A wildlife monitoring network for De Hoge Veluwe National Park: Baseline measurements and design

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1. Aim and background

De Hoge Veluwe National Park (HVNP) is a privately managed conservation area of 5,400 ha in the Netherlands, including a mosaic of woodland, heathland, peat bog and drift sand. Two passages have been created in the fences that enclose the park to allow migration of ungulates between the park and adjacent conservation areas, scheduled to be opened early 2013. The management of HVNP wishes to monitor the consequences of immigration and emigration of ungulates via these openings. The ungulate species currently occurring in HVNP are Red deer (*Cervus elaphus*), Roe deer (*Capreolus capreolus*), Wild boar (*Sus scrofa*) and European Mouflon (*Ovis orientalis musimon*), while the openings may lead to immigration of Fallow deer (*Dama dama*).

This report aims to facilitate ungulate monitoring in two ways: by compiling data that can be used to produce baseline information on the current composition, density and distribution of the ungulate population, and by designing of a camera-based monitoring system that allows for detecting changes in population levels and habitat use over a period of 4 years. The baseline measurements as well as the monitoring of changes rely on randomized deployment of camera traps throughout the NVNP, a relatively new method that allows for standardized and objective assessments of wildlife populations at relatively low cost (Kays et al. 2011). Recent technological advancements in camera trapping hardware and accessories have led to a sharp increase of their use in wildlife surveillance and monitoring. Experiences so far suggest that these surveys produce reliable data (Kays et al. 2011, Rowcliffe et al 2011, 2012).

This project established baseline data on ungulate abundance and distribution by compiling existing data from our camera-trap surveys during 2011-2102 into a central database, and supplementing these data with additional camera deployments in areas that had been undersampled. In addition, this project explored the current camera-trapping technology, and designed an efficient and low-maintenance camera-trap deployment plan for long-term monitoring of abundances and habitat use of ungulates across the park.

2. Baseline monitoring with camera traps

2.1 Deployment scheme

Camera-trapping surveys were conducted in the park during 2011-2012 with three MSc thesis students from Wageningen University, under the supervision of Dr Patrick Jansen and Dr Sip van Wieren of Wageningen University and Dr Marcus Rowcliffe of the Zoological Society of London (Verbelen 2011, Van Veen 2012, Veliz-Rosas, 2012). The student projects aimed to test the 'Random Encounter Model' for wildlife density estimation from camera-trap photographic rates (Rowcliffe et al. 2008, 2012, Kays et al. 2011). Camera traps were deployed at computer-generated random locations throughout the park, stratified by habitat type to ensure that the four major habitats received a similar number of deployments (Table 1; Fig. 1). The fenced central area of the park was excluded, as well al habitat fragments <10ha. Methodologies were comparable between surveys. Resting areas were underrepresented in these campaigns, while game meadows were not sampled at all. To achieve a better balance, an additional set of deployments was assigned to these areas in July-October 2012.

The photographs were processed with a custom-made database, currently accessible via a portal at: http://db.silkyanteater.com. The database groups photographs of a single passage of one or more animals into sequences and allows rapid identification of species per sequence.

Table 1. Distribution of sampling effort across five major wildlife habitats in De Hoge Veluwe National Park during the summers of 2011 and 2012. Area only includes sampled habitat.

Habitat type	Area (ha)	Number of deployments	Samping effort (days)	Mean deployment time (d)
Coniferous Forest	1239	119	1339	11.3
Deciduous Forest	1421	112	1057	9.5
Drift sand	916	107	974	9.1
Heathland	1182	117	1404	12.0
Game meadow	76	15	468	31.2
Total	4834	470	5242	11.2

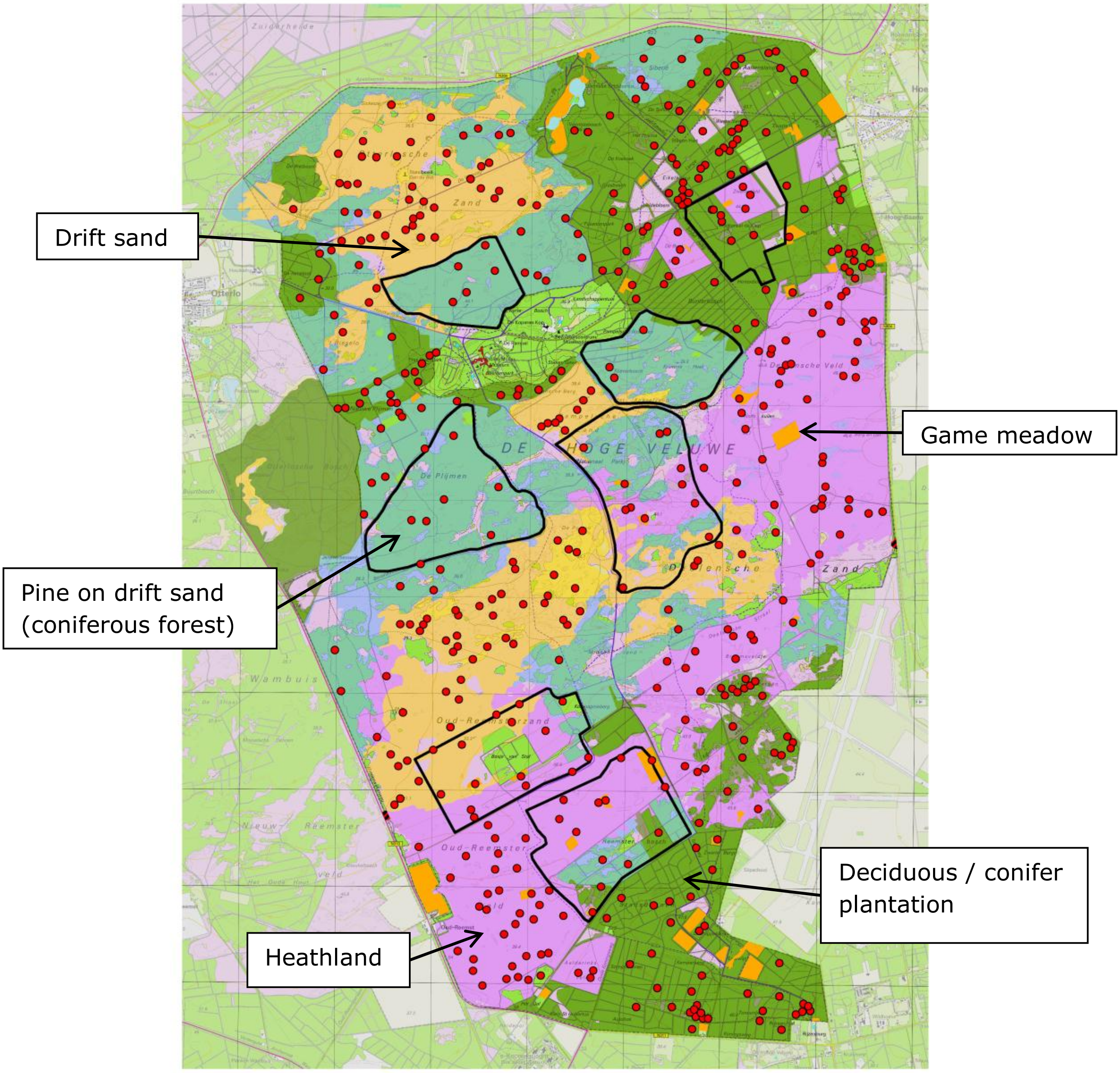
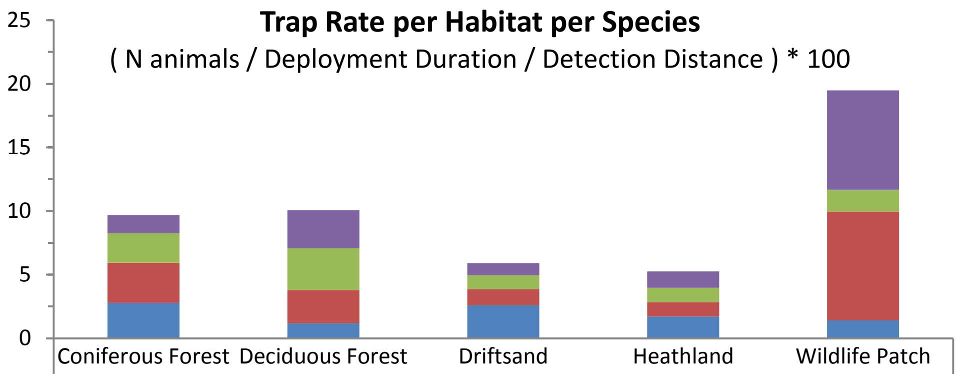


Fig. 1. Distribution of camera trap deployments in 2011 and 2012 across De Hoge Veluwe National Park. Colours correspond with habitat types. Wildlife resting areas are marked with solid black lines.

2.2 Photo rates

The rate at which a species is photographed is a rough correlate of the abundance of wildlife populations. Photo rates give an indication of animal abundance at a sampling point. They can, however, be used to estimate densities by correcting photo rates for species-specific differences in activity level, speed of movement, and body mass of species, and for the sensitivity of the camera sensor, using the so-called random encounter model (REM; Rowcliffe et al. 2008). The REM accounts for the fact that, for example, larger species are detected by sensors over greater distances than smaller animals (Rowcliffe et al. 2012). Activity levels can be calculated directly from camera-trapping data, but movement speed and effective detection area require additional measurements. Such measurements have been carried out by Claudia Véliz-Rosas (2012), to allow for future estimation of densities.



	Coniferous Forest	Deciduous Forest	Driftsand	Heathland	Wildlife Patch
Wild Boar	1.44	2.98	0.96	1.27	7.80
Roe Deer	2.31	3.28	1.07	1.15	1.72
Red Deer	3.15	2.63	1.30	1.11	8.55
Mouflon	2.78	1.17	2.58	1.71	1.41

Fig. 2. Photo rate per habitat for the four ungulate species in De Hoge Veluwe National Park over 2011 – 2012. Photo rates were calculated as 100 times the number of animals / Deployment Duration / Detection Distance.

Because the camera-trapping points covered all five habitat types in the park, the raw photo rates allow for a comparison of habitat use between habitats and species. Photo rates were clearly highest in game meadows, especially for red deer and wild boar (Fig. 2), indicating that ungulates heavily concentrated their foraging activity on these relatively rich patches.

There were clear differences in habitat use between species (Fig. 2). Roe deer and wild boar were seen more often in deciduous forest, while mouflon was seen most on drift sands. These observations on habitat use are in line with expert opinion of game wardens on habitat use by the four ungulates, suggesting that the camera trap data reflect actual captured distribution patterns. Further analysis is needed to derive population densities from the photos and establish robust estimates of spatio-temporal habitat use.

2.3 Daily Activity patterns

A photograph of an animal passing in front of a camera trap at a certain time is evidence for that species being active (rather than resting) at that time of the day. Because camera traps record activity 24 hours per day, the distribution of photographs taken by the camera traps over the day can be used to quantify the daily activity pattern of species. The distribution of photographs over the day (Fig. 3) showed a clear peak in activity in the evening (20h -23h), and a smaller peak early morning (5h-6h), while during the day, relatively low numbers of animals are active.

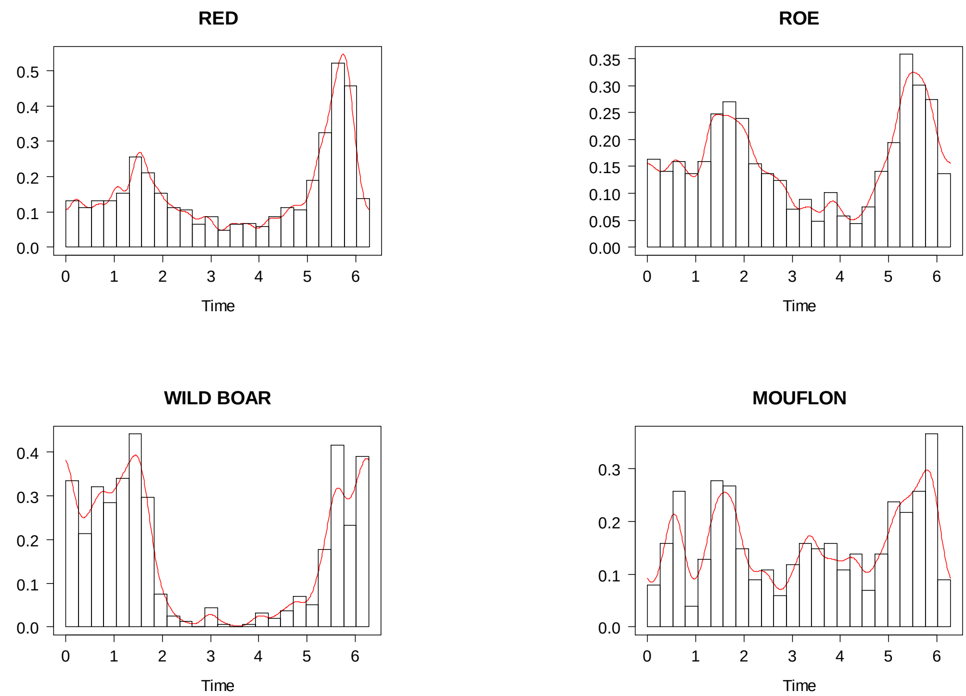


Fig. 3. Daily activity patterns of Red deer, Roe deer, Wild boar and Mouflon in De Hoge Veluwe National Park during spring and summer of 2011 and 2012. Time is shown in radians. Height of the bar is proportional to the probability that an animal is photographed, per hour. From Veliz-Rosas (2012).

The fractions of animals trapped in relation to the exact timing of sunset and sunrise (table 2) indicates the degree to which species are diurnal-nocturnal or crepuscular. Clear differences between the four species emerge. Especially wild boar is predominantly nocturnal. These observations are in line with expert opinion of game wardens on activity of the four ungulates, suggesting that the camera trap data accurately captured daily activity patterns. These data are still to be further explored.

Table 2: Total number of animals photographs during the camera trap surveys in 2011 and 2012, and the percentages of individuals trapped within several periods related to the solar cycle. All data before september 2012.

Species	Total number of individuals	% of individuals		
		Sunset to sunrise	Sunset-1h to sunrise+1h	Sunset +/- 1h and sunrise +/- 1h
Mouflon	2870	39	52	34
Red deer	3211	46	72	50
Roe deer	939	42	57	31
Wild boar	1503	72	87	35
Total	8523			

2.4 Data repository

A central repository was established and the associated database was optimized for processing photographs from HVNP. This system, backed-up daily, serves as archive as well as processing tool. The photo database allows batch selection and – processing of photos and producing customized output according to various formats. The standard query contains information on species, time and date of detection and location for each individual photo sequence. The photo database is currently hosted on an external server, and can only be accessed by individuals with permission from the principal investigator.

2.5 Future Directions

The data collected during the summers of 2011 and 2012 will be used to derive estimates of ungulate population densities in the park, using the Random Encounter Model (Rowcliffe et al. 2008), and to determine the distribution of activity over habitat types. This will provide baseline information on population densities and habitat use for the four ungulate species in the park prior to opening of the fences. The data also allow for advanced analysis of activity patterns, daily shifts in habitat use, use of resting areas, and behavioural responses to people and culling. Several of these analyses are part of on-going research at Wageningen University, the Smithsonian Institution, and the Zoological Society of London, which generally aim to test and optimize the use of camera trap surveys for density estimation and activity patterns. It is expected that first results will be published in peer-reviewed scientific journals during 2013.

3. Design of a Camera survey network

3.1 Requirements

Any survey network using camera traps should meet the following requirements to be suitable for monitoring of ungulate populations and habitat use during several years.

First, replication and randomization are two key requirements for application of the REM for density estimation (Rowcliffe et al. 2008). An additional requirement is that sampling captures the five major habitat types that ungulates so that shifts in habitat use can be detected, which calls for replication at the level of habitat types.

Second, the survey equipment should have sufficient image resolution and efficient data storage and processing. Also, the footage should be suitable for semi-automated measurement of key parameters of the REM, detection area and movement speed.

Third, the monitoring system must be cost-effective, should not be too sensitive to theft and vandalism, and should have a low maintenance level.

3.2 Permanent Wireless Camera Network

We recommend that the basic design for the sensor network involves a solar-powered wireless network of permanent camera stations, placed randomly within each of the four major habitat types.

We recommend to use permanent stations because this greatly reduces the labour cost. The investment in establishing a permanent station is outweighed by the substantial labour costs involved in repeatedly installing and moving temporary stations. Permanent stations also allows for year-round monitoring, which solves the problem that there is no single period in the year for which accurate density estimates can be calculated for all species at once.

Solar powering makes the station self-sufficient in energy. The investment required is outweighed by the labour costs involved in manually charging and replacing batteries at regular intervals. Low visitation by managers also reduces the disturbance of the wildlife around the stations to a minimum.

We also recommend wireless networking of cameras (Fig. 4). Wireless transmission of footage into a central repository yields real-time information not only on the wildlife, but also the functioning of cameras. The extra investment required is easily outweighed by the labour costs of manually recovering and replacing memory cards, and checking of the stations at regular intervals. This further limits the need to visit stations beyond scheduled maintenance; stations need only be checked if data flow indicate problems.

To ensure sufficient replication, we recommend a total number of 10 camera traps per habitat type. Also, an additional 5 stations should be installed in five of the game meadows, which represent a distinct habitat class with high wildlife activity. To ensure representativeness, stations are established in core habitat only. Habitat patches < 5 ha and the enclosed central area of the park should be excluded.

To reduce the risk of people tampering with the equipment, cameras must be in installed with security casing and locked to a steel pole that is firmly secured to the ground. Also, stations must be at >50 m distance from roads and trails.

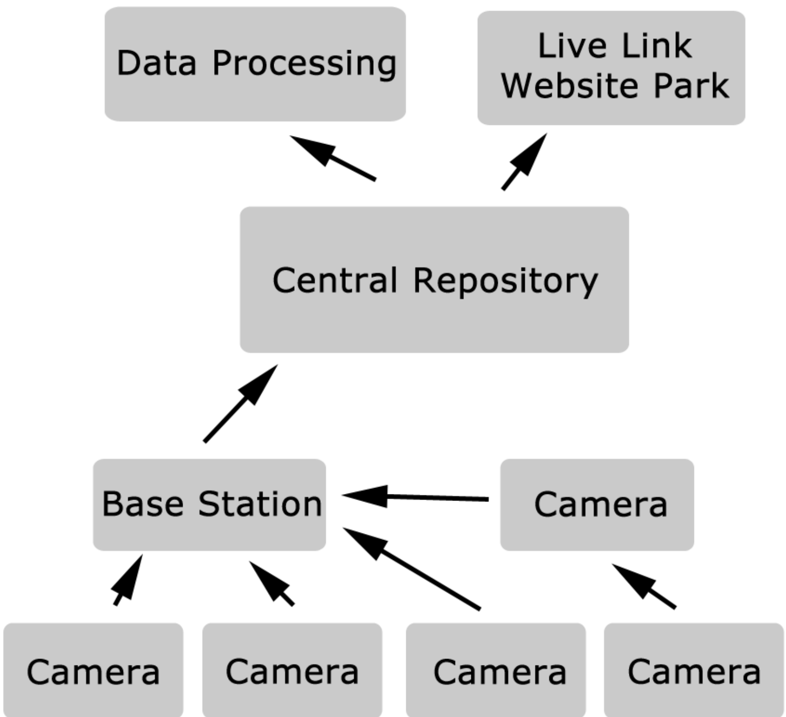


Fig 4. Principle of the wireless survey network. The actual layout of the system in the field depends very much on local vegetation and landscape features and should be evaluated in trials.

We recommend the use of photo camera system rather than a video system. These systems yield high resolution material, , which is sufficient for species identification. They are able to take 1-2 photos per second, which is sufficient to produce time-lapse mode clips of animal movement that can potentially be used to derive movement speed, an important parameter in the Random Encounter Model for calculating animal densities.

Year-round recording at 45 stations will yield a massive amount of photographs. Processing photo sequences takes about 3 minutes on average per camera-day. Processing all photographs of a full year would thus involve an estimated 3 minutes x 45 cameras x 365 days = 50,000 minutes = 100 days of work, which is clearly too much effort. We therefore recommend to store all photographs in the repository, but only analyse the material from one month per season, thus 4 months in a year. This captures seasonal variation with just a quarter of the processing effort; approximately 25 days per year. The remaining photos can be processed later, should this be necessary.

3.3 Camera types

There are many different types of camera traps. Most of them are cheap and developed for consumers, but not suitable for scientific use because of insufficient hardware specifications and construction quality. A few models are also suitable for scientific use. These were evaluated for use in the survey network for the park.

The most promising camera type is the BuckEye X7D (Fig. 5). This camera appears suitable for monitoring wildlife within the park, as well as monitoring animal movement across the wildlife passages. It has the following characteristics:

- Wireless radio connection with a base station for direct photo transmission
- Invisible infra-red flash
- High trigger speed: first photo taken within 0.1 second after movement detection.
- External power supply from 12V gel battery.
- Possibility to add solar panel for battery charging
- 5 megapixel resolution, 1 photo per second as long as movement is detected.

An especially interesting feature of the X7D is the wireless connection to a base station, allowing remote picture download and system management. Technical problems can be detected instantaneously, allowing maintenance efforts to be entirely focused on stations that actually show problems. The combination of a battery and solar panel will allow the system to run autonomously year-round.

Fig. 5. BuckEye X7D camera trap with wireless functionality, here shown without protective housing.

3.4 Material costs

The estimated material costs of the survey network (excluding hosting of the repository and database) amount €44,808.60 (Table 3). These amounts are tentative, since the system has not yet been tested. For example, we do not yet know how many base stations are needed for wireless coverage of the entire park.

The cameras, security enclosures, receivers and antennas can be ordered directly from BuckEyeCam. To make sure the system fits the local situation it is recommended to purchase the solar panels and batteries from a local supplier. This also saves on shipping costs since batteries are considered hazardous cargo.

Table 3: Estimated material cost for a wireless camera trap network for wildlife monitoring across De Hoge Veluwe National Park *.

Component	Type	Unit price	units	total
Camera	BuckEye X7D Wireless Camera	€ 566	50	€ 28,275.56
Battery	Gel Accu 12 volt 7Ah (150x65x95mm)	€ 30	50	€ 1,500.00
Solar panel	X7D 12v Solar Charger	€ 94	50	€ 4,692.37
Casing	Security Enclosure	€ 81	50	€ 4,045.15
Receiver	X7D PC Base Kit + Antenna Upgrade	€ 464	5	€ 2,321.91
Repeater Antenna	Omni antenna, 6dbi, 9' cable	€ 65	5	€ 323.61
Base station	10" Netbook	€ 250	5	€ 1,250.00
Memory card	8GB SDHC min. Class6	€ 8	50	€ 400.00
Post	50x50x5mm, min 2 m.	€ 30	50	€ 1,500.00
Fixation	Beamix NoMix 17.5kg	€ 10	50	€ 500.00
				€ 44,808.60

* Material replacements and extra adjustments to the configuration based on trial are not included. Numbers include 5 spare cameras + accessories.

3.5 Data management

The volume of photographs that the survey system will collect represents a challenge. Data storage of all photographs and data will require an estimated 250 GB per year. We recommend the hosting of the repository and database on a dedicated server at the offices of the HVNP. This will be less expensive than the alternative of external hosting at servers of commercial parties or Wageningen University, because the amount of space and internet bandwidth needed would be substantial. A server on the HVNP network is relatively secure and cost-effective. It can easily be configured to have ad-libitum storage space, so accommodating this amount of data is no problem. An additional advantage is that the photos can be directly linked to a public website for outreach and education purposes. Remote access to this server for investigators is required.

Based on the data collected so far, on average 1.5 photo sequences are collected per camera per day, which take about 3 minutes each to process. Game meadows yield many more sequences and attract more animals, so processing time will be longer than average. Including game meadows in the monitoring system will significantly increase average processing time. Processing includes identification of animals, counting of numbers of individuals present in the sequence, data entry into data base, and archiving the photos. The rate and accuracy of processing requires sufficient experience. Therefore, it is recommended that one person is responsible for data processing.

3.6 System maintenance

Wireless networking, solar powering and secure equipment housing are expected to limit maintenance needs to a minimum. Because the sensor network is connected wirelessly with the internet, the status of all cameras can be remotely checked. Part of the system maintenance could be performed by park personnel. It is not yet possible to estimate the actual time needed for maintenance. This requires a testing phase to determine potential weaknesses in the system and a few months of experience.

3.7 Field testing

To test the suitability of the proposed system, and produce an optimal network design, it is essential that equipment is ordered well in time to make sure it is up and running several weeks before the gates are opened.

4. References

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