Unmanned Aerial Vehicle as a new monitoring tool for detecting traces of winter sports participants in a sensible mountain area

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Abstract

The capercaillie is a mountain grouse species listed on the red list in Switzerland and other parts of Europe. As a consequence of their protection status, some of their habitats are restricted for human uses. One sub-population of the capercaillie is located in the UNESCO Biosphere Reserve Entlebuch. Parts of its territory is overlain by official snow shoe routes and some cross-country skiers use the mountains as well. In order to identify and monitor possible problem zones, it was tested if Unmanned Aerial Vehicles (UAV) can identify snowshoe and cross-country skier tracks. They offer a low-cost tool for air observations also in inaccessible terrain. Results indicate that certain environmental conditions are needed to carry out accurate UAV flights, but that with best technical and aeronautical settings, it is possible to gain aerial images that allow identification and even quantification of the winter use by humans. Hence, UAV's can be used as a new monitoring tool for detecting human winter activities, a fast growing threat to wildlife in mountain areas.

Introduction

Human disturbances and habitat fragmentation are major drivers for the loss of populations across the world (Ewers and Didham 2006; Salafsky, et al. 2008). One species, which is extremely fragile to disturbances is the capercaillie (*Tetrao urogallus*) a forest grouse species that needs very specialized habitats (Graf, et al. 2005). Its natural home range contains open forests of the mountain stage, which are in a late succession stadium (Storch 1995). Through fragmentation of their habitats and disturbances from humans, the distribution area is declining throughout Europe (Cas 2010; Storch 2000) and their subpopulations are restricted to isolated patches (Mollet, et al. 2008). In Alpine systems, winter sports activities are a major source of disturbances (Arlettaz, et al. 2007; Braunisch, et al. 2011) as the habitats of capercaillie are increasingly used by ski tourers and snow-shoe hikers (Coppes and Braunisch 2013; Rupf, et al. 2011). To reduce the so caused disturbance to a tolerable mass for the animals, enormous efforts are needed. For example, by marking sensitive areas, distributing information material or hiring rangers. Controls how and where such actions work are largely missing because they are time consuming and costly (Immoos and Hunziker 2015).

Hence, in order to survey the disturbance to capercaillie habitats and evaluate measures taken, new approaches are required. The data gathering for such approaches must be cost-effective and suitable for large areas. Unmanned Aerial Vehicles (UAV or so called drones) could be a tool for this task. They have been established in recent years for various purposes and could be a key tool to monitor large sensitive areas from the air (Jones, et al. 2006; Weissensteiner, et al. 2015). The impact on wildlife from UAV flights are rather low (Ditmer, et al. 2015; Sarda-Palomera, et al. 2012; Vas, et al. 2015). However, in order to assess the feasibility of this technique for mountainous winter areas, basic aspects need to be examined more thoroughly:

- Which technical, aeronautical and environmental conditions allow accurate UAV flights for detecting traces of snowshoe hikers and ski tourers quantitatively and qualitatively without entering the study area?

- Are there any reactions of wildlife visible that would point at a disturbing effect of UAV's?

These questions were tackled in a case study within the UNESCO Biosphere Reserve Entlebuch (UBE) that houses remnant populations of capercaillie, which are laying within an increasingly frequented area for snowshoe hikers and other winter tourists. Hence, the last question of interest was:

- Are snowshoe hikers and cross-country skiers in the case study region disturbing the capercaillie habitat?

Material and methods

To answer the questions a fixed-wing drone from Bormatec (type of Maja D, Figure 1) was used, offering a wing span of 180cm. It is a fully autonomous UAV which can fly relatively slow (normal cruise speed is 12 m/s) and is hence able to map areas at low altitude and high resolution (ResearchDrones 2014).

***Figure 1** - Our Maja D fixed-wing drone from Bormatec with a laptop containing a telemetry link as ground station and the remote control. © S. Weber 2016*

The flights were carried out fully autonomous with the open source program "Mission Planner" from ArduPilot. This program allows to program the trajectory of the drone on a laptop before starting and to create an accurate flight grid for every flight in order to work as efficiently as possible on large scales (ArduPilot 2016). During the flight, the drone was linked by telemetry with the laptop in order to make corrections and to follow the flight process. In addition it was constantly linked to the normal remote control. Furthermore, it was kept to sight distance all the time (legal obligation in Switzerland).
In the fuselage of the drone a Canon SX260HS was installed for gaining images vertically downwards without zoom. The camera software has been hacked with an intervallometer script to allow interval images every two seconds (DroneMapper 2015). On the nose of the drone a GoPro 3 was attached with a downward tilt to film in flight direction eventual movements of wildlife.

The flights were conducted in the UBE in the Central Alps of Switzerland (Figure 2) during the winter month from January to March 2016. The study area for the first phase was surrounding the small hill "Wagliseichnubel". This is a normal mountain area without special protection status which offers several snowshoe trails in the immediate vicinity (SVS 2015). 12 flights on seven days were conducted to defining the environmental conditions, the aeronautical and the technical aspects which allow accurate drone flights over mountain areas and gaining best images.
After obtaining the best settings, 10 flights on five days were held on the second test site. It was located on the other side of the valley and includes a habitat of capercaillie (access prohibited) in combination with an official snowshoe trail leading around this protected area (SVS 2015). This site was chosen for the practical tests because it offers a typical setting for snowshoe hikers, is easily accessible and frequented by many hikers.

In order to locate the snowshoe hiker traces, the images were first evaluated individually with Windows Photo-Viewer in order to delete diffuse images and to gain information how the traces can be made visible. Later in the case study the gained images were joined together for Orthomosaics with Pix4Dmapper and ArcGis. As a middle way between single photos and Orthomosaic, Photoshop was used for manually combination of some pictures. To estimate the

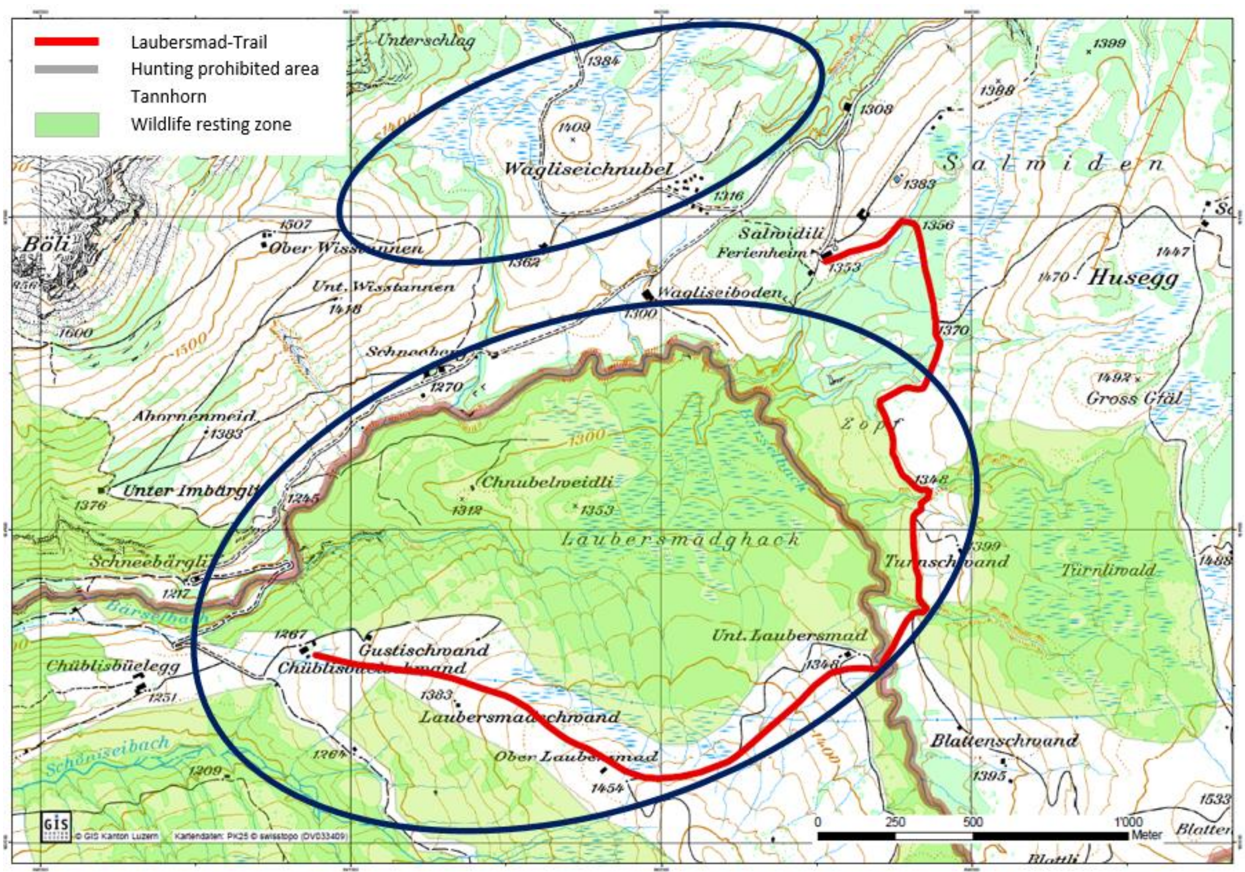

__Figure 2 -__ The first test site was around Wagliseichnubel in the smaller circle. The second test site was around the restricted capercaillie habitat (Laubersmadghack) in the larger circle. It is also shown the official snow shoe trail from Salwideli to Laubersmad (red line). © GIS Kanton Luzern

amount of traces we compared the gained photos with photos from self-made traces.

Results

Environmental conditions

The weather conditions played a crucial role for accurate drone flights. The biggest problems were caused by the wind because of the sensitiveness of the drone. Once the average wind speed was over 8km/h or wind gusts came up, the flights could not be flown safely anymore. An additional factor that comes up in sunny mountain areas are thermal lifts. Especially when crossing ledges and hilltops the drone had some problems to fly calm.

The cloud coverage did not cause strong restrictions. Only when it was raining, snowing or foggy, the drone could not be flown. However, the visibility of the UAV limited its working range: because with cloud cover, the UAV could not be seen over long distances by eye. For aerial photos, only deeper and repeatedly travelled tracks could be identified if clouds were present. During the flights, the temperature range was partly below 0°C (up to -8°C). These low temperatures caused some problems with the wireless connection between the drone and the laptop, which led to reduced control possibilities.

__Figure 3 -__ Traces from snow shoe hikers from about 100m height with a Canon SX260HS. © S. Weber 2016

Another important factor was the take-off and landing point. There has to be an area where no trees or other higher objects (e.g. power lines or radio masts) are present in the immediate vicinity. Moreover, the radio link to the UAV should not be interrupted by an object in direct line and the whole flight area should be visible. For the landing it is important that the ground is flat and uniform. Landings on snow covers were generally gentler for the UAV itself.

Aeronautical and technical aspects

In autonomous flight mode the drone's flight time (max. 35min) could be fully exploited. For this reason, we programed the desired flight path before take-off on a laptop and saved it to the drone. After the manual start, the drone flew autonomous along the pathways with the right altitude and landed then automatically at the predetermined location.
To increase the flight stability and the duration of flight, the flight altitude was performed relative to the take-off point. For safety and wildlife conservation reasons we flew never closer than 50m to the ground surface (including trees and other objects).
As optimal airspeed 12m/s has been proven. This allowed flying relatively large distances without losing to much energy. In addition, it was possible for the UAV to correct disturbances caused by wind or gusts without difficulties and the images were mostly sharp.
The most efficient way of flying over a large area were by flights with a programed flight grid (Figure 4) as parallel transects with distances of 100m between the transects (flight altitude 100m). Because of the manoeuvring of the drone, the flight grid is required to expand slightly beyond the study area.

Practical application

In the first test site 80 – 90% of the tracks followed the official route (in consideration of 50 people per day using the area). The traces, which were not following the marked routes, originated mostly from ski tourers.
In the second test site no trespassing into the restricted zone could be observed. However, some single traces, which left at some points the official route, were detected (Figure 5). Considering the length of the route and the number of tracks (up to about 30 tracks a day), these were only isolated cases.

A reaction of wildlife to the drone flights could not be observed at any time. Generally, there were no wild animals seen in the images, although it is known that the area contains many wildlife species (including Ungulates).

Figure 4 - Flight grid for a flight over Wagliseichnubel. The flight height was about 100m above ground and the transects were separated from each other with a distance from about 80m. © S. Weber 2016

Possibilities for detection of traces

Traces of snowshoe hikers and ski tourers were clearly visible on most pictures (Figure 3). Compared to photos from our self-made tracks, the traces found could also be classified into quantity categories (1x, 2x, 3x, 4x, 5-10x, >10x). Therefore, we compared the intensities from the traces on the photos against each other.

An important factor for accurate pictures was the flight stability of the drone. The more stable it has flown (nice and calm weather), the better the quality of the images. The time around noon, when the sun was at its highest position, led to the best shots. The snow present had to be as powder or wet snow for clear visible traces. In slightly frozen snowpack the tracks were less obvious.

Discussion

With this case study it was possible to show another practical opportunity which an UAV can offer. Its possible to detect traces from snowshoe hikers and cross-country skiers qualitatively and quantitatively without entering the study site. So it had shown that the steering mechanism for winter sport participants in the UBE is working and no trespassing into the restricted zone could be seen. Hence, the capercaillie in this area is not under direct disturbance from snowshoe hikers or ski tourers.

Monitoring possibilities with UAV's in areas which are not easy accessible by foot or which should be left undisturbed (Pavelka, et al. 2014) are technically feasible. UAV's offers several advantages for the operator for small scale research such as providing data at high spatial and temporal resolution if the UAV is equipped with capable sensors (Anderson and Gaston 2013). Also the possibility of systematic and permanent data gaining process with a low-cost tool provides new opportunities for users with the advantage of a low-risk technique (Linchant, et al. 2015).

On the other side, there are a couple of drawbacks. As shown in the case study and other similar studies (Anderson and Gaston 2013;

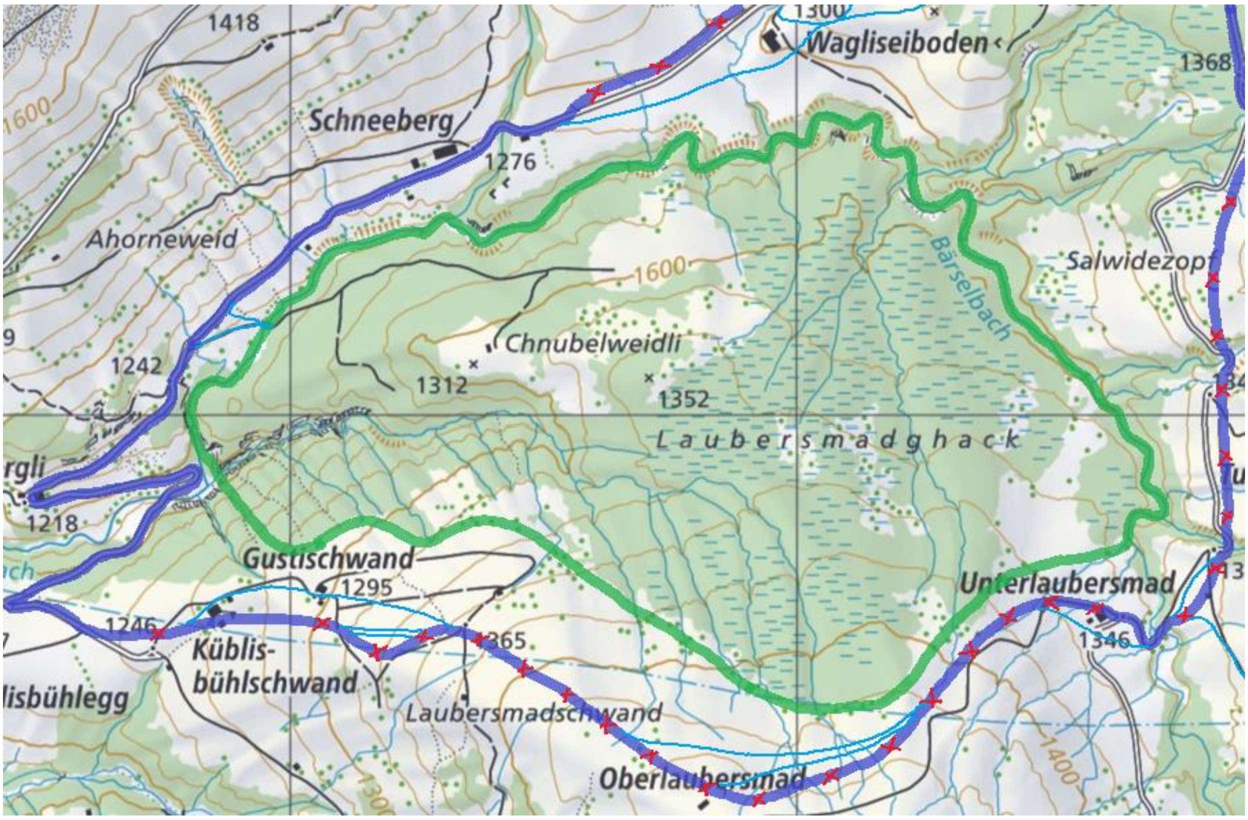

Figure 5 - *The second test site with the official snow shoe trail marks (red crosses) and the effective traces (blue lines). Some of the traces left the official trail (light blue) but don't enter the restricted zone (green framed area). © S. Weber 2016*

Christie, et al. 2016) UAV's are sensitive to high wind speeds or bad weather. Some drawbacks could be left away with the use of quadcopters or other kind of UAVs.
As an integrative approach for the future there could be the combination between the use of UAV's and controlling by foot. It's possible to gain information about diverse ecological questions, e.g. human disturbance in combination with presence of wildlife from UAV's. Further investigation could be done with conventional methods. So it would be possible to reduce the disturbing effect on wildlife from humans.

In our case study there were hundreds of aerial photos to analyse. It was time-saving to process an Orthomosaic. This allowed to analyse the entire flight area at once and the tracks could be transferred directly to a map. The downside was that the individual images overlapped themselves not exactly. A more exact GPS signal from the camera could solve this problem.

For the wildlife its important, that UAV's have less disturbing effects than conventional methods. In this study there was no wildlife seen in the pictures or videos. That refers to no disturbances through our UAV flights or at least to no escape movements. Earlier studies showed similar results with fights from a certain distance (Ditmer, et al. 2015; Sarda-Palomera, et al. 2012; Vas, et al. 2015). But Bears for example shows some limited physiological reaction of close flights (Ditmer, et al. 2015). Also could it be that the larger mammals were absent from our study site during the wintertime. E. g. it is known that red deer's move to lower mountain range with less snow in the winter (Mysterud, et al. 2011).

The use of marking trails for the growing number of snowshoe-hikers in combination with active information about the potential negative impacts of their activities seems to work for now. However, viable grouse populations need large interconnected areas of natural or semi-natural habitats without much disturbance to thrive (Storch 2007). This goal is currently not met in the region and will need further activities by the UBE management and winter sports providers.

Conclusion

Drones provide a new monitoring tool for mountain areas. They can cover large areas and have a low impact on wildlife, when flown at adequate heights. Fixed-wing drones hold some drawbacks given their sensibility to fluctuating environmental conditions that multicopters could compensate, however, those only cover smaller areas. Further studies could optimize the technical aspects of droning in mountainous areas as well as the still time consuming image viewing process. Also the possible reaction from wildlife should not be ignored and need more species comprehensive studies.

Concerning the capercaillie population in the UBE it can be said that the case study site is not negatively impacted by the winter sports tourists and that the steering instruments work. For the long-term survival of the population, the surrounding areas should be included by expanding the steering measures geographically and monitoring the impact of these measures by drones and conventional methods.

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