focus on low frequency sounds was because of their ability to travel further in the forest. The SD cards were replaced by a trained field team – along with the sensors' batteries – every three months.

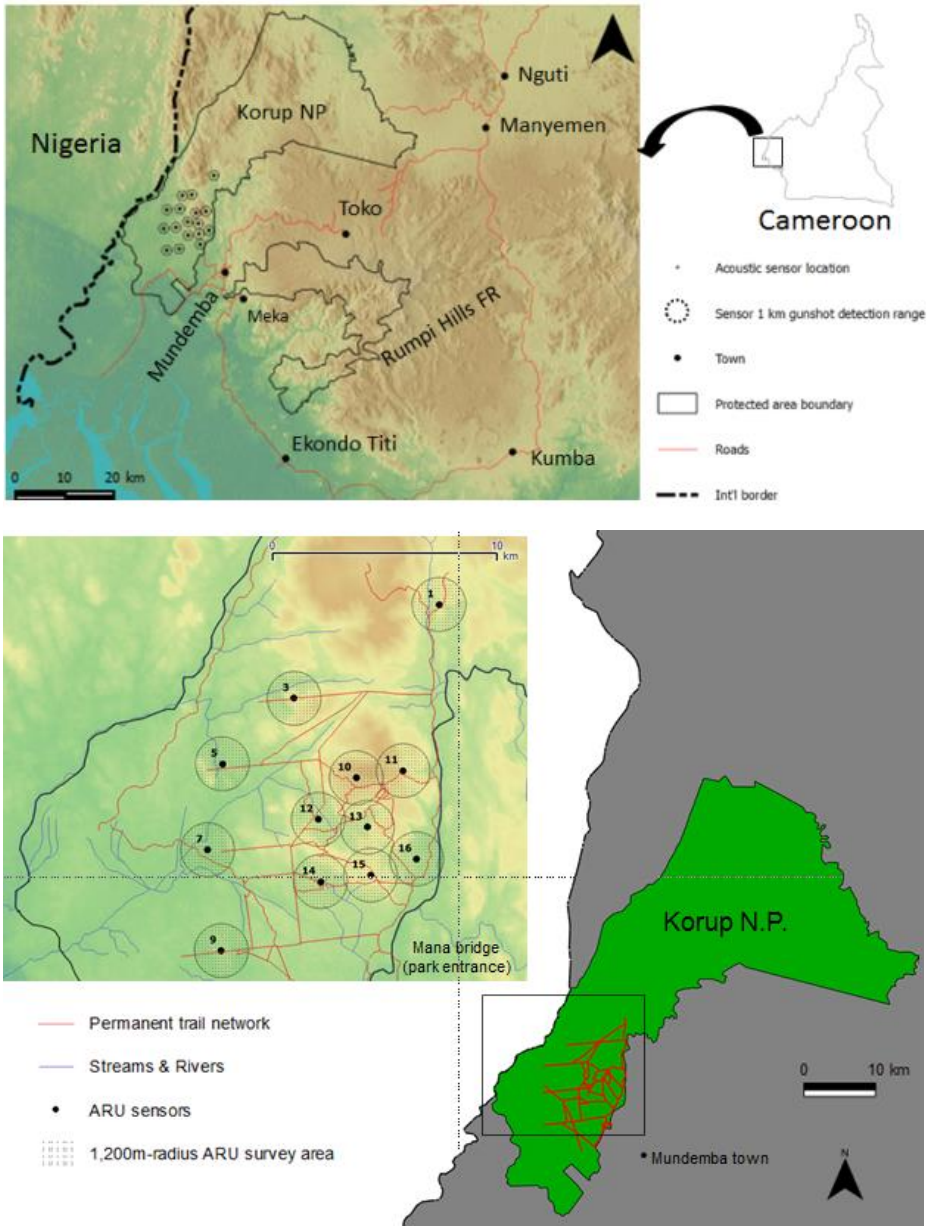


Figure 1: Location of Korup National Park in Southwest Region of Cameroon (above), as well as the passive acoustic monitoring grid established in June 2013 (below). [Coordinates of Mundemba town: N 4.971° E 8.910°]

Figure 2: SM2+ Wildlife Acoustics sensor (ARU) within weather proof container and external batteries ready for field deployment.

The minimum spacing of ~3.5 km was such to reduce the probability of double counting gunshots in >1 ARU, but we also actively searched for possible double counts using the ARUs' time stamps on the sound. When duplicates were encountered, we removed from analysis the shot that was had the "weaker" signal according a 5-10 scale rank where 5-6 were unclear loud bang sounds but not likely gunshots, and 7-10 were with increasingly confidence gunshots. Based on a series of in-situ control gunshots, we estimated gunshot detection range to be ~1.2 km on average. As a result, we assumed that the 12 sensors effectively monitored an area of ~54 km^2.

The acoustic data were scanned using an automatic detection algorithm developed by Cornell University to locate putative gunshots (Fig. 3). The list of flagged gunshot-like were then manually screened by Peter Wrege (Cornell University) and ranked according to the 5-10 scale mentioned earlier. The false-positive rate of the detector algorithm was high, but out of ~1,000 detector "flagged" sounds the vast majority were screened very quickly by visually reviewing the sound signature in the software Raven 1.4 Pro, with only ~60-70 sounds requiring audio review, of which ~less than twenty would typical receive a 7-10 rank and would therefore be included in the data. We felt that this process ensured that the detector's sensitivity ensured that there were practically no gunshots missed. Typical sounds that received a rank of 6 would be tree or branch breakings, branch or fruit falls, and distant thunders. We always – and consistently – erred on the side of caution and excluded a sound that was not too clear it was a gunshot (which often happened with distant gunshots which could not be confidently differentiated from distant thunders). Manual hand browsing of day-long sound files across seasons was also undertaken in Cornell and University of Oxford to compare the performance of the detection algorithm against a known count of gunshots. The ability of the sensor to detect gunshots approached 98-99%. Given all the measures we took to identify gunshots, we are very confident in the data set generated and consider it to be a robust if somewhat conservative estimate of gun hunting intensity within the PAM grid.

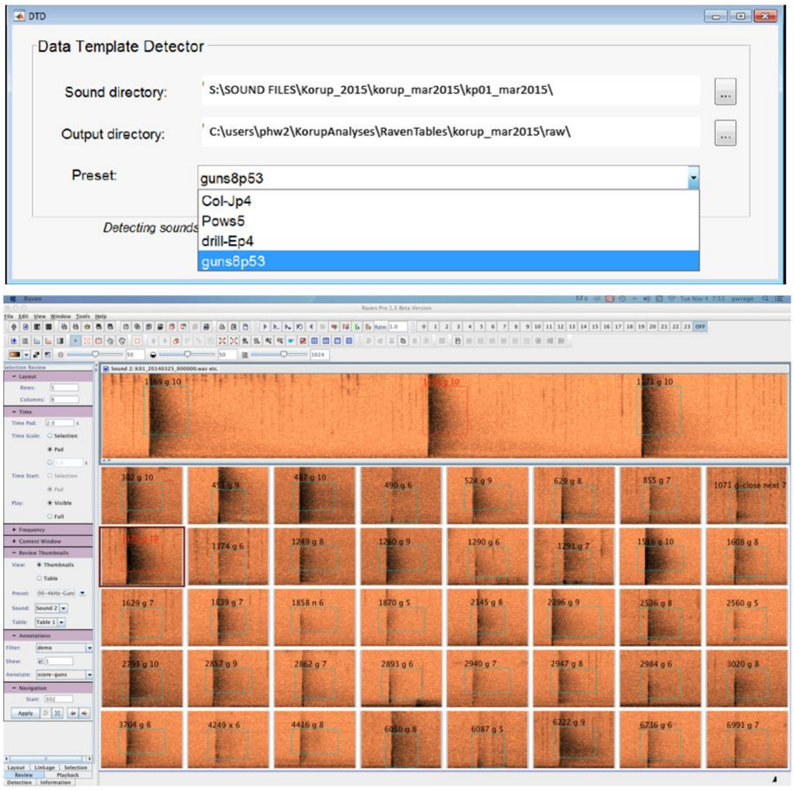


Figure 3: (above) Screen capture of the standalone gunshot detector algorithm developed by the Project; (below) Screen capture of the Raven Pro 1.4 software's main window showing a selection of putative gunshots "flagged" by the detection algorithm that are to be ranked by sound or image.

We obtained records of the KNP game guards' Cybertracker patrol records for the study period from the WWF-CFP's KNP site managers, and imported them in Quantum GIS (v. 2.12). The raw patrol routes of the Cybertracker files had to be first cleaned of erroneous routes/non-patrol routes, and "spikes" due to short-term location errors in the GPS of the cybertracker loaded handheld PDAs (Fig. 4 - 5). Without removing such "ghost patrolling" it would have been impossible to a) properly estimate the patrol effort at any given time, and b) be able to effectively compare patrolling effort across time periods.

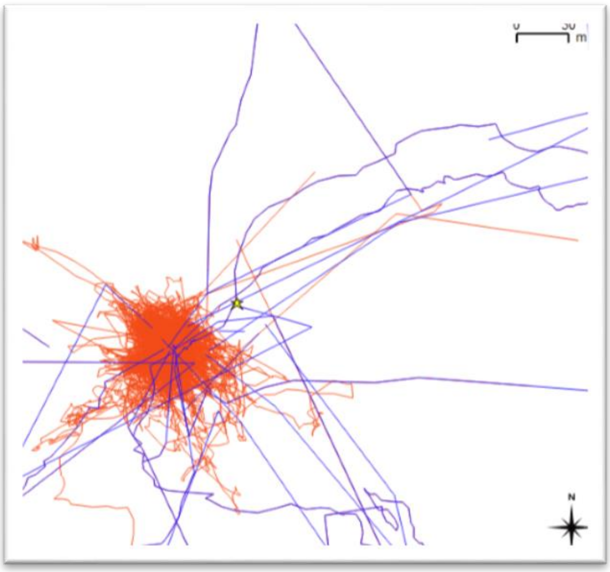


Figure 4: (left) Example of typical non-patrol movement (ORANGE lines) included in the raw Cybertracker data around camp-sites (here Chimpanzee camp). These lines were removed manually using the dat/tiem information of the lines and a fixed width of 100m radius around obvious camping sites.

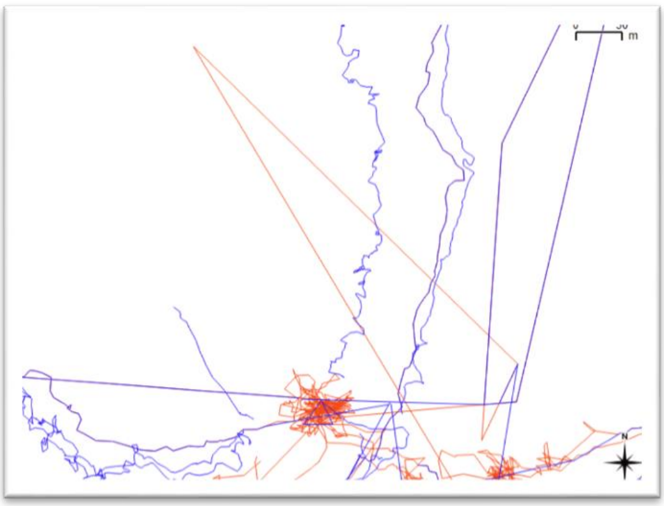


Figure 5: (right) Example of a typical "spike" (or "GPS jump") location error encountered periodically in the raw Cybertracker data that had to be removed. In this example the orange lines include both one large "spike" (750m) and a series of "ghost patrols" that happened around campsite due to the fact that the game guards left the GPS units on.

A few of the patrol routes had to be converted into routes from GPS waypoints and field comments. We clipped all patrols for a minimum convex polygon area containing the entire length of the line transects (P-Q-R-S) and the 1.5 km buffers of the ARUs. We calculated patrol effort at the level of day but summarized it at the level of week for the comparison with gun hunting pressure as prior analysis of gunshot and hunter survey data showed a strong weekly pattern and we felt that this would lower temporal correlation between subsequent measurements. Data from sensors that did not run for at least 4 days in a week were excluded from the analysis. Using the start-end time of a patrol we differentiated them between day (6.30am – 6.30 pm) and night (6.30 pm to 6.30 am) patrols. We calculated the overall weekly patrol effort both at the level of the PAM grid and each ARU (km of patrol within 1.2 km radius from the sensor). Finally, we estimated the patrol effort on and off trails, considering any segment of a patrol more than 50m from a main trail as being off trail, so as to account for the natural spatial error in the GPS data (evident from more closely examining the spatial variation of routes along frequently used paths). In general, the patrol preparation process was very time consuming but it afforded us the unique opportunity of estimating very accurately and with high precision the overall anti-poaching patrol effort across the three 4-month periods.

The patrol effort in the 2015-16 period (Nov. – Feb.) was markedly higher than in previous years at the same period (or for any other month in the past during the project period…or the history of the park as far as we are aware). Based on the evidence of a prolonged and pronounced peak in hunting activity in the weeks leading to and including the Xmas and NY celebrations, we identified this 4-month period as ideal for testing not only if anti-poaching patrols work as a deterrent of gun hunting in KNP, but also if an "ideal" (but realistic!) patrol protocol that included good spatial spread of the patrolling effort, day and night, on and off trails, and constant presence of patrols in the area for 4-months could achieve a noticeable decline in the gun hunting pressure. A brief description of the protocol is included in Appendix 1.

We ran general mixed effect linear models using as response variable the gunshot intensity in the PAM grid and as predictors the weekly rainfall (mm) obtained from a PAMOL Plantation weather station at Mana camp (daily measurements), and moon luminance index estimated as the product of the proportion of the face of the moon illuminated and the number of hours that the moon was visible above the horizon at the given location (used coordinates of Mundemba town) between sunset and sunrise (see Appendix 2 for more information). The moon face and moonrise and moonset data were downloaded from Astronomical Applications Department of the United States Naval Observatory (http://aa.usno.navy.mil/data/docs/RS_OneYear.php). Preliminary analysis during the project had shown a very significant and negative relation between rainfall and gun hunting intensity in the PAM, which is logical as hunting is not possible in strong rain. In addition, we speculated that there may be a relationship between overall moon light and the animal's activity, the hunters' activity, and the animals' detectability by the hunters. We did not speculate what the relationship maybe but similar moon cycle related effects on animal activity patterns is well documented. Appendix 3 contains a brief description (key) of all the fields in the final dataset used in the statistical software R to run the glm models. The final analysis was overseen by Paul Johnson – WildCRU's (University of Oxford) in-house statistician.

In parallel, the Darwin Initiative partnership undertook hunter surveys (30 hunters) in three villages in the periphery of the study area, so as to obtain additional information that could help interpret better the actual impact of the gun hunting activity recorded by the acoustic sensors (Fig. 6; see Appendix 3 for hunter survey form).

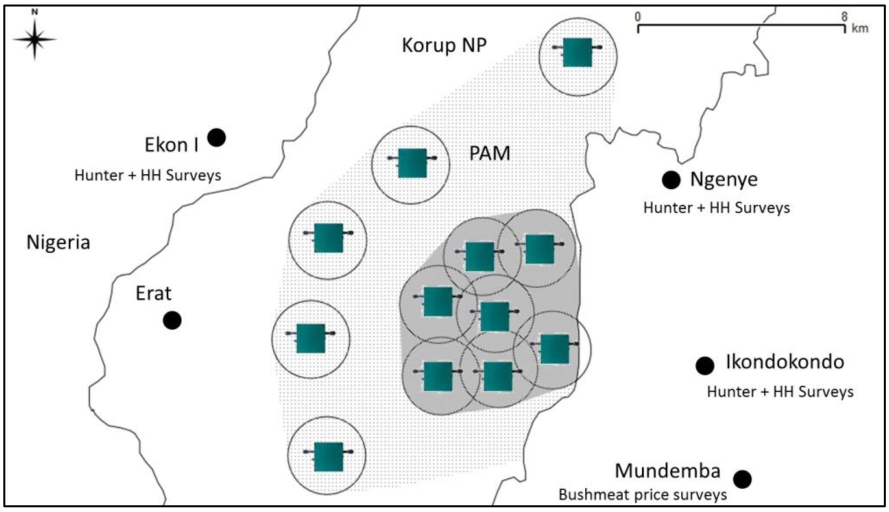


Figure 6: Location of hunter, household and bushmeat price surveys in relation to the acoustic grid in Korup NP.

3. Main findings

Gun hunting intensity

The twelve ARUs recorded over a two year period 185,353 hr of sound data (Year 1 /June 2013 – May 2014: mean 332.3 recording days/sensor; Year 2 /June 2014 – May 2015: mean 311.3 recording days/sensor). Appendix 5 shows the mean days that ARUs operated each month in Year 1 – 3. It should be noted that for the gun hunting intensity/patterns analysis we used only the first 2 years.

Overall, the SM2+ sensors were reliable and the occasions that sensors did not record data were primarily to either faulty battery connections or problems with the external microphones – not the ARUs themselves. No ARU was lost to due to the elements or vandalism by the end of the project.

We detected a total of 1,937 gunshots in Year 1 and 2,077 gunshots in Year 2. Adjusting for the number of days that each sensor operated *each month* (when a sensor recorded for at least 7 days), we estimated the total number of gunshots within the 54 km^2 PAM grid to be 2,044 in Year 1 and 2,246 in Year 2 – a 9.9% increase in gun hunting pressure. The mean number of gunshots detected per sensor per day was 0.47±0.08 in Year 1 and 0.55±0.15 – a significant 15.3% increase.

Analysis of the hunter survey data showed that the hunters' success rate is ~75%, meaning that a total of 1,533 animals were killed by gun within the study area in Year 1 (28.4/km^2) and 1,685 in Year 2 (31.2/km^2). If the hunting intensity reported within the PAM grid in the first two years reflects the gun hunting pressure across the park's 1,260 km^2, there were total of 35,784 and 39,312 animals killed in Year 1 and 2 respectively (or more conservatively 34,364 and 37,752 if we remove 50 km^2 of estimated farmland – and hence lower hunting intensity – areas around the 4 villages located within KNP; 2 km radius around them). The hunter surveys also showed that gun hunting accounted for 78% of all animals killed by hunters on average (higher for more active/professional hunters). If we account for the additional animals killed by snares, by dogs, or by machete, the total number of animals that KNP "bleeds" each year is closer to 45,876 – 50,400 (or more conservatively 44,056 – 48,400) – a staggering number for one of the jewels of Cameroon's PA network.

The above number should be considered a conservative one as it ignores animals that maybe injured but not retrieved by the hunters. Given that the 2/3 of the animals reported killed by hunters were duikers (blue *Philantomba monticola* – mean weight ~5kg*;* or "red" *Cephalophus ogilbi* or *Cephalophus dorsalis* mean weight ~18kg) and brush-tailed porcupines (*Atherurus africanus;* mean weight ~3 kg) we could assume that the typical weight of an animal killed may be ~7.5 kg (rough estimate). If this is the case, then the KNP ecosystem loses between 330,000 and 378,000 kg of biomass (or 272 - 312 kg/km^2). Since studies have shown that biomass extraction rates of 150-200 kg/km^2/year are considered to be the maximum sustainable levels for tropical rainforests (Robinson and Bennett, 2004), we can expect that the current estimates of biomass extraction from only a fraction of Korup's wildlife species – and only for human use – are certainly unsustainable for at least some heavily hunted species and for large sections of the park. This finding in itself is not surprising given previous reports of primate declines in high hunting areas within and in the periphery of the park (Waltert et al., 2002; Linder, 2008).

But how many hunters are likely operating in the KNP? Again, the PAM data combined with the hunter surveys can help us make a rough estimate. The mean number of animals killed by the 30 surveyed hunters with every hunting method was 559. Applying this mean to the lower and upper estimates of animals killed annually in the first two years, there are between 78 – 90 hunters operating regularly in the park.

The use of acoustic monitoring has provided a reliable baseline of current level of biomass extraction within Korup – Cameroon's flagship rainforest park – that can serve both as the call for action for responsible management authorities and a high resolution monitoring tool to evaluate success of ensuing conservation actions. It is also apparent from this analysis that Korup is unlikely to serve as a source of wildlife populations in neighbouring forest areas where sustainable hunting regimes could theoretically be designed. On the contrary, Korup is gradually being drained, endangering the food security of rural communities in the region.

Temporal Patterns of Gun Hunting Activity

The acoustic monitoring data have not only shed light on the extraction rates within Korup NP, but have – critically for combatting the current levels of poaching – provided unprecedented information on the spatial and temporal gun hunting patterns. It is with such information that the anti-poaching patrols can be designed to achieve maximum impact given current resources, and to evaluate their efficacy in the long run.

Specifically, the analysis of the gunshot timings show that most of the gun hunting (>65% gunshots) takes place at night (Fig. 7). This pattern remains true across sensors, seasons and years. Interestingly, the 30 surveyed hunters reported making 2/3 of their gunshots at night, matching in effect the pattern observed here. In contrast only ~7% of the already limited anti-poaching patrols were conducted during the night in year 1 (and practically none in year 2). This strongly suggests that current patrols are not optimally designed for deterring and/or apprehending poachers. It is not clear from our data whether the pattern observed is due to the hunters being more active when animals are most active or easy to locate/shoot, or the hunters avoiding day time when rangers may be patrolling.

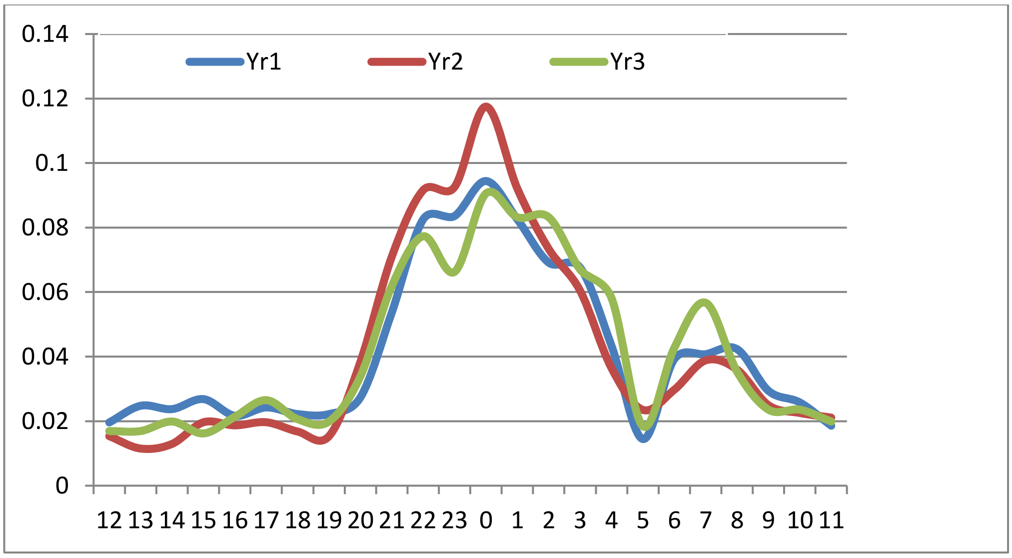


Figure 7: Proportion of gunshots during different time of the day (Year 1 – 3) / Note: X-axis ranges from noon to noon.

There is also a clear weekly pattern in the hunting activity. There is a peak in gunshots recorded on Tuesday – Wednesday, with gun hunting pressure declining gradually by the weekend (Fig. 8). This pattern is again consistent across seasons and years. We can only speculate as to the reasons for this, but a similar strong pattern was observed in the timing of the >17,000 gunshots reported by the surveyed hunters (Fig. 9). The fact that most local markets are on Saturday (incl. in Mundemba), suggests that many hunters time their hunting so as to exit the forest in time to sell it for that week's market. This could be again a useful information for the anti-poaching patrols which could target certain trails on Wednesday – Thursday.

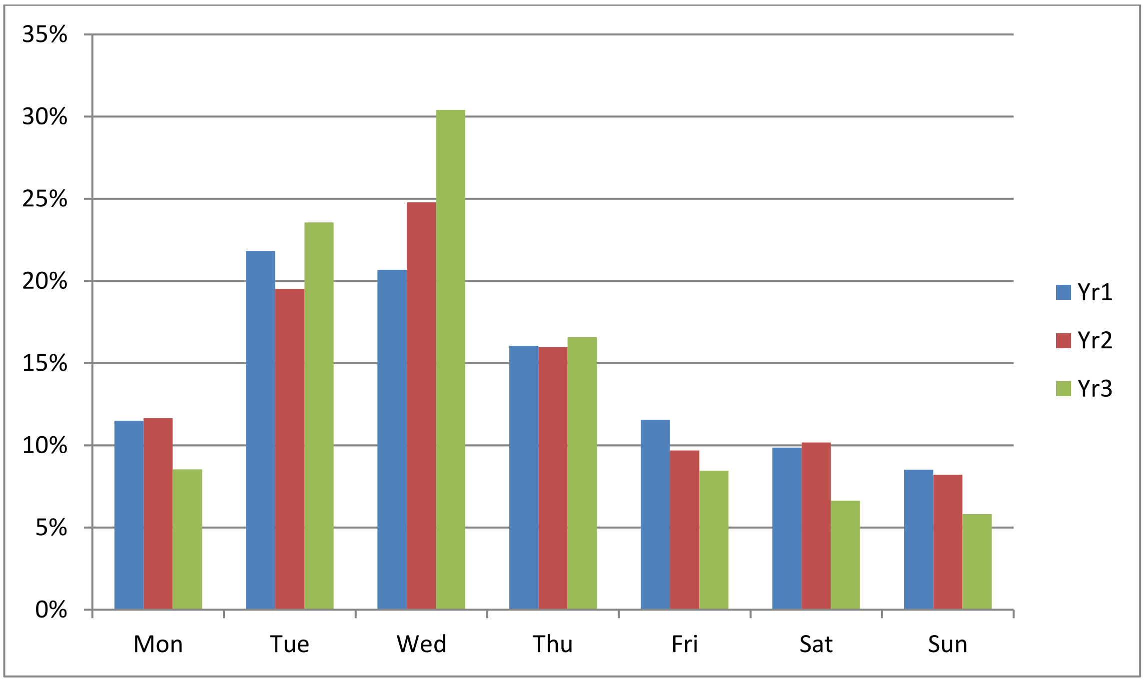


Figure 8: Weekly distribution of gunshots across days of the week (Year 1 – 3) / Note: Year 3 data only from June to March (10 months)

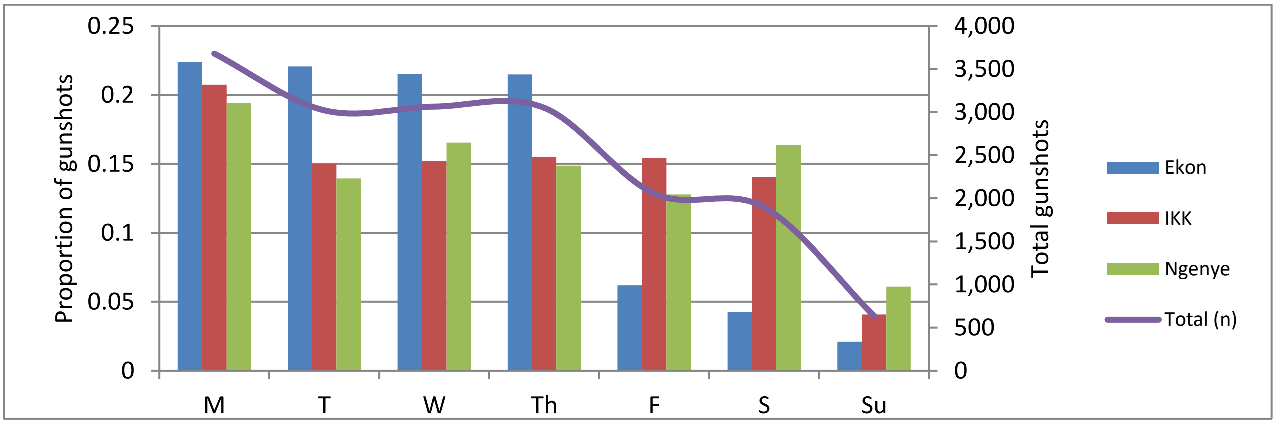


Figure 9: Weekly pattern of gunshots made over the year by the surveyed hunters (n=17,401 gunshots)/ Note: Year 3 data only from June to March (10 months)

There is also considerable seasonal variation in gun hunting intensity persists across years but with different intensity in the peaks and troughs (Fig. 10 – 11). The annual cycle is characterized by low gun hunting pressure in the rainy season (June – September) and a very pronounced peak in December which in Year 2 reached a 600% increase in intensity over the rainy season when there was a short-lived (mid-August – September) but significant decline in gun hunting activity due to bushmeat market closures in Nigeria as a result of the arrival of the Ebola virus there. The effect of this pronounced perturbation in the hunting patterns was only picked up as clearly in the acoustic data which highlights the ability of acoustic monitoring to provide high temporal resolution regarding gun hunting activity in an area. There is a second peak in gun hunting in April-May in both years.

This seasonality in gun hunting pressure was also reflected in the hunting data reported by villagers in terms of animals killed by all methods. The April-May peak was more pronounced however than the Xmas/NY period one. In the village of Ngenye, the proportion of animals killed by gun also declined sharply in the rainy months. The hunters in the other villages however reported just a decline in overall hunting effort, but no significant switch from gun hunting. Given that the villages of Ekon I and IKK account for overwhelmingly the majority of the hunting records reported, we can assume then the following three points about the nature of hunting in the PAM grid:

a) the rainy season dip observed in the actual gun hunting events (acoustic data) is mostly an actual decline in overall hunting (both gun + snare) and not a switch in hunting methods,

b) the marked increase in the pre-Xmas/NY weeks in gun hunting pressure is due to an influx of outsider hunters in the PAM grid and less so due to an increase in hunting effort of the hunters operating regularly in the area, and

c) the April – May peak is caused primarily by an actual increase in the hunting effort by the hunters typically operating in the PAM grid and less so by an influx of additional hunters.

The detail of information that can be obtained from the acoustic data is unparalleled to what has ever been available to PA managers in the area. It is also noteworthy how the additional hunter survey data can enhance the interpretation of the acoustic data.

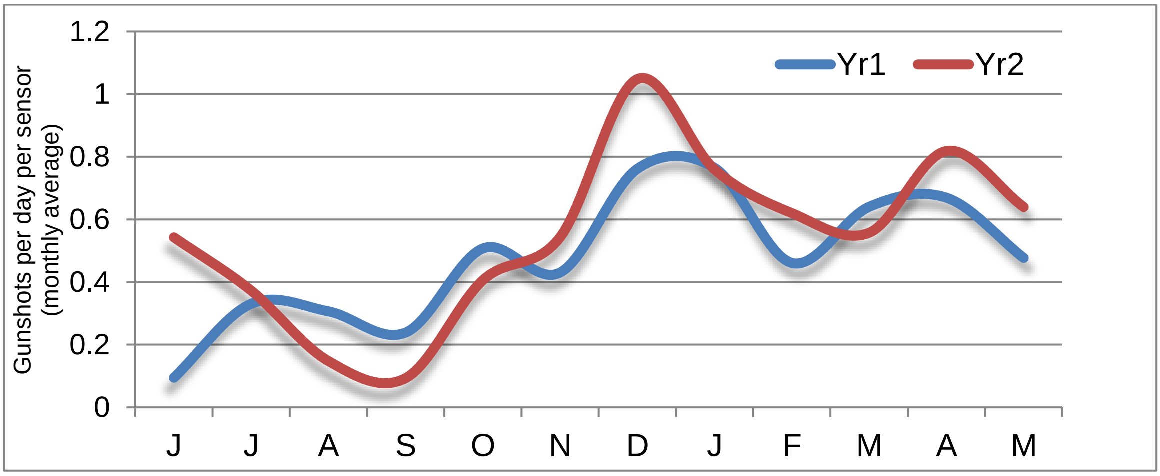


Figure 10: Annual trend in gun hunting intensity - mean gunshots per day recorded across the entire 54 km^2 acoustic monitoring grid (12 sensors) / Note: Bush market closures in Nigeria took place from mid-August to end of September in Year 2.

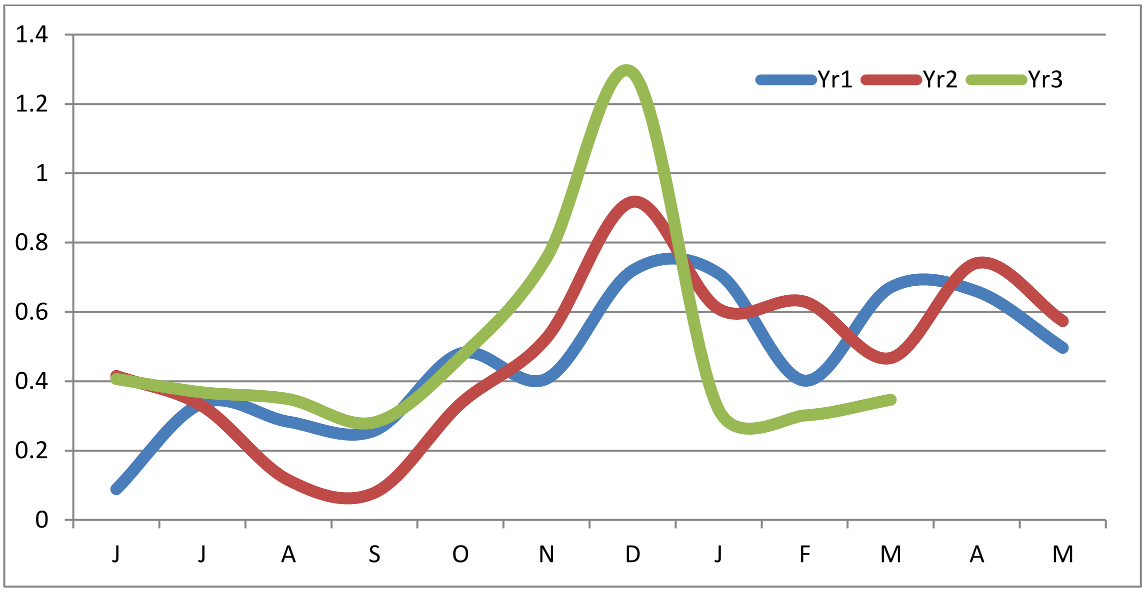


Figure 11: Annual trend in gun hunting intensity - mean gunshots per day recorded across the entire 54 km^2 acoustic monitoring grid based on 9 ARU data only (those that were fully operational in Year 3 – see Appendix 5. We have not yet analysed the data for April-May in Year 3.

Spatial Patterns of Gun Hunting Activity

Examining the spatial distribution of the hunting pressure it is apparent that not all areas of the PAM grid were under the same gun hunting pressure or experienced the same change in gun hunting pressure in Year 2 (e.g. Fig. 12; see Appendix 6 for specific values for both years). In fact, the mean increase of ~10% in gunshots recorded in Year 2 does not capture the fact that the increase in most sensors was higher and especially in sensors along the periphery of the PAM located to the west along the lien transects (sensors KP1 – 3 – 5 – 7; see Fig. 1 for ARU codes).

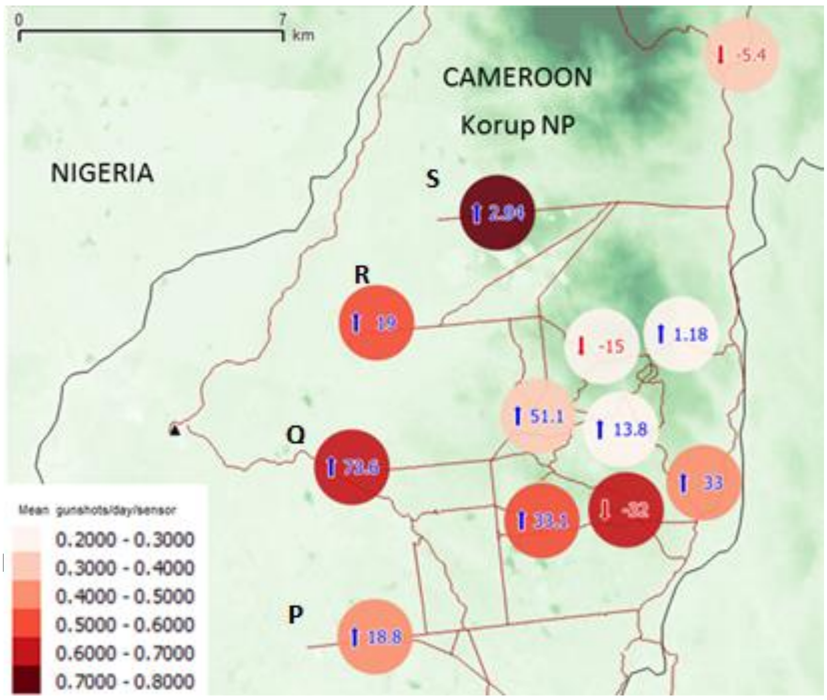


Figure 14: Mean gunshots per day per sensor for Year 1 (see legend for values) with % changes in gun hunting intensity of Year 2 overlaid (blue: increase / red: decrease). / Letetrs P-Q-R-S refer to the four permanent ~5 km line transects that were surveyed monthly during the DI project.

The spatial distribution of the hunting pressure observed in the acoustic data (actual hunting events) was not captured accurately in the encounter rates of hunting signs recorded during the monthly line transect surveys (Fig. 13). While the relative hunting intensity hinted by the number of signs was approximately correct for the first three transects (P-Q-R), the line transect data completely failed to capture the very high hunting pressure in transect S. This may be due to the fact that the terrain there is more rough (possibly increasing the decay rate of signs and/or decreasing their detection rate by the field team), but it could also be because the ARU is placed closer to the hunting activity spot in the area than in the other transects. Regardless, the ARU data record actual hunting events as compared to indirect ones.

Similarly, the transect survey data on hunting signs did not detect the actual ~10% increase in gun hunting observed in the acoustic data (Year 1: 0.43 ± 0.06 signs/km; Year 2: 0.40 ± 0.07 signs/km).

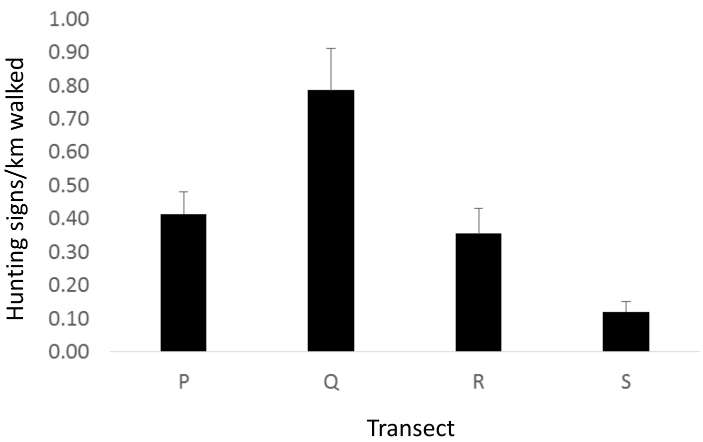


Figure 13: Hunting sign encounter rate along each transect (signs/km walked).

The ad hoc recording of hunting signs by the anti-poaching patrols failed to show any significant seasonal or spatial patterns that matched the data of the PAM grid. This is not surprising however given the great inconsistency in the data collection protocol across teams and time and the very poor notes that accompany those notes. This is one more reason for detaching the hunting intensity data from the law enforcement focused patrols – field signs should be used only to help guide the patrols as to the potential location of the hunters during the patrols duration etc. – so very useful still, but not for long term monitoring of hunting trends.

Overall, the temporal (day, week, season, year) and spatial resolution on gun hunting patterns provided to the KNP management by the passive acoustic monitoring grid is truly unprecedented for any PA in Central Africa (and most likely across the tropics). As we will show in the next session, it provides the robust field-based evidence needed to robustly and transparently evaluate the efficacy of anti-poaching patrols to curb poaching in a target area and helps guide adaptively future anti-poaching strategies.

Do anti-poaching patrols work?

The primary objective of the DI project was to develop a protocol for evaluating and designing the efficacy of anti-poaching patrols to curb illegal hunting within PAs. Until now we have demonstrated that the PAM grid has the ability to provide unprecedented resolution on the gun hunting activity in the area, but we have yet to report whether that data can be effectively used to evaluate the patrols' impact.

Specifically, we wanted to answer the following two questions:

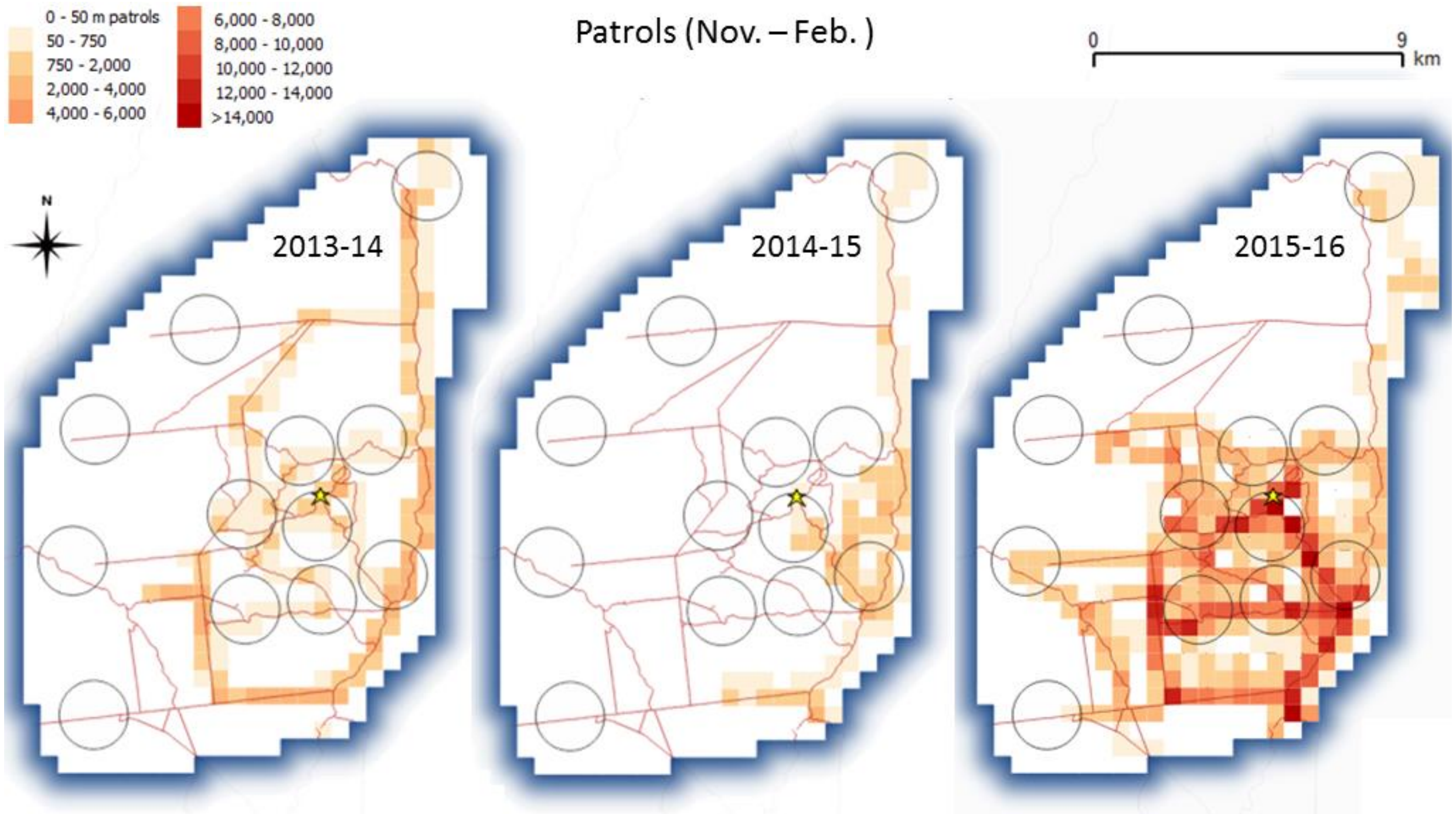
- Do anti-poaching patrols have a measurable effect on the levels of gun hunting in KNP?
- Did the increased patrol protocol delivered by the KNP rangers in the 2015-2016 XMAS/NY period deliver the goal of a marked decrease in hunting intensity in the area compared to the same periods in the previous two years?

The anti-poaching patrol effort differed significantly across the three 4-month periods, both in terms of total effort (days and km patrolled) and in the nature of the patrols (spatial coverage, day- - night and on-off trail ratios) (Fig. 14). The records of any patrols in Jan-Feb. 2014 (Year 1) were not clear so we excluded that month from the analysis (only for that year). We know only that one brief patrol of a few kilometres was made within the PAM grid but the exact route could not be inferred from the poor records. While we do not think that an assumption of "0 effort" would be far from the truth for these months, we did not want to introduce any error in the final analysis. This is why those weeks were removed from the analysis for that year.

Specifically, the patrol effort in terms of km patrolled was 450% higher in 2015/16 compared to the 2013/14 period and 1,150% compared to the 2014/15 period. This increased effort was delivered via having more patrol days in the PAM grid (16, 7, 82 days for the three years in chronological order; Fig. 14) and not an increase in overall km patrolled per day per team. This means that the 2015/16 protocol did not ask the patrol teams to rush through more kilometres. The spatial coverage was also significantly different, with only 8.5% and 3.2% of the 0.25 km^2 patrol grid cells receiving at least 1 km of patrolling effort in the first two years, compared to 27% in Year 3. The increased patrol effort was focused on the "core" of the PAM grid with little variation of patrolling occurring in the peripheral ARU buffers. This means that the actual increased patrol effort in those "core" ARU areas was even higher – in effect achieving a "flooding" of the area by rangers compared to previous years. The total off trail patrol effort was 186 km (~1/5 of all km) in 2015/16, compared to only a fraction of that in the previous two years (2013/14: 12.6 km; 2014/15: 34.9 km). Similarly, 41% of the patrol effort (km) was conducted at night, when we knew most of the gun hunting activity taking place, compared to 0% and 4% in previous years.

The rainfall differed considerably over the three years, with the dry season being longer and a lot more pronounced in Year 3 compared to previous years (Fig. 16)

It is therefore clear that a dramatic and sustained increase in the patrol effort and quality was achieved in Year 3, and that it was primarily focused in the "core" of the PAM grid. Figure 15 shows the patrol effort within the 1.2 km radius of each ARU for the three 4-month periods. Figure 17 show the weekly trends in total patrol effort and total gunshots per day within the entire PAM grid during the 17 weeks of each of the three years.



Total patrols	175.2 km
Total days (km/day)	16 (10.9km/day)
ON trail (%)	92.8%
OFF trail (%)	7.2%
NIGHT (%)	0%
Extent of patrols	8.5% cells (>1km)

Total patrols	77.8 km
Total days (km/day)	7 (11.1km/day)
ON trail (%)	55.2%
OFF trail (%)	44.8%
NIGHT (%)	4%
Extent of patrols	3.2% cells (>1km)

Total patrols	971.0 km
Total days (km/day)	82 (11.8km/day)
ON trail (%)	80.8%
OFF trail (%)	19.2%
NIGHT (%)	41.6%
Extent of patrols	27% cells (>1km)

Figure 14: Summary of anti-poaching patrol effort metrics for the Nov –Feb. period over 3 years [Patrol grid shown: 0.25 km^2] / Circles mark the 1,000m radius buffer around each of the ARUs / Star marks the main tourist/research/ranger camp location / Red lines mark the permanent trails/transects. *Note that the record for Jan. 2015 patrols was poor – a patrol took place (few ~10 km length) around Rengo Camp but we could not infer its accurate route.*

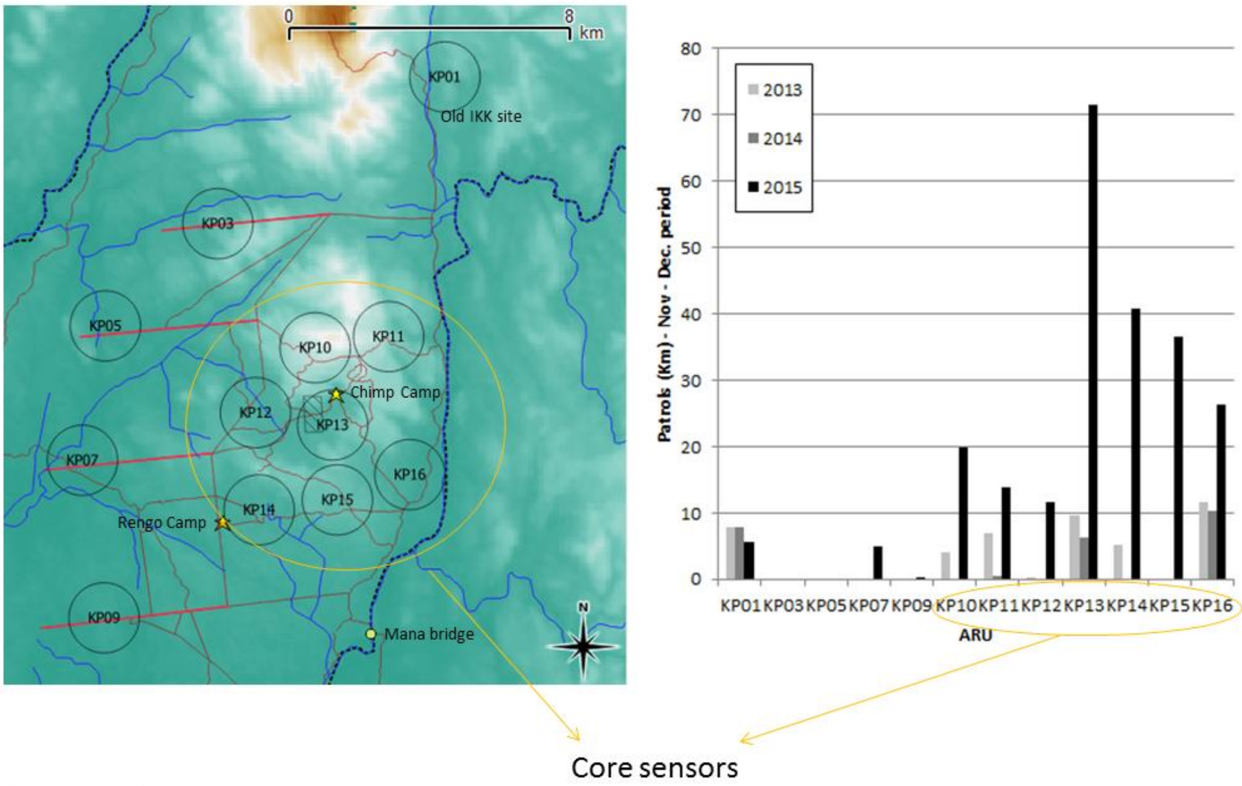


Figure 15: Total patrol effort (km) across the three 4-month periods within a 1.2 km radius from each ARU. *Note that the record for Jan. 2015 patrols was poor – a patrol took place (few ~10 km length) passing within the KP14 ARU, but the exact route could not be inferred from the poor ranger records. We removed those weeks from the analysis.*

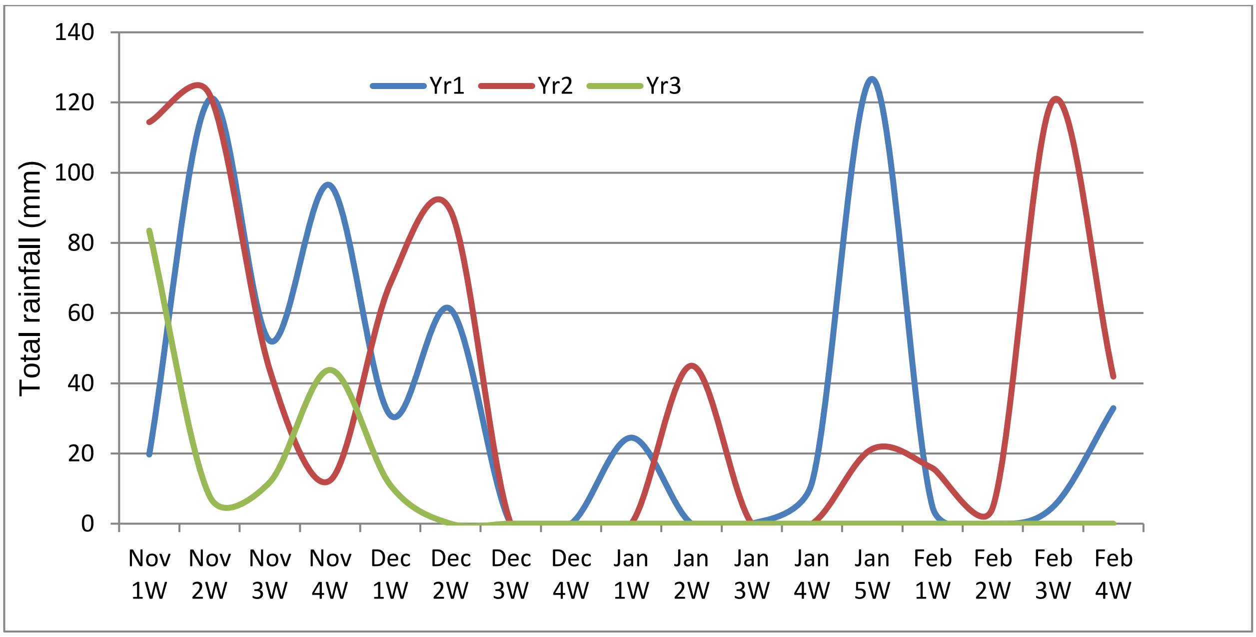


Figure 16: Total rainfall across the 4-month period (Nov. 1 – Feb. 28) in the three years of the study calculated at weekly level.

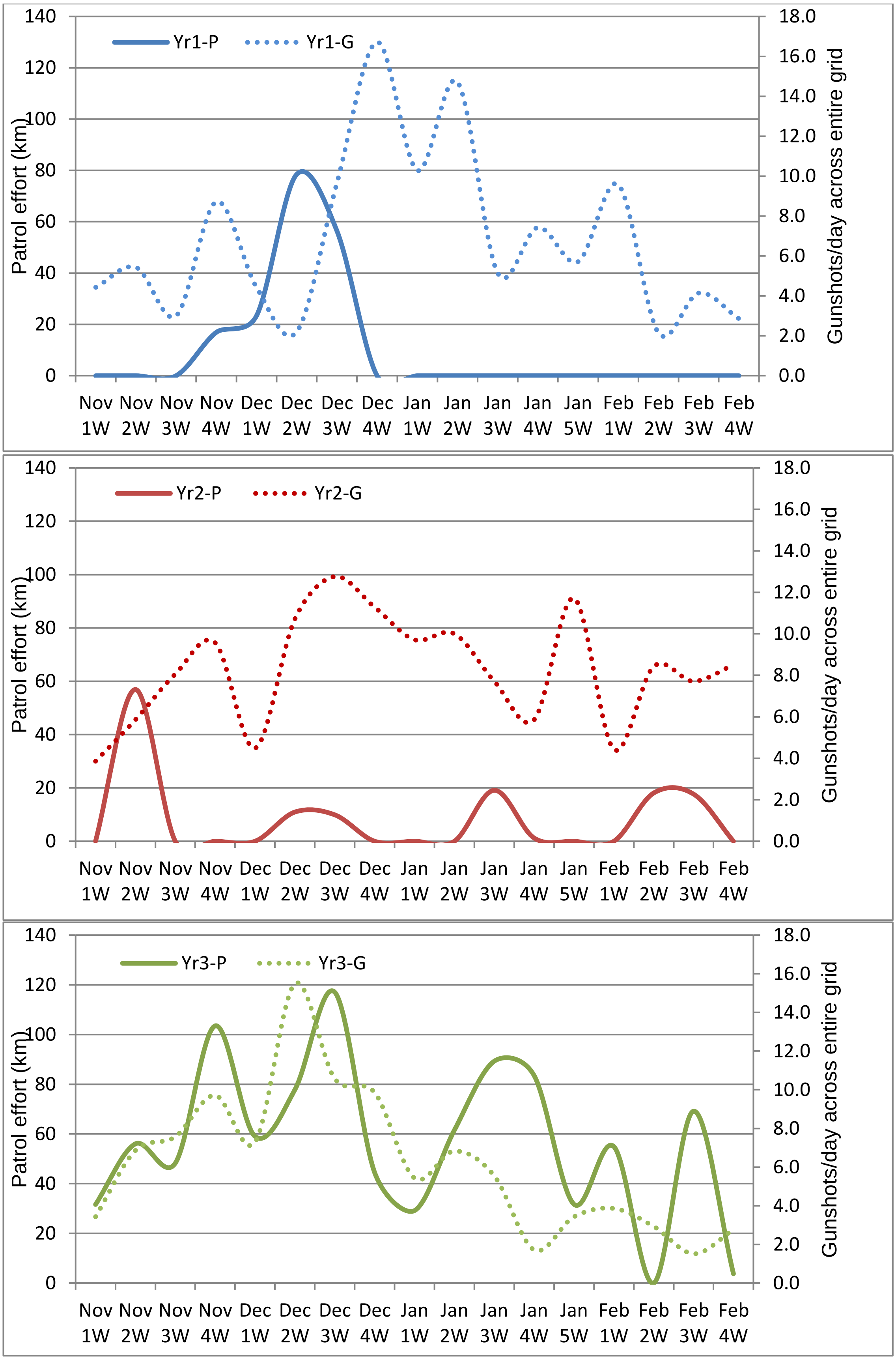


Figure 17: Total patrol effort (km; solid line – primary Y axis) and gun hunting intensity (total gunshots/day; dotted line – secondary Y axis) across the entire PAM grid for 2013/14 (top/blue), 2014/15 (middle/red) and 2015/16 (bottom/green)

A simple regression of overall gun hunting measures against total patrol effort at a week's time scale showed no effect of patrols (Fig. 18).

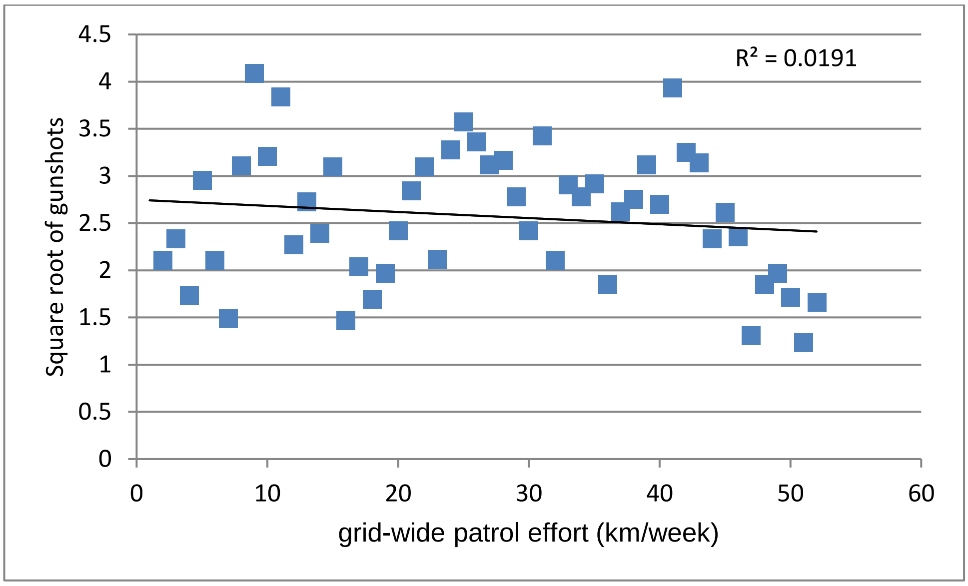


Figure 18: Scatterplot (and linear regression line) of the square root of gunshot activity across the grid (mean weekly number of gunshots across all sensors in a day) and patrol effort across the total PAM grid in that same week (km)

Earlier preliminary analysis had shown rainfall to be negative correlated to gun hunting, so we proceeded with a series of incrementally more complex multi-variate general and generalized linear models in order to test for any evidence of patrols and reduced hunting after accounting for other covariates that could be "masking" any effect.

Rainfall and moon illumination effect on hunting

Both rainfall and moon illumination were negatively related to gun hunting intensity, with the lowest levels of hunting happening in rainy, dark nights (Fig. 19-20).

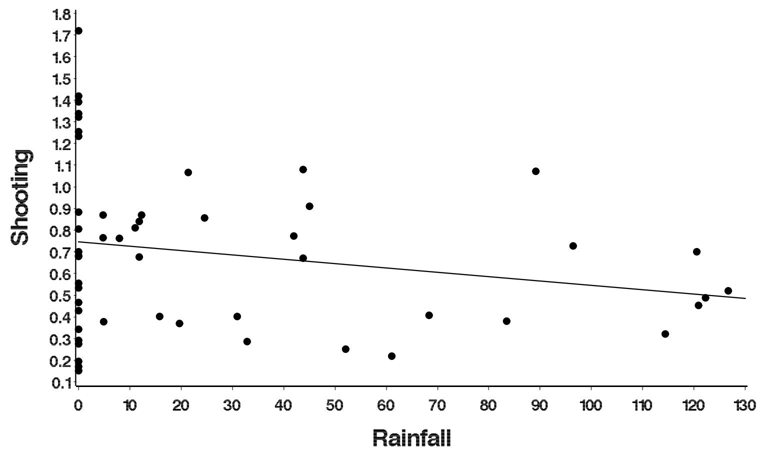


Figure 19: Plot and fit line showing the significant negative relationship between gun hunting activity (gunshots/sensor/day) and rainfall (total mm) at weekly level.

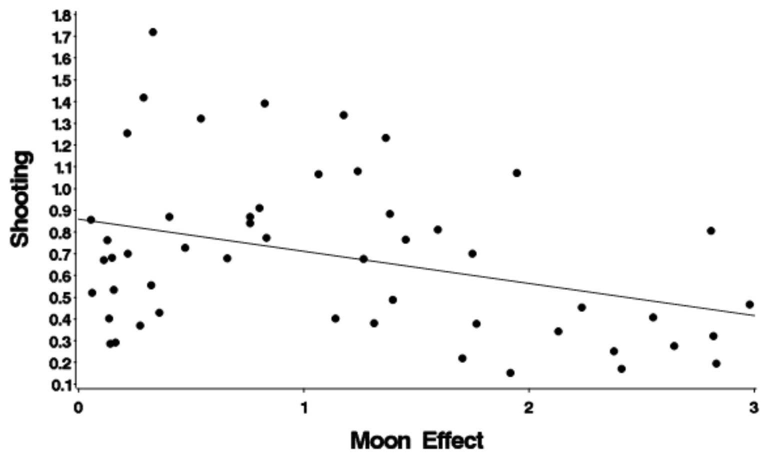


Figure 20: Plot and fit line showing the significant negative relationship between gun hunting activity (gunshots/sensor/ day) and moon illumination at weekly level; higher moon illumination index values mean brighter nights

Having determined the importance of rainfall and moon as hunting predictors, we included them in future models and tried to test additional covariates to help further improve the model.

The data were now examined with the response (gun hunting) being measured at the sensor per week per year level -so, we had 17 weeks* 3 years* 12 ARUs as data points. Table 1 shows the summary results of a model that examined for a possible (polynomial) effect on gun hunting by the number of weeks to XMAS (i.e. whether there was a sharp increase in hunting as we approach XMAS) (Fig. 21). There was no evidence to support such a trend – on the contrary there was a negative significant relationship which suggests that people "wrap up" hunting as XMAS approaches, and that peak hunting (for meat or cash) happens a few weeks before the celebration days. Importantly, there was no significant effect of patrol effort on gun hunting intensity in this model (i.e. p-value >0.05 / beta coefficient's 95% CI contains zero).

Table 1: Summary of model with gun hunting (week level) as response, and year, rainfall, moon illumination, patrol effort and weeks to XMAS (polynomial) as predictors. Note that the values of weeks before Xmas were inversed in their sign (compared to Fig. 21) for this model, so the positive relation should be interpreted as a decrease in hunting as we approach Xmas.

R-Square
0.434802

Source	DF	Type I SS	Mean Square	F Value	P
Year	2	0.11587339	0.05793669	1.64	0.2094
Rainfall	1	0.12565828	0.12565828	3.55	0.0680*
Moon	1	0.23926146	0.23926146	6.76	0.0137*
Patrol effort	1	0.09125908	0.09125908	2.58	0.1175
Weeks to XMAS	1	0.14780136	0.14780136	4.18	0.0488*
Weeks to XMAS^2	1	0.20544818	0.20544818	5.81	0.0215*

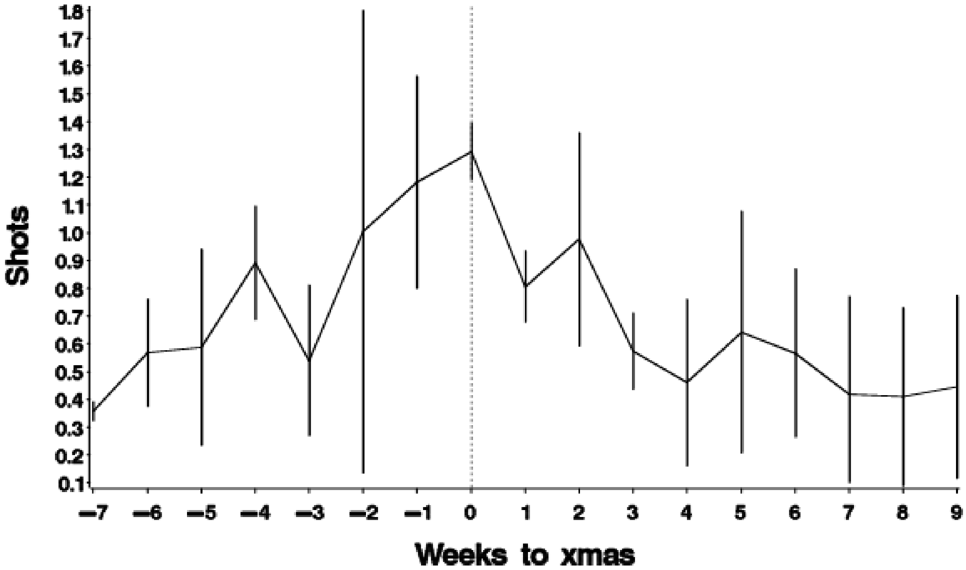


Figure 21: Variation of gun hunting intensity (shots/sensor/day) across weeks leading to and following XMAS

Additional exploration with general linear models testing for an overall PAM wide positive relation between patrols and day or night shots only showed no evidence of a significant relation, so we continued using as response variable total gunshot pressure.

We proceeded in our exploration of the data with generalized mixed effect models that examined the effect sensor level patrol effort (i.e. patrols within 1.2 km of an ARU) on sensor (ARU) level of gun hunting (i.e gunshots detected at specific sensors rather than the entire PAM grid). In effect these models examined whether hunters operating near different sensors responded differently to the patrol intensity within their hunting grounds (and if so, if they were significantly deterred by them). This question is logical to examine, as we can expect that hunters do not necessarily respond uniformly to the same risk – they are individuals driven by different levels of tolerance to risk depending on personal character and their incentives to hunt. Moreover, it is logical to anticipate that hunters are not omniscient of patrol intensity in areas where they do not hunt, and hence sensor level patrol efforts are reasonably better suited predictors for these models than PAM grid level.

We used the lmer4 package in R to test incrementally more complex models that included moon, rainfall, and year as covariates with an equal (fixed) or random effect of patrol effort at sensor level gun hunting. An example of the simplest of those models' code in R is the following:

```
model1<-(lmer(sy~Year+z_pst+(1|Sensor),REML=FALSE,data=sdata_p))
```

where

sy = square root of mean gunshots/day/given sensor in a given week

Year = the week's year (1-3)

z_pst = the standardized total sensor-level patrol effort in kilometres in that given week

Sensor = ARU

There was no evidence of a patrol effect on gun hunting intensity in that model. Adding as predictors rainfall and moon illumination did not result in a better effect of patrols on hunting either (model code: model1.2<-(lmer(sy~Year+z_moon+z_rain+z_pst+(1|Sensor),REML=FALSE,data=sdata_p)) - see results below). There was once again a significant (bold values) negative effect on hunting by moon illumination as in the simpler general linear models. The effect of rainfall was not significant.

```
Random effects:
 Groups   Name        Variance Std.Dev.
 Sensor   (Intercept) 0.1348   0.3672
 Residual             1.2320   1.1099
Number of obs: 402, groups:  Sensor, 12
```

Fixed effects:

	Estimate	Std. Error	df	t value	Pr(>|t|)	
(Intercept)	1.83200	0.16795	43.10000	10.908	5.60e-14	***
YearYr2	0.14061	0.15547	390.70000	0.904	0.366	
YearYr3	-0.05497	0.18012	396.40000	-0.305	0.760	
z_moon	**-0.25808**	**0.06169**	**389.70000**	**-4.183**	**3.55e-05**	*******
z_rain	-0.08959	0.06611	389.70000	-1.355	0.176	
z_pst	-0.08669	0.05725	400.40000	-1.514	0.131	

The effect of moon illumination in overall gun hunting activity differed across sensors, but had consistently the same relation (Fig. 22)

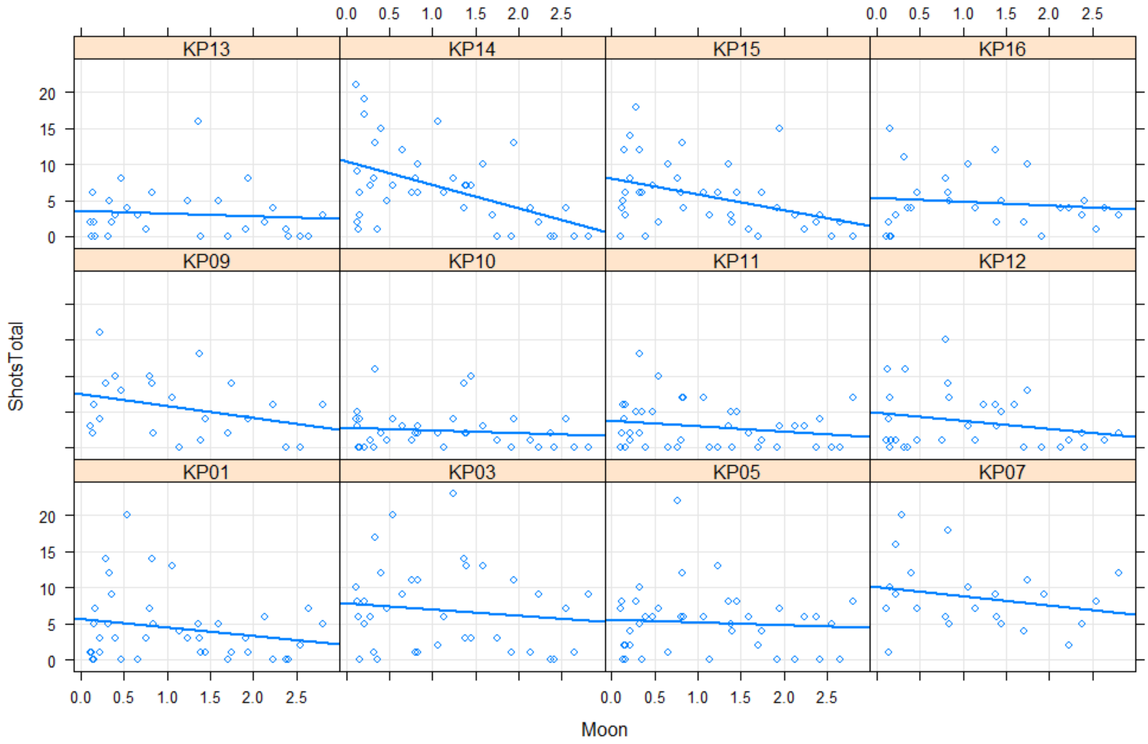


Figure 22: Effect of moon illumination on gun hunting intensity at ARU site level.

Using AIC for model selection, we selected the following model as the best performing among plausible combinations,

model1.7<-(lmer(sy~Year+z_moon+z_rain+z_pst+z_pgtlag+Core.S+Weeks2Xmas+(1|Sensor), REML=FALSE,data=sdata_p))

…where sensor-level gun hunting was predicted by fixed effects of moon illumination, rainfall and year, patrol effort at sensor level, patrol effort at PAM level in the previous week (testing a potential lag in the response of hunters to the presence of rangers – which would be logical), an effect at being a Core sensor, and the number of weeks until or since XMAS.

```
Random effects:
 Groups   Name        Variance Std.Dev.
 Sensor   (Intercept) 0.110    0.3317
 Residual             1.158    1.0762
Number of obs: 402, groups:  Sensor, 12
Fixed effects:
             Estimate Std. Error        df t value Pr(>|t|)
(Intercept)   1.93780    0.21023  27.10000   9.217 7.61e-10 ***
YearYr2       0.46456    0.16492 391.20000   2.817 0.005096 **
YearYr3      -0.03817    0.19320 396.30000  -0.198 0.843481
z_moon       -0.24648    0.06093 390.10000  -4.045 6.30e-05 ***
z_rain       -0.12172    0.07006 390.10000  -1.737 0.083125 .
z_pst        -0.09866    0.05610 402.00000  -1.759 0.079389 .
z_pgtlag      0.20787    0.07710 390.10000   2.696 0.007318 **
Core.SYes    -0.37779    0.22643  12.50000  -1.668 0.120132
Weeks2Xmas    0.05110    0.01349 391.70000   3.787 0.000176 ***
```

Moon and rainfall remained equally significantly (or near significantly) negatively related to sensor level gun hunting. There was for the first time a weak (near significant) negative effect of sensor-level patrol effort (z_pst) on ARU level gun hunting, but the trend – when plotted – was not consistent across the sensors (Fig. 23).

Counterintuitively, there was also a significant positive relation between previous week's grid-level patrol effort (z_pgtlag) and the current week's sensor level hunting (Fig. 24). A possible explanation for this may be that hunters are informed either from contacts in Mundemba or from other hunters/own field observations that the rangers were in KNP patrolling at a given week and that they considered the risk of encountering rangers the following week to be lower, probably because of the historically short patrol durations, and chose to hunt then. Another explanation could be that rangers patrolled often before peaks in gun hunting intensity because of personal/cultural reasons – e.g. exited the forest before a big local celebration to be with their families, at the time when the hunters were going in to hunt for cash or meet for that same occasion. These potential reasons behind the observed pattern would need closer examination but the effect is quite significant and strong not to be actually reflecting some true pattern. This effect was especially pronounced in the peripheral ARUs near the villages of Erat and Ekon I, where most of the increase in gun hunting intensity in year 2 occurred (Fig. 24).

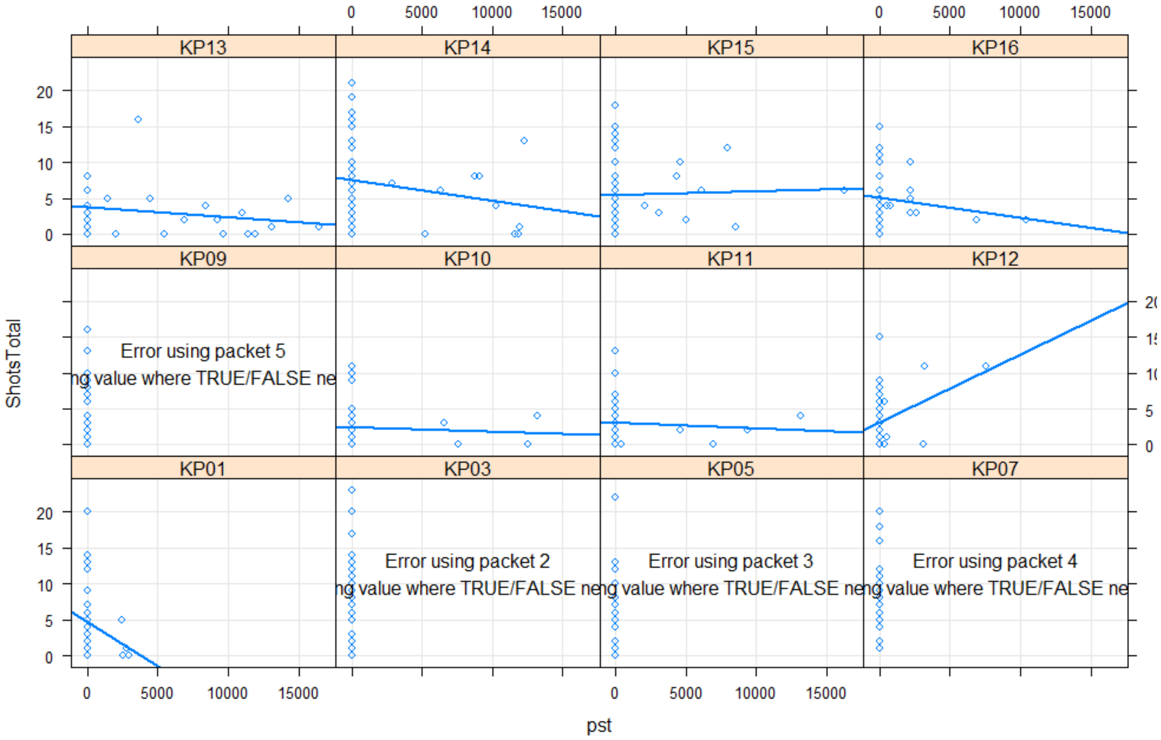


Figure 23: Effect of ARU (sensor) level patrol effort on gun hunting intensity at ARU site level. It was not possible to generate graphs for sensors with zero patrol effort. The overall relationship was weak and not significantly negative, probably because of the inverse trend in sensor 12.

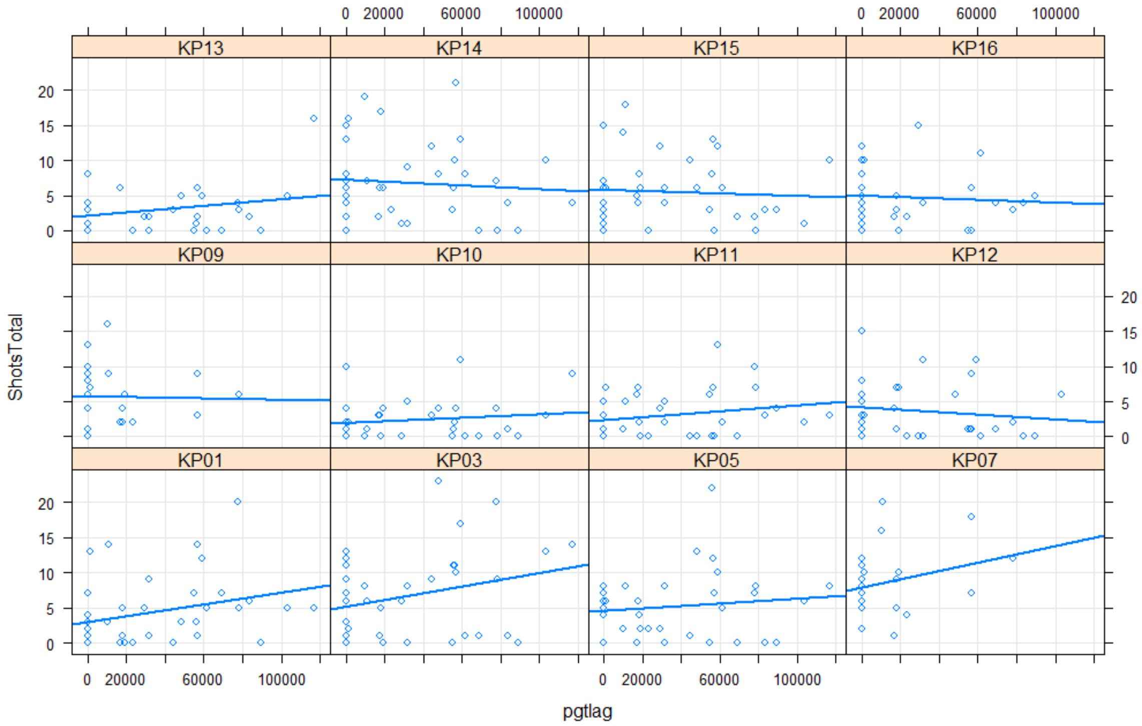


Figure 24: Effect of gird wide patrol effort the previous week (pgtlag) on gun hunting intensity at ARU site level the following week.

A final model examined the potential effect of sensor level off-trail patrol effort on gun hunting intensity at sensor level. There was once again no evidence to support that off trail patrols had a significant effect on overall hunting pressure at the sensor level.

Overall, our analysis has shown that there is no clear evidence of a significant negative relation between anti-poaching patrol efforts (whether at the grid or the sensor level) on sensor or grid-level gun hunting intensity. We also conclude that there was no significant effect on gun hunting of the dramatically increased patrolling effort in Year 3 (Nov 2015 – Feb 2016) since "year" was not a significant parameter in the models (i.e. the models could not differentiate based on the gun hunting data in a given week if that week came from Year 1, 2 or 3). There are of course additional models that can be run, which may show some weak effect of patrolling at some scale in time/space. However, as Fig. 11 shows, it is apparent that even after raising the patrol effort by 500-1,000% in total effort compared to previous years, the Xmas hunting peak remained high (higher in fact than inprevious years). Patrols did not even seem to displace hunting pressure away from the intensively patrolled area to the peripheral areas of the PAM grid in year 3.

While the lack of a patrol effect on gun hunting in the study area even in Year 3 can be a bit disheartening for the KNP management since a newly developed anti-poaching strategy failed to deliver the results sought, there should be hope as well. We were able for the first time to obtain baseline data on gun hunting patterns in an area, use that information to develop and deliver a new anti-poaching strategy, and then robustly evaluate its impact using data of actual hunting events. This process – though it may sound a simple goal for managers in sectors beyond tropical conservation – has never been concluded in Korup or any other Central African park as far as we are aware – at least not in such a time frame, transparency, and direct measure of hunting pressure.

4. Recommendations

We hope that by this point the value of passive acoustic monitoring as a tool for monitoring gun hunting activity with high spatial and temporal resolution is recognized by the reader. In this final section we recommend some "next steps" in anti-poaching strategies that we think should be tried and subsequently evaluated by the KNP management. These recommendations build on the knowledge accumulated regarding the patterns of gun hunting in KNP and the evaluation of the 2015/2016 4-month "flooding" of the PAM grid area by patrols. They are not meant to be "one bullet solutions" but rather a combination of the methods below should be methodically tried for an entire year, at which time an evaluation can take place to compare the impact of these new approaches compared to the first 3 years of gun hunting data.

- Acoustic monitoring should be extended to other parts of the park (even in shorter 3-4 month periods) to see if the patterns observed in the southern sector apply to the entire park (e.g. emphasis on night hunting, mid-week weekly peak in hunting, seasonal fluctuations).
- Arrange for sustained, significant and wide ranging disruption of the bushmeat trade in the region (both within Cameroon and across the border) – the only significant "dent" in the gun hunting pattern that we were able to observe in the nearly 3 years of monitoring hunting patterns in KNP was as a result of the government enforced closures of the bushmeat markets across the border in Nigeria in response to the arrival of the Ebola virus in the region. Of course the hunting intensity quickly bounced back once the markets reopened, so any such effort has to be sustained and to affect the movement of bushmeat to Nigeria as well (as it would not have

any impact on the hunting of KNP's wildlife – just on where their carcasses will be traded, if the pressure is not on both sides of the border).

- Focus in interfering with the illegal trade and sale of cartridges in the region. Unlike other regions in Cameroon, there are relatively few roads in and out of Mundemba town, and cartridges are brought form Kumba mainly (or Nigeria for the villages closer to the border). The use of sniffer dogs trained to detect cartridges should be considered, as well as sniffer dogs for bushmeat. Training and maintaining such dogs is not a small task, so we believe that any such canine unit should be maintained at the regional level and deployed as needed in the region's PAs.
- It is of critical importance that the patrol objectives are focused on making arrests. It is really hard to understand how hunting continued like "business as usual" in the core of the DI acoustic grid even at the peak of the anti-poaching efforts there in December 2015 when hunting was rampant in the patrol area. Either the rangers are incapable (physically/mentally) to make the arrests – which we do not believe is the case – or unwilling to make the arrests. If there are no strong incentives to put one-self in physical danger by making an unrest, one should not be surprised if the rangers are happy to continue "ticking" kilometres to satisfy patrol metrics, but not actually enforce wildlife law during these patrols.
- The potential corruption of the ranger force by hunters should be seriously considered as a risk given the really significant amount of money made by the most active hunters. Such risks could be combatted with a zero-tolerance policy (one strike and you are fired), introduction of performance based bonuses (successful prosecutions + % reduction in gun hunting activity over a year), and the cultivation of a sense of pride and honor within the ranger force and of respect within the broader community.
- Create a "crack team" of experienced and physically fit rangers (6-8 in size) that will go on patrols aimed at arresting hunters operating in known hunting hotspots, as identified by field observations and the PAM data. These e.g. 10-day mission specific patrols should end with an arrest that can lead to a prosecution, and the team members should get a bonus + full 10-day per diems even if they made the arrest in one day. That way they have the incentive of achieving their goal quickly so as to get back to their families, rather than wait for the days to pass relying on the per diems as their de facto "bonus" of being a ranger. Becoming a member of this team should be limited to those rangers who have made a physical arrest in the recent past. Joining the special team should be considered an honor and a privilege that newer rangers should look up to as a career goal (better pay/more respect by colleagues).
- Invest in communication equipment that can facilitate the field coordination at close distance of ambush teams.
- Periodically – but not with predictable regularity – mobilize the entire ranger force (e.g. at least 20 people) and send them all together to surround a known hotspot at an optimal for hunting period (e.g. mid-week days with full moon) in a closing-noose style. Half the force should split in five 2-team ambushes at known exit routes/trails, and the remaining force should create two 5-member teams sweeping through the area. Such missions can only last for 2-3 days maximum and would require secrecy in their preparation and deployment as almost certainly there is communication to the hunter sof the rangers' movements.
- Introduce action-cameras (e.g. like GoPro but cheaper alternatives exist) that the patrol teams can use during ambushes to generate evidence that can result in arrests afterwards even if the hunters managed to escape.
- Invest in smalls sized spy-cameras (not bulky wildlife camera-traps) that can be placed at known hunting trails or detected bush huts, so as to record illegal activity that can then result in

arrests (without having to physically chase the hunters in the forest, but rather arrest them at their village).

- Consider bringing rangers from different PAs for short-term deployments in KNP (and vice versa) so that the teams learn from each other, build a feeling of belonging to a larger team, and reduce possible signs of hunter-ranger collusion by having teams of unrelated members.

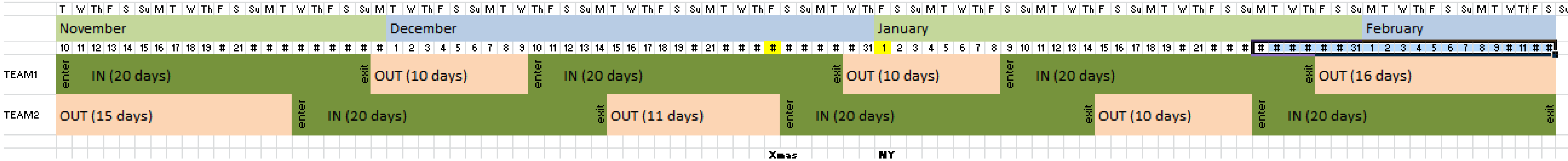
I think also a focus on targeting (somehow) the professional and foreign hunters. Look – the "occasional" hunter who mostly focuses on farming is less of a problem and their arrests will simply look bad.

It is obvious that none of the above recommendations single handily will dramatically change the efficiency of KNP management to curb poaching within the park. Some of them are also not cheap to implement. However, the anti-poaching patrols in their current form are already costing significant amount of funds and have precious little to show for it. In the same way that undertaking monitoring for monitoring's sake is pointless unless one is willing to act on the new information, patrolling for sake of the patrol happening is also not acceptable. There is strong evidence to suggest that this may have been the case in KNP. Significant restructuring of the patrol strategies needs to take place, otherwise the rangers would be probably be more effective in disrupting the bushmeat trade by conducting continuous market and bulk-seller searchers for bushmeat, rather than continuing to patrol in the way they have been doing until now.

Appendices:

Appendix 1: Brief description of the Nov. 2015 – February 2016 increased patrol effort protocol adopted by the KNP management on recommendation of the DI project and in consideration of preliminary reports on the very high gun hunting activity in the PAM grid during the same period in previous years.

In brief, two 6-man patrols were rotating (with slight overlap) in the field, patrolling for 20 days using a 3-day cycle of on trail, off trail and night ambushing patrols across the “core” of the PAM grid. The resulting patrol effort would be 400-500% higher in terms of days in the field, total kilometres worked and even higher in terms of on trail/off trail and day/night kms ratio. In many ways this was a test to see if an “ideal” in intensity but realistic in field logistics/field stamina would achieve a measurable and significant dent in the gun hunting pressure in the study area. As far as we are aware no other PA has ever attempted to evaluate with such robust spatio-temporal resolution data (provided by the acoustic sensors) a new patrolling strategy so as to judge whether it should be more widely adopted.



TEAM1

Sector	Nov. 10-29	Dec. 10-29	Jan. 9-28
1	1E, 1I, 1M	1K, 1G, 1H	1K, 1L, 1N
2	2D, 2E, 2H	2C, 2D, 2G	2G, 2I, 2K
3	3B, 3C, 3F	3A, 3B, 3E	3D, 3E, 3F
4	4A, 4B, 4D	4B, 4C, 4D	4B, 4D, 4E
5	5G, 5H, 5I	5C, 5D, 5H	5A, 5B, 5C
6	6C, 6D, 6G	6B, 6C, 6F	6D, 6F, 6G

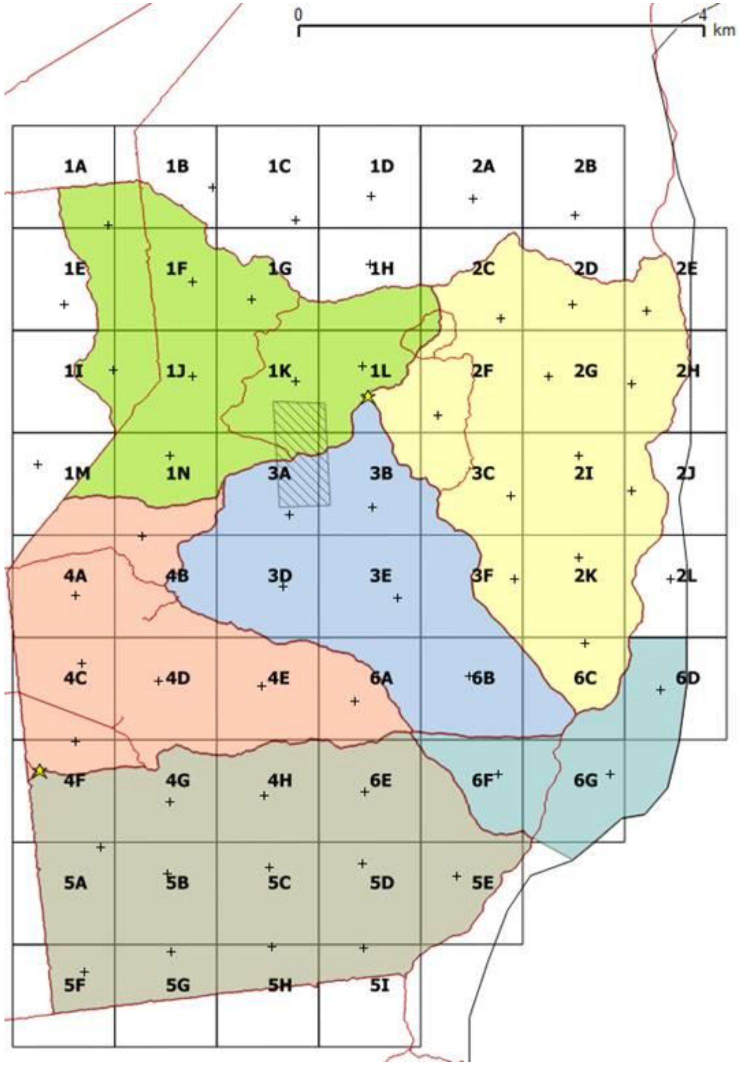
TEAM2

Sector	Nov. 25 - Dec. 14	Dec. 26 – Jan. 14	Jan. 25 - Feb. 13
1	1F, 1G, 1J	1I, 1J, 1N	1J, 1M, 1N
2	2I, 2K, 2L	2A, 2B, 2C	2H, 2J, 2L
3	3A, 3B, 3D	3C, 3E, 3F	3A, 3B, 3C
4	4A, 4C, 4F	4D, 4E, 4H	4E, 4G, 4H
5	5A, 5B, 5F	5D, 5E, 5I	5B, 5G, 5H
6	6A, 6B, 6F	6E, 6F, 6G	6B, 6C, 6D

TEAM1	Nov. 10-29	Dec. 10-29	Jan. 9-28
TEAM2	Nov. 25 - Dec. 14	Dec. 26 – Jan. 14	Jan. 25 - Feb. 13

What is the patrol schedule for a 20 day patrol?

Day 1: Team enters KNP - (early start! 7am? it is still a patrolling day) from Mana bridge. They take any route they want (but most likely IKK trail – Big Boudler trail) to Chimpanzee camp. They respond to any gunshots they may here from the campsite during the day.
Day 2: Day patrol of in Survey Sector 1
Day 3: Off-trail patrol of Survey Sector 1
Day 4: Night patrol + ambush in Survey Sector 1
Day 5: Day patrol of in Survey Sector 2
Day 6: Off-trail patrol of Survey Sector 2
Day 7: Night patrol + ambush in Survey Sector 2
Day 8: Day patrol of in Survey Sector 3
Day 9: Off-trail patrol of Survey Sector 3
Day 10: Night patrol + ambush in Survey Sector 3
Day 11: Entire team leaves Chimpanzee campsite and moves to Rengo camp early in the morning AND Day patrol of Survey Sector 4
Day 12: Off-trail patrol of Survey Sector 4
Day 13: Night patrol + ambush in Survey Sector 4
Day 14: Day patrol of in Survey Sector 5
Day 15: Off-trail patrol of Survey Sector 5
Day 16: Night patrol + ambush in Survey Sector 5
Day 17: Day patrol of in Survey Sector 6
Day 18: Off-trail patrol of Survey Sector 6
Day 19: Night patrol + ambush in Survey Sector 6
Day 20: Team packs campsite / exits from whatever route they wish (while still being attentive) to Mana bridge.


0
4
km
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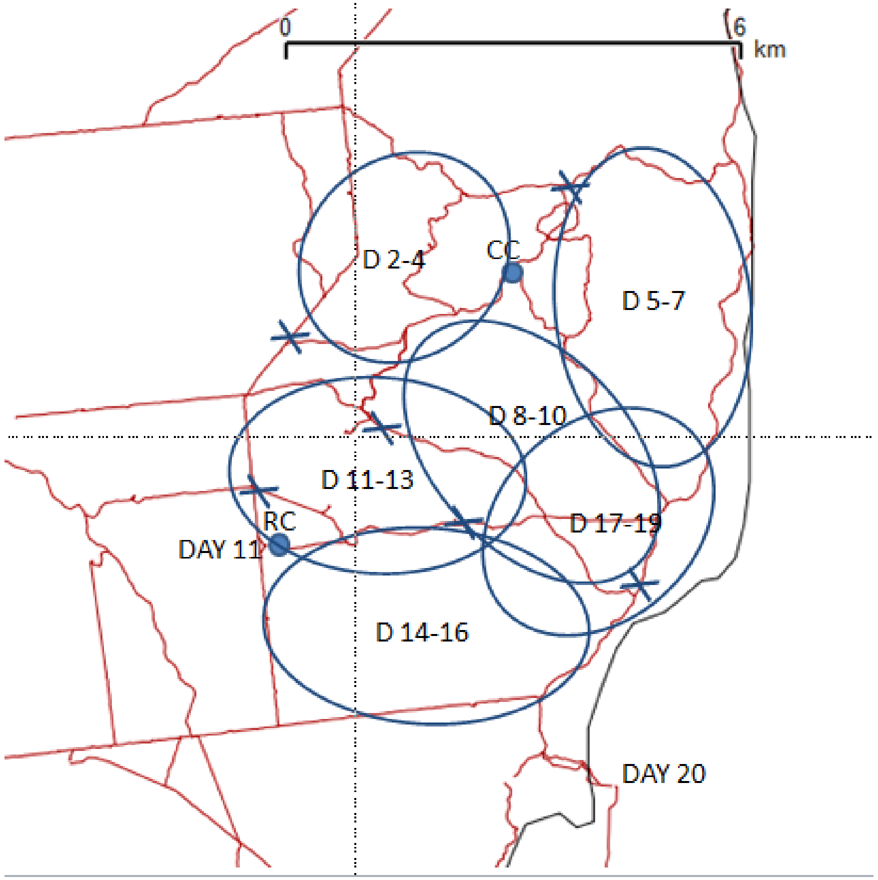
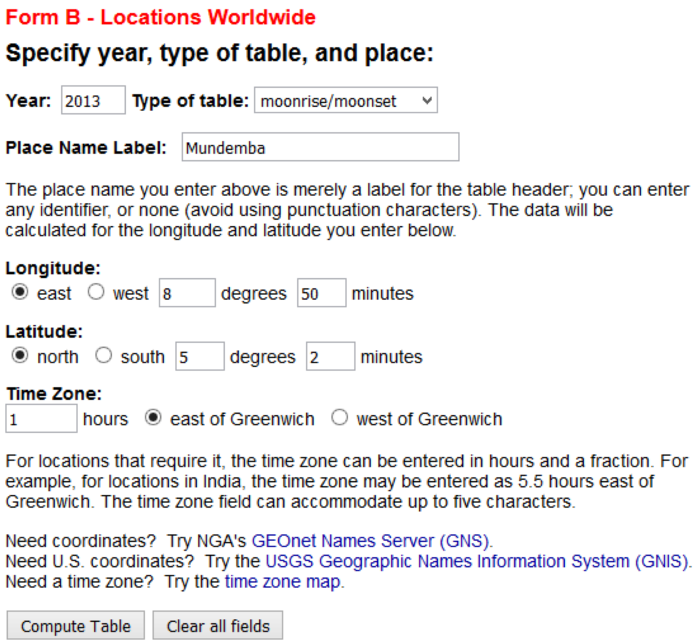

0
6
km
D 2-4
CC
D 5-7
D 8-10
D 11-13
RC
DAY 11
D 17-19
D 14-16
DAY 20

Appendix 2: Moon Illumination Index

The data on the face of the moon and moonrise and moonset times was obtained from the Astronomical Applications Department of the United States Naval Observatory (http://aa.usno.navy.mil/data/docs/RS_OneYear.php).

The screen capture below contains the information input in the USNO page to download the moon face related data.



Form B - Locations Worldwide

Specify year, type of table, and place:

Year: 2013 **Type of table:** moonrise/moonset

Place Name Label: Mundemba

The place name you enter above is merely a label for the table header; you can enter any identifier, or none (avoid using punctuation characters). The data will be calculated for the longitude and latitude you enter below.

Longitude:
(•) east ( ) west 8 degrees 50 minutes

Latitude:
(•) north ( ) south 5 degrees 2 minutes

Time Zone:
1 hours (•) east of Greenwich ( ) west of Greenwich

For locations that require it, the time zone can be entered in hours and a fraction. For example, for locations in India, the time zone may be entered as 5.5 hours east of Greenwich. The time zone field can accommodate up to five characters.

Need coordinates? Try NGA's GEOnet Names Server (GNS).
Need U.S. coordinates? Try the USGS Geographic Names Information System (GNIS).
Need a time zone? Try the time zone map.

Compute Table | Clear all fields

The moon illumination index was the product of the proportion of the face of the moon and the number of hours that the moon was visible above the horizon during night time (sunset to sunrise) in Mundemba, Cameroon.

For example, on Jan. 3, 2016 42% of the moon face was illuminated by the Sun and rose in the horizon in Mundemba at 00:57am, setting at 13.13pm next day (past noon). Since the moon's illumination after sunrise is irrelevant, we calculated the moon as "illuminating" for a total of 5hr 33 min (00:57 am to 6:30 am). The moon illumination index was therefore calculated as 0.099 which is the product of 0.42 (moon face proportion illuminated) * 0.231 (5hr 33 min as an integer where 24hr is 1).

Appendix 3: Key of fields of final dataset used for the analysis of the impact of anti-poaching patrol effort on gun hunting intensity in Korup NP

Month	Rainfall	Moon	ShotsDiurn	ShotsNoct	ShotsTotal	ShotsDiurnPDay	ShotsNoctPDay
Nov - Feb months	Cumulative rainfall per week (same across all sensors) - measured in mm	Moon illumination index was calculated by multiplying the face of the moon by the time of hours that the moon was in the sky on that day in that part of the world. The value is averaged across the 7 days of that week.	Number of diurnal shots recorded at that sensor in that week	Number of nocturnalshots recorded at that sensor in that week	Total number of shots recorded at that sensor in that week	Ratio of diurnal shots/days that sensor run that week	Ratio of nocturnal shots/days that sensor run that week

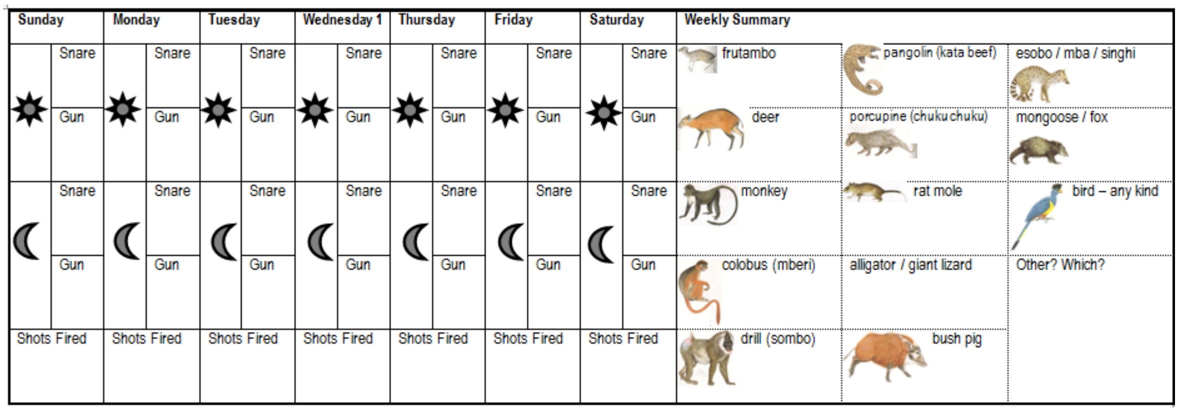
ShotsTotalPDay	PropNoctShots	Patrol-S-OFF	Patrol-S-ON	PropOFF-S	Patrol-S-Night	PropNight-S	Patrol-S-Total
Ratio of totalshots/days that sensor run that week	Proportion of all shots that week which were nocturnal	Patrol effort in meters AT **SENSOR** LEVEL (S) that were **not** next to main trails (beyond 100m buffer from trails)	Patrol effort in meters AT **SENSOR** LEVEL (S) that were next to main trails (beyond 100m buffer from trails)	Proportion of OFF TRAIL patrol length AT **SENSOR** LEVEL out of total patrol effort that week at sensor level	Patrol effort in meters AT **SENSOR** LEVEL (S) that were done during the **night** (between 18.30pm and 6.30am)	Proportion of NIGHT patrol length AT **SENSOR** LEVEL out of total patrol effort that week at sensor level	**TOTAL** Patrol effort in meters **AT SENSOR LEVEL** (S) for that week

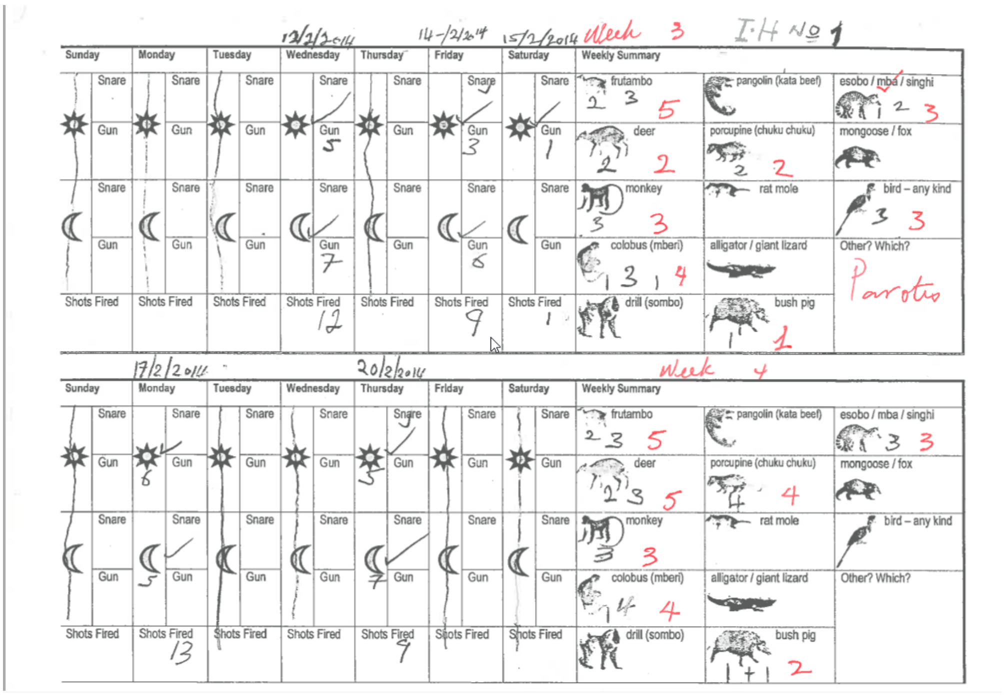
ShotsTotalPDay	PropNoctShots	Patrol-S-OFF	Patrol-S-ON	PropOFF-S	Patrol-S-Night	PropNight-S	Patrol-S-Total
Ratio of totalshots/days that sensor run that week	Proportion of all shots that week which were nocturnal	Patrol effort in meters AT **SENSOR** LEVEL (S) that were **not** next to main trails (beyond 100m buffer from trails)	Patrol effort in meters AT **SENSOR** LEVEL (S) that were next to main trails (beyond 100m buffer from trails)	Proportion of OFF TRAIL patrol length AT **SENSOR** LEVEL out of total patrol effort that week at sensor level	Patrol effort in meters AT **SENSOR** LEVEL (S) that were done during the **night** (between 18.30pm and 6.30am)	Proportion of NIGHT patrol length AT **SENSOR** LEVEL out of total patrol effort that week at sensor level	**TOTAL** Patrol effort in meters **AT SENSOR LEVEL** (S) for that week

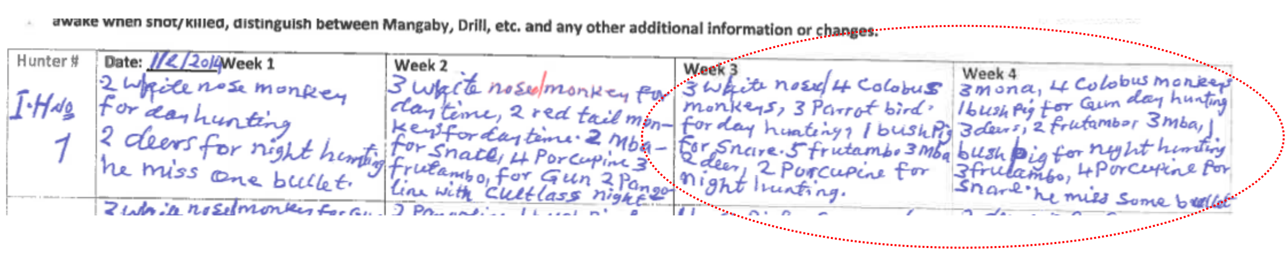
Patrol-G-OFF	PropOFF-G	Patrol-G-Night	PropNight-G	Patrol-G-Total	atrols_G_Total_1WeekBa	Core-S	Weeks2Xmas
Patrol effort in meters AT **GRID** LEVEL (S) that were **not** next to main trails (beyond 100m buffer from trails)	Proportion of OFF TRAIL patrol length AT **GRID** LEVEL out of total patrol effort that week at sensor level	Patrol effort in meters AT **GRID** LEVEL (S) that were done during the **night** (between 18.30pm and 6.30am)	Proportion of NIGHT patrol length AT **GRID** LEVEL out of total patrol effort that week at sensor level	**TOTAL** Patrol effort in meters **AT GRID LEVEL** (S) for that week	**TOTAL** Patrol effort in meters **AT GRID LEVEL** (S) for **PREVIOUS** week	Description whether a sensor is in the core of the acoustic grid (i.e. KP10-16) or the periphery (i.e. KP1-9).	Weeks until (7-0) or after (-1-9) Xmas.

Appendix 4: Hunter survey form

Each form covered one week (2 weeks per A4 sheet). The hunters were asked to record with an X whether they went hunting in a given day (day and/or night) with a gun and/or snares. At the end of each day, the hunter was asked to record also the number of gunshots made that day. The animals harvested were summarized at the weekly level. The village animator ensured that the week for which the data referred to was noted on the sheet along with the respondents anonymous code, and that the way of killing (gun/snare/other) of each animal was recorded via handwritten comments on a separate sheet completed for each respondent/month by him. See example of a completed 2-week period, including the survey coordinator's + village animator's comments.







Appendix 5:

Table 1: Number of acoustic survey days per sensor and map in Year 1(top), Year 2 (middle), and Year 3 (Jun – Mar only; below)

YR1	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	MEAN	SD
KP01	17	31	31	26	31	30	28	31	28	31	30	30	28.7	3.8
KP03	18	31	31	26	31	30	16	31	28	31	30	31	27.8	5.1
KP05	19	31	31	27	31	30	29	31	28	31	30	31	29.1	3.3
KP07	22	31	31	25	31	30	29	31	28	31	30	31	29.2	2.8
KP09	23	31	31	6	3	30	31	31	28	31	30	31	25.5	9.7
KP10	21	31	31	22	31	30	21	7	0	12	30	31	22.3	10.3
KP11	21	31	31	22	31	30	28	31	28	31	30	31	28.8	3.4
KP12	21	31	31	19	31	30	30	31	28	30	30	31	28.6	3.9
KP13	21	31	31	21	31	30	29	31	20	12	30	31	26.5	6.1
KP14	22	31	31	19	31	30	28	31	28	31	30	31	28.6	3.8
KP15	20	31	31	21	31	30	29	31	28	31	30	31	28.7	3.8
KP16	20	31	31	21	31	30	28	31	28	31	30	31	28.6	3.8
MEAN	20.4	31.0	31.0	21.3	28.7	30.0	27.2	29.0	25.0	27.8	30.0	30.9	**TOTAL:**	**3,986**
SD	1.7	0.0	0.0	5.3	7.7	0.0	4.1	6.6	7.9	7.0	0.0	0.3		

YR2	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	MEAN	SD
KP01	18	31	14	0	29	30	31	31	28	3	27	31	22.8	10.9
KP03	18	31	31	27	30	30	31	31	28	23	28	31	28.3	3.9
KP05	18	31	31	26	31	30	30	31	28	22	29	31	28.2	4.0
KP07	18	31	31	25	31	30	31	31	28	6	30	31	26.9	7.3
KP09	19	31	31	25	31	30	31	31	28	11	30	31	27.4	6.0
KP10	8	31	31	10	28	30	30	31	28	13	26	31	24.8	8.5
KP11	17	31	31	28	28	30	31	31	28	24	26	31	28.0	4.0
KP12	20	29	31	30	27	21	5	31	28	14	24	31	24.3	7.7
KP13	9	31	31	29	28	30	16	0	0	0	26	31	19.3	12.8
KP14	20	29	31	30	27	30	31	31	28	27	24	31	28.3	3.2
KP15	3	30	31	29	27	30	31	31	28	26	25	31	26.8	7.5
KP16	17	30	31	30	27	30	11	31	28	26	25	31	26.4	6.0
MEAN	15.4	30.5	29.6	24.1	28.7	29.3	25.8	28.4	25.7	16.3	26.7	31.0	**TOTAL:**	**3,735**
SD	5.3	0.8	4.7	8.9	1.6	2.5	9.0	8.6	7.7	9.3	2.1	0.0		

YR3	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	MEAN	SD
KP01	30	29	31	30	18	30	31	31	26	30	26.3	8.2
KP03	30	28	31	30	18	30	31	31	29	30	28.8	3.7
KP05	30	28	31	30	18	30	31	28	29	29	28.4	3.6
KP07	30										30.0	0.0
KP09	16										8.0	8.0
KP10	22	24	31	30	17	30	31	31	23	7	24.6	7.5
KP11	22	24	31	30	17	30	31	31	29	31	25.3	8.6
KP12	24	22	31	30	23	30	11	27	29	31	23.5	9.1
KP13	30	29	31	30	11	30	31	31	29	27	27.9	5.8
KP14	30	31	30	30	26	30	31	31	29	31	27.3	8.4
KP15	30	29	31	30	16	30	31	31	23	31	26.2	7.8
KP16								28	29	31	21.0	12.1
MEAN	27.0	27.3	30.9	30.0	18.0	27.4	25.9	30.0	27.5	27.8	**TOTAL:**	**2,788**
SD	4.6	2.8	0.3	0.0	3.8	7.8	10.5	1.5	2.4	7.0		

Table 2: Mean number of gunshots recorded per sensor per day in Year 1(top), Year 2 (middle), and Year 3 (below); the value was calculated only for sensors that operated at least 7 days in any given month.

Yr1	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	MEAN	SD
KP01	0	0.1	0.1	0.2	0.8	0.2	0.7	0.8	0.3	0.8	0.367	0.47	0.4	0.3
KP03	0.1	0.5	0.2	0.4	1.1	0.6	1.3	1.1	0.4	1.1	1.733	0.87	0.8	0.5
KP05	0.1	0.2	0.4	0.2	0.5	0.6	0.8	0.8	0.8	0.7	0.833	0.74	0.6	0.2
KP07	0	0.6	0.5			0.6	1.2	1.2	0.5	0.6	1.067	0.39	0.7	0.4
KP09	0	0.3	0.5	0.2	1	0.5	0.7	0.6	0.1	0.2	0.667	0.45	0.4	0.3
KP10	0	0.2	0.4	0.2	0.1	0.5	0.2	0.4		0.3	0.367	0.39	0.3	0.1
KP11	0	0	0	0	0.1	0.2	1	0.5	0.1	0.7	0.4	0.13	0.3	0.3
KP12	0	0.6	0.6	0.2	0.4	0.4	0.5	0.4	0.3	0.4	0.4	0.19	0.4	0.2
KP13	0.3	0.1	0	0	0.2	0.5	0.5	0.4	0.3	0.9	0.133	0.29	0.3	0.3
KP14	0	0.4	0.2	0.4	0.8	0.2	0.6	0.6	0.8	0.5	0.967	0.9	0.5	0.3
KP15	0.4	0.9	0.5	0.7	0.5	0.4	0.9	1.5	0.3	0.6	0.733	0.48	0.6	0.3
KP16	0.3	0.1	0.1	0.1	0.3	0.4	0.8	0.9	1.3	0.9	0.367	0.42	0.5	0.4
MEAN	0.1	0.3	0.3	0.2	0.5	0.4	0.8	0.8	0.5	0.6	0.7	0.5		
SD	0.1	0.3	0.2	0.2	0.3	0.2	0.3	0.3	0.3	0.2	0.4	0.2		

Yr2	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	MEAN	SD
KP01	0.2	0.1	0		0	0.2	0.7	0.6	0.5		0.519	0.29	0.3	0.2
KP03	1.6	0.9	0.4	0.1	0.7	1.3	1.1	0.2	0.5	0.4	1.286	1	0.8	0.5
KP05	0.8	0.7	0.1	0.1	0.5	0.6	0.9	0.6	0.6	0.2	1.621	0.97	0.7	0.4
KP07	0.6	1	0.3	0.4	1	1	1.8	1.4	0.8		1.933	1.71	1.1	0.5
KP09	0.2	0.4	0.3	0	0.5	0.6	1.3	1.1	0.4	0.4	0.5	0.65	0.5	0.3
KP10	0	0.3	0.2	0	0.2	0.3	0.4	0.3	0.5	0	0.5	0.29	0.2	0.2
KP11	0	0	0	0	0	0	0.4	0.4	0.5	0.5	0.462	0.87	0.3	0.3
KP12	0.2	0.7	0.1	0.2	0.5	0.2		1.1	0.5	0.6	0.75	0.45	0.5	0.3
KP13	0.1	0.1	0.2	0.1	0.2	0.3	0.6				0.885	0.45	0.3	0.3
KP14	0.4	0.1	0.1	0.1	0.6	1.7	1.6	1	1.2	0.9	0.167	0.58	0.7	0.6
KP15		0.1	0	0	0.4	0.1	1.6	0.8	0.8	0.7	0.48	0.26	0.5	0.5
KP16	1.9	0.1	0.2	0	0.4	0.2	1.1	1	0.6	1.4	0.72	0.16	0.6	0.6
MEAN	0.5	0.4	0.1	0.1	0.4	0.5	1.0	0.8	0.6	0.6	0.8	0.6		
SD	0.6	0.3	0.1	0.1	0.3	0.5	0.5	0.4	0.2	0.4	0.5	0.4		

Yr3	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	MEAN	SD
KP01	0.3	0	0.1	0.4	0.6	0.5	1.2	0.5	1	0.5	0.5	0.3
KP03	1.1	1.5	0.6	0.4	1.4	1.6	2.3	0.3	0.1	0.6	1.0	0.7
KP05	0.7	0.9	1	0.4	0.6	1.7	1	0.3	0	0.1	0.7	0.5
KP07	1.3										1.3	0.0
KP09	0.6										0.6	0.0
KP10	0	0.1	0.1	0.1	0.3	0.3	1	0		0	0.2	0.3
KP11	0	0	0	0	0	0.1	0.9	0.4	0.4	0.4	0.2	0.3
KP12	0.5	0.2	0.5	0.3	0.5	0.7	1.5	0	0.1	0.2	0.4	0.4
KP13	0.2	0	0.2	0.2	0	0.3	1.1	0.1	0.1	0.3	0.2	0.3
KP14	0.4	0.3	0.2	0	0.4	0.9	1.5	0.4	0.1	0.5	0.5	0.4
KP15	0.4	0.3	0.5	0.8	0.4	0.8	1.1	0.8	0.7	0.5	0.6	0.2
KP16								1.3	0.3	0.5	0.7	0.4
MEAN	0.5	0.4	0.3	0.3	0.5	0.8	1.3	0.4	0.3	0.4		
SD	0.4	0.5	0.3	0.3	0.4	0.5	0.4	0.4	0.3	0.2		

Appendix 6:

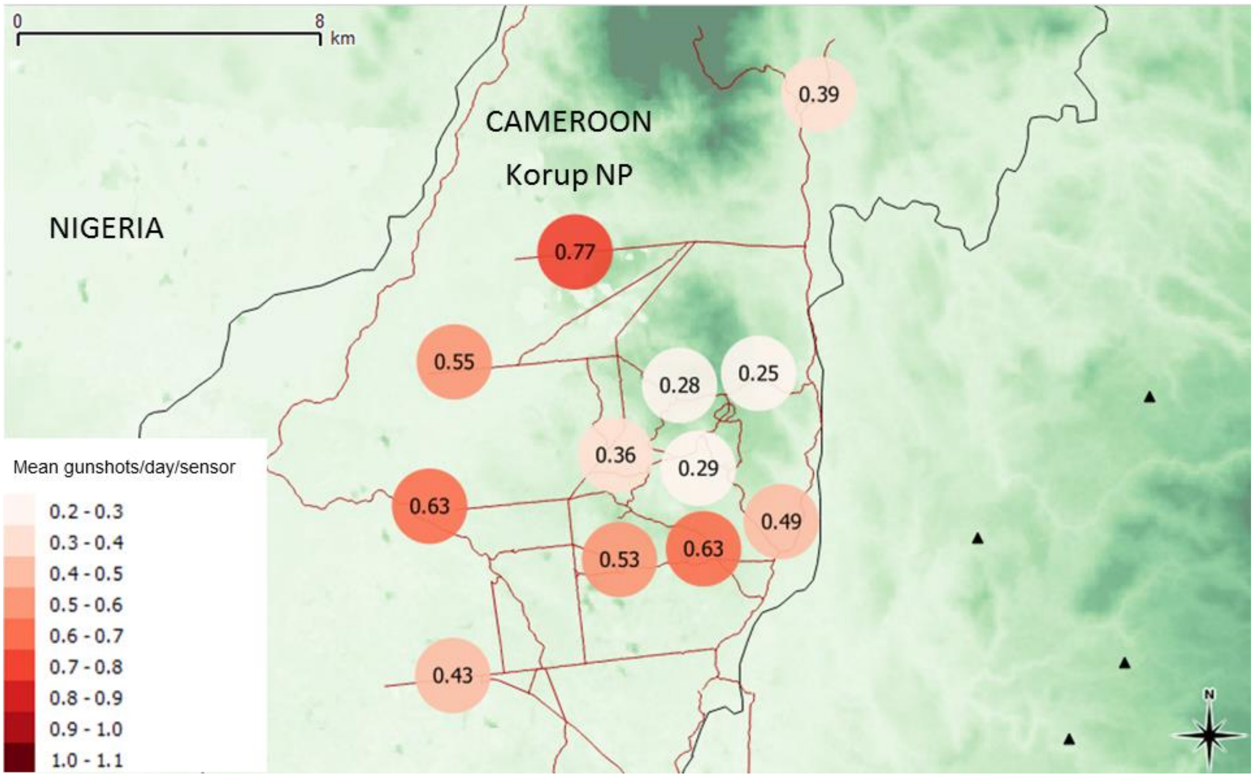


Figure 12: Mean gunshots recorded per day per sensor in Year 1 (June 2013 – May 2014) across the PAM grid's 12 ARUs.

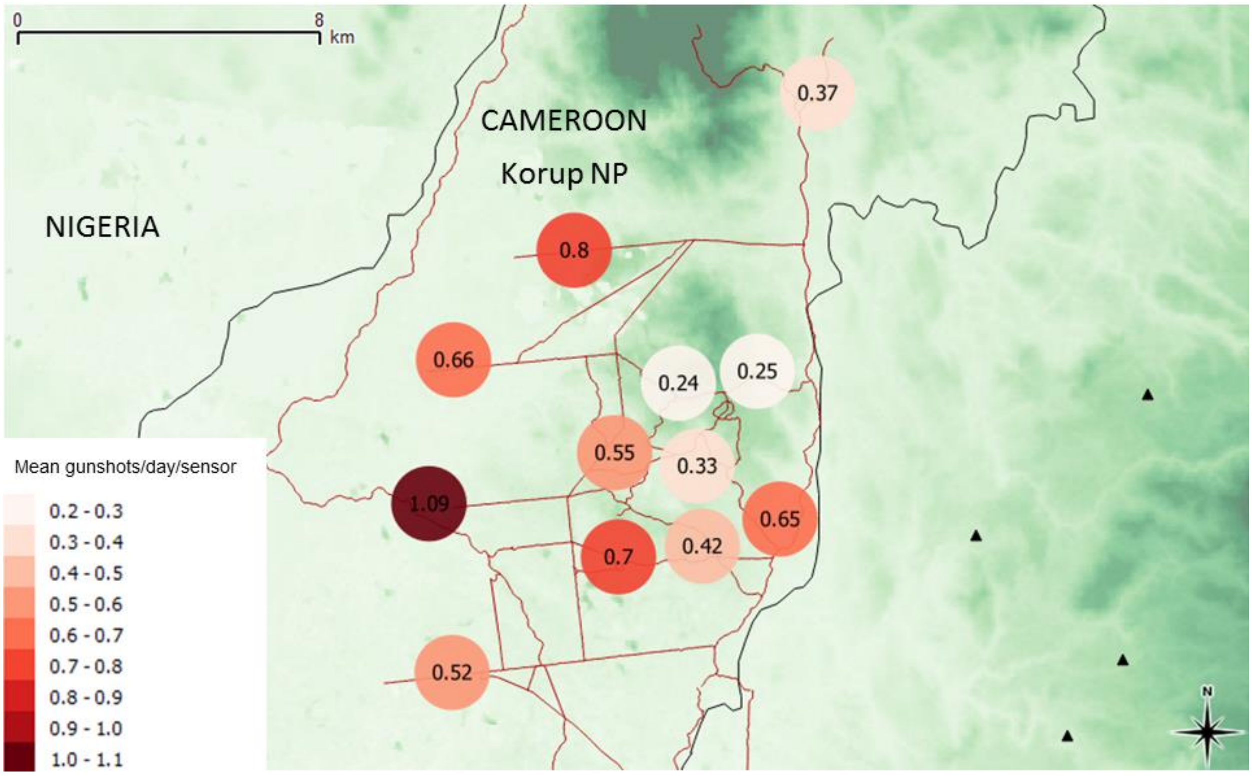


Figure 13: Mean gunshots recorded per day per sensor in Year 2 (June 201 – May 2015) across the PAM grid's 12 ARUs.

Project Partnerships

Since its inception, the Darwin Initiative project has been collaboration among the Cameroonian government (Ministry of Forest and Wildlife/Korup National Park management), international research institutions (University of Oxford, James Madison University, Cornell University), the German-Cameroonian international development Programme for the Sustainable Management of Natural Resources in Southwest Region (PSMNR-SWR) and conservation NGOs (WWF-CFP, Korup Rainforest Conservation Society). Funding has been provided primarily via a UK Government grant scheme called the Darwin Initiative (www.gov.uk/government/groups/the-darwin-initiative) that helps to protect biodiversity and the natural environment in developing countries. Additional funding has been obtained by the US Fish and Wildlife Service, SAVE Wildlife Conservation Fund, and the KfW (German Development Bank) through PSMNR-SWR.

Funding:

Partners: