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Master thesis

Monitoring reproduction in moose by use of unmanned aircraft system:

- detectability, effectivity and behavioral responses

Individual E1819 with her calf May 29, 2021. Drone foto: Erlend Furuhovde

Master thesis in applied ecology

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Table of content

Sammendrag

Å forbedre metoder for blant annet tetthet- og reproduksjons studier er en del av forvaltningen og forskningens ansvar. Å utvikle og teste ny teknologi som kan forstyrre dyrene i mindre grad, men også være mer effektiv I forhold til et tid- og kostandsrelatert aspekt vil alltid være viktig.

I denne studien undersøkte jeg adferden og reproduksjonsraten til 24 GPS-merkede, viltlevende elger (*Alces alces*) ved bruk av drone- og bakkesjekker. Elgene oppholdt seg i Sørøst-Norge inntil grensen mot Sverige. Jeg undersøkte hvordan drone- og bakkesjekker påvirket elgene, oppdagbarhet av kalver, adferd når støkt og om elgene viste tegn til endring av adferd under droneforsøket.

Av totalt 17 kalver ble det funnet 15 (88,2%) med dronesjekk og 14 (82,4%) med bakkesjekk. En dronesjekk bruke i gjennomsnitt 17 minutter (± 12-22, n=41) og en bakkesjekk 97 minutter (± 26-244, n=35). Under bakkesjekk ble 59,5% (n=22) av elgene støkt, og 35% (n=14) støkt av dronesjekk. Den gjennomsnittlige fluktdistansen under bakkesjekk var 1420 meter (95%CI: 757-2665, n=17), under dronesjekk var den 353 meter (95%CI: 172-725, n=13). Elg som oppholdt seg i åpen skog beveget seg også lenger i forhold til intermediær skog under en dronesjekk.

Dronesjekker er raskere og forårsaker mindre forstyrrelser mot elgene i en kritisk periode hvor kalvene er små og avhengige av sin mor. Det at elgen blir mindre forstyrret av en dronesjekk burde vektlegges selv om dronesjekker muligens er noe dyrere å gjennomføre.

Nøkkelord: Adferd, *Alces alces*, Drone, Elg, Reproduksjon, Ubemannet luftfartøy

Abstract

Improving methods for abundance and reproduction surveys is a part of management and research. Developing and testing new technology that can aid the animals in terms of less disturbance and likewise be more efficient in time and cost-related aspects will always be important.

In this study I investigated the behavioral response and reproduction rate of 24 GPS collared free-ranging female moose (*Alces alces*) to drone and ground approaches. They were located south-east in Norway close to the border to Sweden. I tested how drone and ground approaches affected the moose, the detectability of calves, flush response and if the moose showed signs of change in behaviour during a drone approach.

Of a total of 17 calves, 15 (88,2%) were found with drone and 14 (82,4%) with ground approach. A drone approach uses on average 17 minutes (± 12-22, n=41) and ground approach 97 minutes (± 26-244, n=35). During ground approaches 59,5% (n=22) of the moose was flushed, and 35% (n=14) by the drone approach. The average fleeing distance during the ground approach was 1420 meters (95%CI: 757-2665, n=17), for drone approach it was 353 meters (95%CI: 172-725, n=13). Moose staying in open forest moved further than moose in intermediate forest.

Drone approaches are faster and cause less disturbance for the moose in a critical period when calves are small and dependent of their mother. The fact that moose are less disturbed during this sensitive time of reproduction should be emphasized even if the drone approaches might be a bit more expensive to conduct.

Key words: *Alces alces*, Behavior, Drone, Moose, Reproduction, Unmanned aerial vehicle

1. Introduction

Infrastructure and human usage of the landscape can affect wildlife directly and indirectly (Nilsen & Strand, 2017; Rochelle et al., 1999). Hence, it is important to understand the effects of our direct and indirect interference with wildlife caused by infrastructure, settlements, and human activities. The boreal forests are used intensively through forestry and human settlements and infrastructure are found throughout. Because of human expansion, rapid habitat loss may occur (Huxel & Hastings, 1999), which in turn can lead to decreased fitness levels and a less sustainable wildlife population (Nilsen & Strand, 2017). In order to understand and manage these processes, it is important to monitor wildlife populations. Regular biodiversity and abundance surveys are important tools to study wildlife populations and apply adaptive management accordingly (Jachmann, 2001). Regular monitoring requires both financial and physical effort. However, wildlife research and management are often bound to an economical budget. It is therefore crucial to develop new, effective monitoring methods based on recent technological advancements.

Methods used to conduct wildlife surveys will vary by species, season, habitat and the research goal. Methods can be invasive or non-invasive, and among the most common non-invasive surveys are camera traps (Meek et al., 2014), aerial photo with use of aircraft or satellite (Fretwell et al., 2014; Schleper, 2020; Vermeulen et al., 2013), acoustic monitoring (Blumstein et al., 2011), transect lines (Anderson et al., 1979), E-DNA sampling (Pawlowski et al., 2018), spotlight counts (Kavanagh & Peake, 1993) and hair-traps (Lindenmayer et al., 1999). Often, abundance or reproduction surveys of big mammals in large areas are done by aircraft (Dyal et al., 2021; Jachmann, 1991; Lethbridge et al., 2019; Strand et al., 2015, p. 38).

Although the wildlife monitoring using a manned aircraft has shown to be effective for many species (Hennig et al., 2021; Strand et al., 2015, p. 20), there are disadvantages to the method. The costs are high and the application of manned aircrafts is often financially dependent on external funding as well as local weather conditions that can restrict the usage of manned aircrafts (Watts et al., 2010). This uncertainty makes the planning of aerial surveys difficult since the aircraft and operator must be booked ahead of time. Lastly, the method can be dangerous for personnel. Aircraft crashes happened to be the main reason for work-related deaths of field biologists, and during the period 1937-2000, 66% of all deaths was related to this (Sasse, 2003). Therefore, aircraft operators and field personnel training will be important and also vary between countries because of legislation and safety procedures. Consequently, these disadvantages can lead to large gaps between successive surveys, which can in turn lead to inaccurate information about the population (Bouché et al., 2011). Also, successive surveys may no longer be comparable because of changes in time of year or equipment used (Ferreira & van Aarde, 2009). This can be problematic when inaccurate information is used to make management decisions, which could affect the wildlife population.

Helicopters or small aircrafts are today often replaced by Ultra-Light Motorized aircrafts (ULM) or Unmanned Aircraft Systems (UAS), also known as drones (Ellis et al., 2003). Drones can be used in various situations, such as environmental monitoring (Getzin et al., 2012; Hardin & Hardin, 2010; Lejot et al., 2007), law enforcement (Finn & Wright, 2012), forestry (Wing et al., 2013), and agriculture (Sugiura et al., 2005). This also opens up new possibilities when it comes to abundance and reproduction studies of wildlife (Linchant et al., 2015). The technological development of drones has made this an affordable and user-friendly method to apply.

Animals' response to drones is important to study, considering the increasing use of drones by researchers, managers, photographers and recreationists. Disturbance-triggered antipredator behaviour is costly, since reduced time for foraging and resting will affect the animal negatively both in short- and long-term (Naylor et al., 2009). It is also important to take into account the period when offspring are born and are dependent on their mother. Responses to disturbance are shown to vary between individuals, and females with offspring are shown to be more vigilant than females without offspring (Childress & Lung, 2003; Stankowich, 2008). Factors such as habitat type, snow depth, and time and place can also affect how the individuals will respond to disturbance (Lima & Dill, 1990; Wikenros et al., 2009). Long-term exposure may cause habituation and lead to negative consequences (Samia et al., 2015). Individuals might become more exposed to predation and other human disturbance as a result (Wheat & Wilmers, 2016).

In northern Europe, the moose *(Alces alces)* is a common species and has a big economic and cultural value (Lavsund et al., 2003; Milner et al., 2005). With its high numbers, it also comes with human-wildlife conflicts such as traffic accidents and browsing on young trees in planted forest stands (Ericsson et al., 2002; Lavsund et al., 2003). The moose is also an important game species; in Norway, approximately 35 000 moose are harvested yearly and the hunting has a total economic value of ~107 million Euro (Pedersen et al., 2020; Statistics Norway (SSB), 2021). It is also one of the most important prey species for wolves (*Canis lupus*) and brown bears (*Ursus arctos*) (Niedziałkowska et al., 2019; Sand et al., 2016). Other species such as the red fox (*Vulpes vulpes*) and wolverine (*Gulo gulo*) also scavenge on the wolf-killed carcasses (Kronenberg, 2018; Nordli & Rogstad, 2016).

In this study, I developed and evaluated a new method to monitor reproduction and behavioural responses of moose when using a drone and compared it to the traditional ground approach method (Fremstad, 2021) where sneaking on ground with use of an VHF-receiver to get a visual observation of the moose to determine if it has a calf. I examined 24 free-ranging female moose and their behavioural responses to drone and ground disturbance, and the detectability of calves. With GPS collars on all the moose, I approached them using coordinates plotted into the drone's software to investigate behavioural responses towards the drone at different heights, and the presence of calves. I also wanted to evaluate if the traditional method for reproduction studies done in the GRENSEVILT project, sneaking on ground by foot with an VHF-receiver, would get the same results as the drone, and compare the behaviour toward the drone versus human on ground. I predict that **P1)** the drone will be as effective or more at detecting calves as the field personnel from the ground. Secondly I predict that **P2)** the drone will be more efficient, measured in time used for each approach, and that **P3)** moose will have a stronger behavioural response to the human doing the ground approach (flee more often and over longer distances) compared to the drone.

2. Materials and Methods

2.1 Study area

The study was conducted in south-east Norway close to the border to Sweden, in Innlandet county (Figure 1). Within the study area, all four big carnivore species in Norway were present, wolf (*Canis lupus*), brown bear (*Ursus arctos*), wolverine (*Gulo gulo*), and lynx (*Lynx lynx*). The area is dominated by a boreal coniferous forest of Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*) with elements of bogs, dams, lakes, and deciduous trees of aspen (*Populus tremula*), birch (*Betula pendula and B. pubescens*), willow (*Salix spp.*), alder (*Alnus incana and A. glutinosa*) and rowan (*Sorbus aucuparia*). Because of forestry, the area has a large network of gravel roads which makes it easily accessible (Zimmermann et al., 2014). The area is covered with snow 3 to 6 months of the year, ranging mainly from November to April, and is characterized as cold and dry in winters (Milleret et al., 2017; Zimmermann et al., 2015). The moose densities are relatively high compared to other areas and range between 1-3 per km^2 (Zimmermann et al., 2014). The habitat use for moose varies through the year because of changes in temperature and snow depth (Gundersen, 2003). Generally from November moose start to migrate to areas with less snow , often valley bottoms and forested lowlands (Gundersen et al., 2004). From April to May, they migrate back again to summer habitats at higher altitudes (Gundersen, 2003).

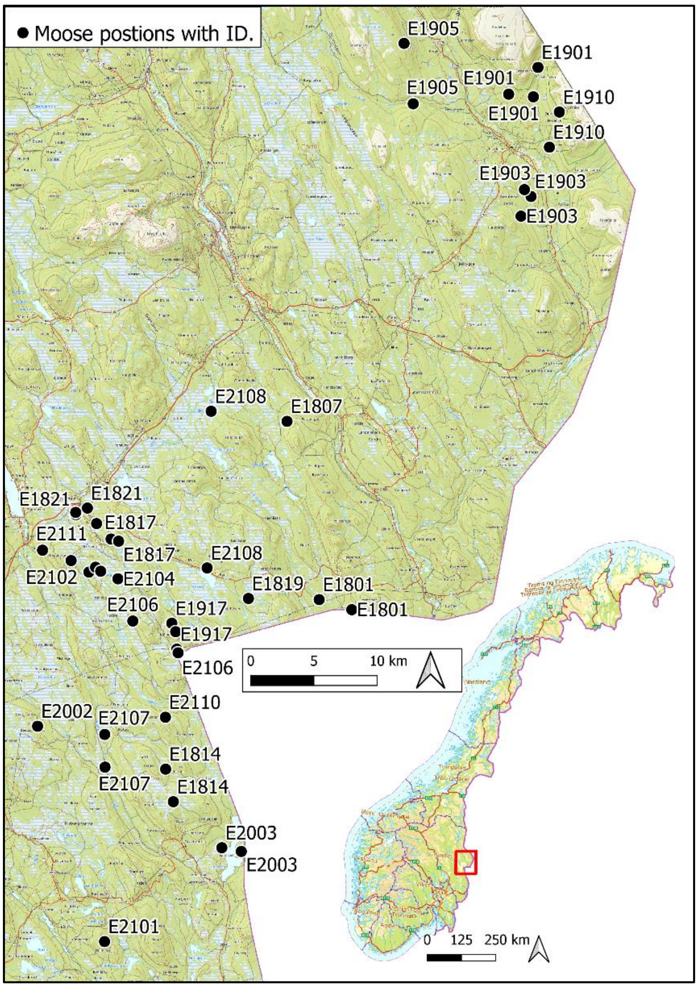

Figure 1. Study area including positions from moose the same day drone flights were done.

2.2 Study animals

Since 2018 and all years following, multiple moose have been darted from a helicopter with a CO_2-powered dart gun. The immobilization procedure followed the procedure for anesthesia and handling techniques described in detail elsewhere (Evans et al., 2012; Græsli, Thiel, et al., 2020; Lian et al., 2014). Captures were approved by the Norwegian Animal Research Authority (FSA), the Norwegian Environmental Agency, and the Norwegian Food Safety Authority. A total of 59 moose captures have been conducted on 55 individuals, one of which turned out to be a calf at closer inspection and was not collared.

2.3 GPS collars

On days of drone approaches and ground approaches, GPS (global positioning system) collars (VERTEX PLUS Collar) were programmed to take one position every 10 minutes between 08:00-18:00 GMT +1 and sending every third position (30 minutes) with use of VHF-antennas. In 2021, five individuals were equipped with GPS collars with built-in cameras that recorded a 30-second video every time they took a GPS position. This function drains the battery capacity and these collars were therefore only programmed to take 1-hourly GPS positions and sending every single position (1 hour) during this study. The positions from the GPS collars were sent to a server and shown in a web-application with a map at www.dyreposisjoner.no. The web-application also supports SMS-notifications and lets the drone pilot and ground field team get the latest GPS-positions to pinpoint the moose location (Supplementary, S1).

During 29.05.2022 - 19.12.2022 I conducted a total of 44 drone approaches on 22 individuals, and 57 ground approaches with VHF-receiver on 24 individuals between 27.05.2022 – 26.09.2022.

2.4 Protocol and field registrations

To be able to compare responses between drone approaches and ground approaches, the GPS collars were programmed equally for both approaches. For comparing detectability of calves, we made a design where there was only one day between drone and ground approach to minimize the risk of the calf being killed between trials. In about half of the cases, the drone approach was conducted on day one (day 1), followed by a "silent" day for the moose (day 2), and the ground approach on the third day (day 3). In the other half of the cases, the ground approach was conducted first (day 1), and the drone approach on the last day (day 3).

2.4.1 Drone approaches

By following the drone protocol (Supplementary, S1) I programmed the drone to fly to the last known position of the moose at hundred meters altitude while I was staying >= 500 meters away. When the drone arrived at the last known position, it was hovering for two minutes while recording video. If the moose was detected, it went down to seventy meters altitude if the result was no severe response (fleeing from the site). This continued but with one minute hovering intervals for each altitude, 70m, 50m, 30m, and 20m if the moose didn't have any severe response to the drone at different altitudes (fleeing from the site) (Figure 2).

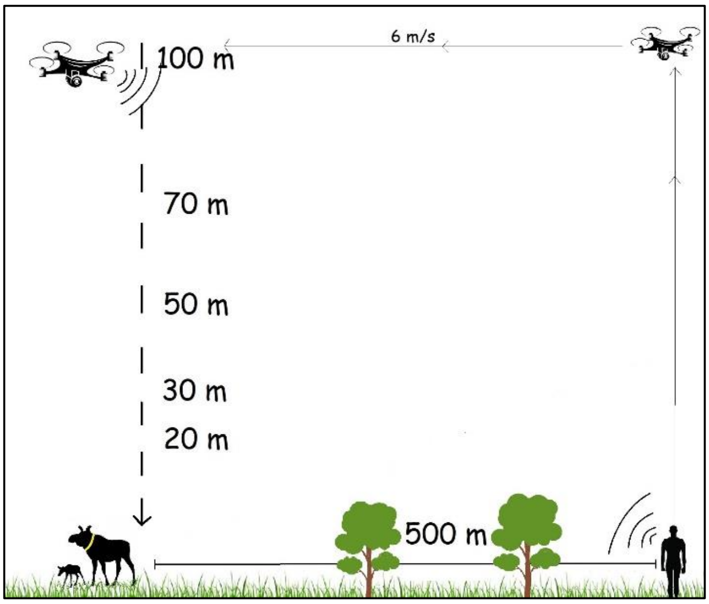

Figure 2. Sketch of a drone approach.

When hovering at different altitudes I wrote down if I detected offspring(s) and what the moose response was (Supplementary, S2). If the moose started running at any time during the approach, or when the drone had hovered for one minute at twenty meters altitude, the trial was done. I flew the drone up to hundred meters altitude again and the same route back to my position. The speed for lowering or elevating the drone was set to 2 m/s.

The drone was a "DJI Mavic 2 Enterprise Dual" (Figure 3) with GPS+ GLONASS system and have a ± 1,5 m horizontal accuracy range and ± 0,5 m vertical accuracy range (*Table 1*).

Table 1 Overview spec. DJI Mavic 2 Enterprise Dual

Flight time	31 min
Flying range	6000 m (CE)
Weight	899 g
Dimensions	322x242x84 mm
Max speed	72 kph
Max wind speed resistance	29-38 kph
GNSS	GPS+GLONASS
Hovering accuracy range vertical /horizontal:	±0,5 m / ± 1,5 m

Figure 3. Drone used during approach trials on wild moose: DJI Mavic 2 Enterprise Dual

2.4.1.1 Classification of habitat and weather

To define the habitat the moose was in during the drone approach, I classified it visually through video from hovering 100 meters above the moose. I classified the habitat into three classes: dense, intermediate, and open forest. Dense forest was classified when the canopy cover was more than 80% around the last moose position within a 20x20 m frame (Figure 4; A). When the canopy cover was between 30-80% I classified it as intermediate forest (Figure 4; B) and open forest was classified with no forest to a maximum of 30% canopy cover (Figure 4; C).


A) B) C)

Figure 4. Classification of habitat.

To classify the weather, I used the video recordings when the drone was hovering above the moose. I used four classes: sun (Figure 5; A), cloudy (Figure 5; B), rain (Figure 5; C) and fog (Figure 5; D). I had only two flights with (light) rain and three with fog.


A) B) C) D)

Figure 5. Classification of weather conditions during drone approaches on wild moose. Categories were sun (A), cloudy (B), rain (C) and fog (D).

2.4.2 Ground approach

Approaches from ground were done on foot while using a VHF receiver (RX98, Followit AB, Sweden). We followed the same study design, approaching the last known position from the GPS-collar while using the VHF-receiver to get signals in case the moose had moved. All approaches were done with headwind and the track was recorded with a handheld GPS unit. The goal was to tell if the moose had offspring or not. When we were close enough to see the moose, we observed it until we could detect offspring or assume it was without offspring (Figure 6). If possible, we sneaked back the same route to minimize the chance for disturbing the moose. If the wind had turned or changed direction during the approach, we choose the best way back to minimize detection.

Figure 6. Ground approach on individual E2106 June 15, 2021 at Kjølberget wind farm. Conclusion was no calf. Foto: Erlend Furuhovde

2.5 Data analyses

I used the program R Studio 4.1.2 (RStudio Team, 2022) for analyzing the data and making figures. For maps and calculations of fleeing distance and daily distance moved I used QGIS (*QGIS Development Team*, 2021), Garmin BaseCamp (*Garmin Basecamp*, 2018) and Microsoft Office Excel 2021. I downloaded all the GPX-files of the moose individuals from the platform www.dyreposisjoner.no and GPS Plus X (VECTRONIC Aerospace, 2019). I explored the data using the R packages *ggplot2* (Wickham, 2016) and *tidyverse* (Wickham et al., 2009). I used them for data cleaning, organizing and plotting graphs. I used the package *lme4* (Bates et al., 2015) to run GLMs and GLMMs with random effects, and *AICcmodavg* (Mazerolle, 2020) to compare the AIC scores (Akaike information criterion). The package *ggeffects* (Lüdecke, 2018) was used to get predicted values from the final models, and the package *emmeans* (Buerkner et al., 2022) to get estimated marginal means and look for significant difference between groups (p < 0,05).

2.5.1 Spatiotemporal analyses

GPS data were downloaded from www.dyreposisjoner.no. I was able to download 42 of 44 tracklogs from the moose during drone approaches and 54 of 57 tracklogs during ground approaches. Due to bad GSM coverage, not all moose received the 10-minute reprogramming and were excluded when analyzing flight response. I calculated the Euclidean distance between consecutive positions. For calculating time used I set the start and end time for both the drone and ground approaches 500 meters away from the last position for the individual since we both had similar approaches until this point (walking, biking, driving). From a 500-meter straight-line distance from the individual, I recorded the time used by the GPS tracklog for the ground personnel, and with the timestamp from the drone video.

2.5.2 Analysis of flight response and daily moved distance

I tried to use changepoint analysis to automatically detect movement caused by disturbance from the drone based on all positions of the moose the day of the approach with 10-min intervals. For the drone approaches, many of the individuals I saw through the recordings, moved small distances for a short time (< 10-min) before they stopped and became stationary again. Because of the short duration, the changepoint analysis would not detect the movement as a changepoint even though I could see that the moose was slightly disturbed through the video recordings.

Based on this I chose to calculate the area used (m^2) for the seven last positions (1 hour) from the moose before the approach started, and compared it to the area used for a similar time period after the approach was done to tell if the moose was back to a normal behavior in case of a translocation response. I combined this with what I saw through the video recordings since I had three cases where moose showed a small response (went from laying to eating/walking) during the drone approach but did not move out of the area used for the last hour. For these three cases, I compared the timestamp from the recordings and the timestamp on the GPS positions from the moose to calculate the moved distance.

I also wanted to test if there was a difference in the total distanced moved the days (24 hours) with no approach and the days with approaches. To do this I downloaded GPS data from the moose from the day between our approaches (day2). These days the moose only recorded two-hourly positions, and therefore I had to scale down to two-hourly positions during drone and ground approaches as well.

3. Results

I conducted a total of 44 drone approaches on 22 individuals and 57 ground approaches on 24 individuals (Table 2).

Table 2. Moose ID, number of drone- and ground approaches, and the calf end results.

Moose ID	Drone approaches	Ground approaches	Calves
E1801	2	2	1
E1807	1	3	0
E1814	2	2	1
E1817	2	2	1
E1819	1	2	1
E1821	3	3	1
E1901	3	2	2*
E1903	3	2	2
E1905	2	2	1
E1907	0	1	na
E1910	2	3	1
E1917	3	4	1
E2001	2	2	1**
E2002	2	3	0
E2003	2	2	0
E2101	1	1	1
E2102	3	3	1
E2103	0	2	1
E2104	1	1	0
E2106	2	4	0
E2107	2	3	1
E2108	2	2	1
E2110	1	3	1
E2111	2	3	1
Sum	44	57	20

**The first approach (ground) found twins, but she lost one within 8 days (3 drone and 1 ground approaches conducted later).*

***The calf was filmed by a local, ground and drone approach did not detect the calf.*

3.1 Detectability

The drone detected 43 out of 44 possible adult female moose (97,7%), ground approaches detected 28 of 36 adult female moose (77,7%). The only individual not detected during a drone approach (E2108) moved over 1,5 km from the last transmitted GPS position 20 minutes before the approach started. At that time, I was over 1 km away from the moose and the reason for the movement behavior is unknown.

The drone approach detected 15 out of 17 known calves (88,2%) with the study design “day one drone - day three ground”, or opposite. Ground approaches detected 14 of 17 (82,4%) known calves (Figure 7).

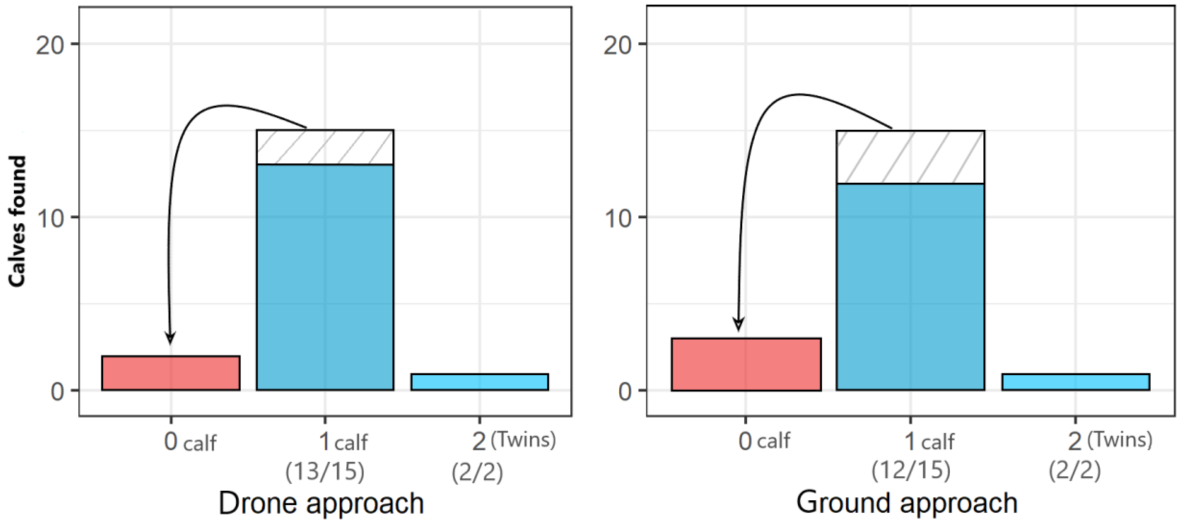

Figure 7. Number of calves (0, single (1) or twins (2)) detected by the drone and the ground approaches out of number calves possible (n=17). The drone and ground personnel both found the twin calves belonging to one adult female. The drone approach missed two single calves, ground approach missed three single calves. In total the drone detected 88,2% of the known calves and the ground personnel detected 82,4%.

3.2 Moose response towards the drone

Most of the moose were laying throughout the whole drone approach; 30 moose (75%) were laying when the drone hovered at 100 meters height and 22 moose (64,5%) that were approached down to 20 meters were still laying. Only 2 moose (5%) ran off at 50 meters hovering height, and 1 moose (3%) ran off at 20 meters hovering height (Figure 8).

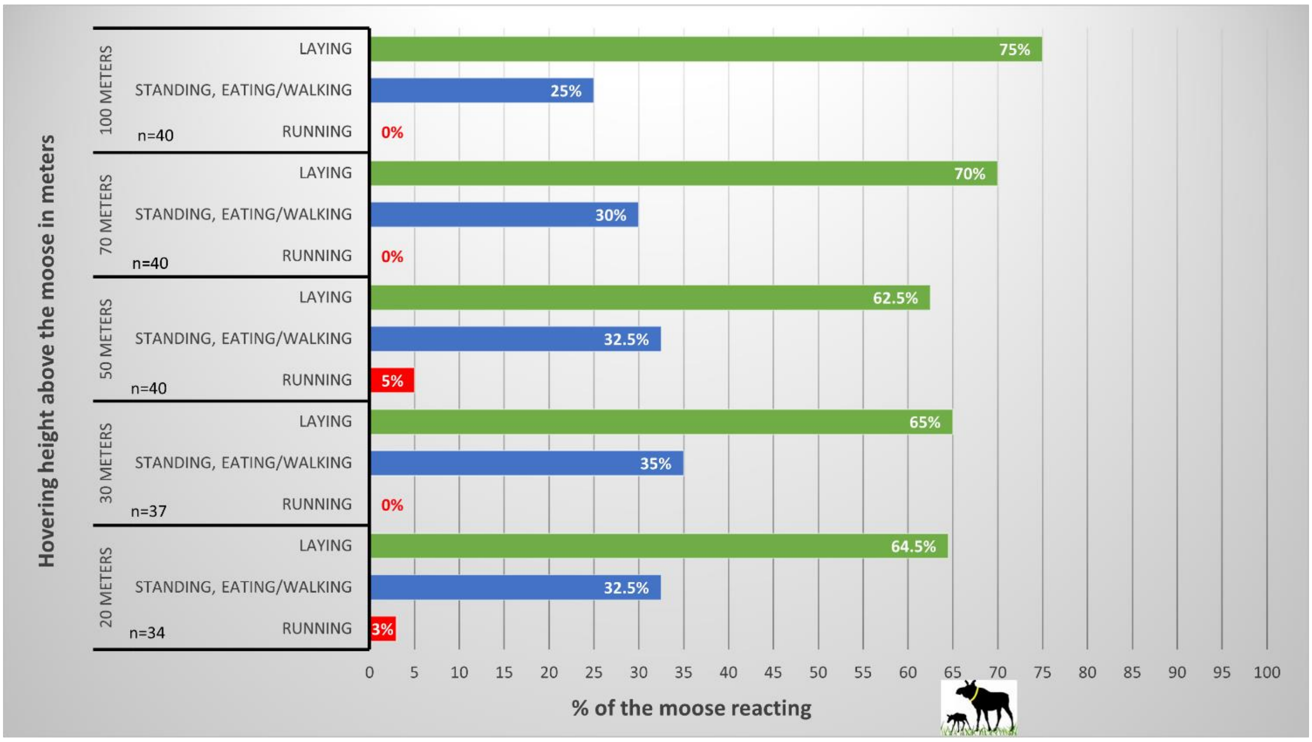

Figure 8. The figure reads from top to bottom, following the approach protocol with flying in at 100 m and hovering before lowering to next level. Percentages are of the number of moose that were approached at each hight (i.e. moose that had not already fled).

The drone detected 18 of 25 known calves (72%) at 100 meters hovering height and 23 of 25 (92%) at 70 meters hovering height. There was only one out of 40 moose (2,5%) that left the site at 70 meters height, 3 of 40 moose (7,5%) at 50 meters height, 2 of 37 moose (5,4%) at 30 meters height, and 8 of 33 moose (24,2%) at 20 meters height (Figure 9).

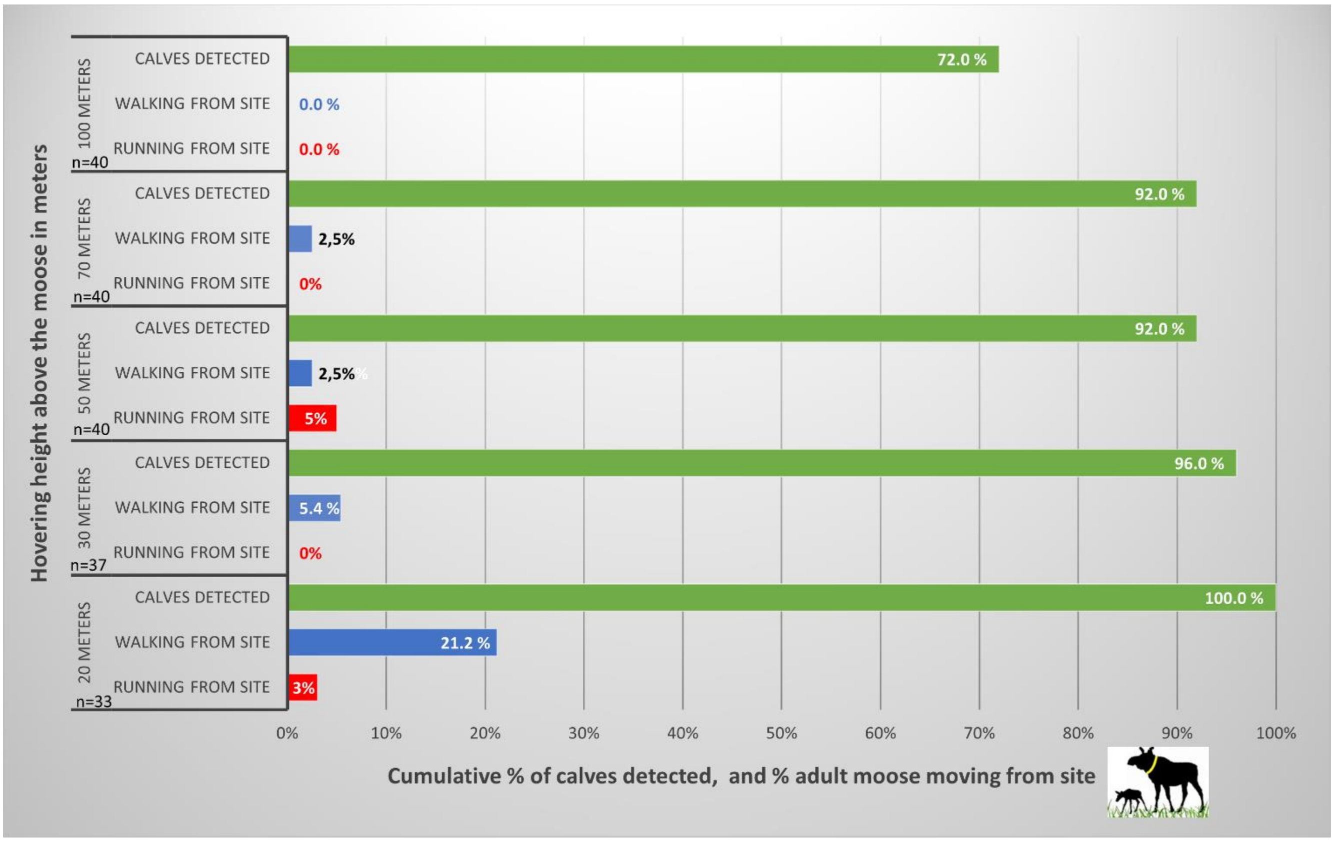

Figure 9. Calves detected by a drone hovering at different heights, and the reaction of the adult female moose at the different hovering heights. The figure reads from top to bottom, following the approach protocol with flying in on 100 m and hovering before lowering to next level. Percentages are of the number of moose that were approached at each hight (i.e. moose that had not already fled).

3.3 Time used for drone and ground approaches

The average time used for ground approaches was 97 minutes (± 26-244, n=35) and drone approaches 17 minutes (± 12-22, n=41), df=34, $p<0{,}05$ (Figure 10).

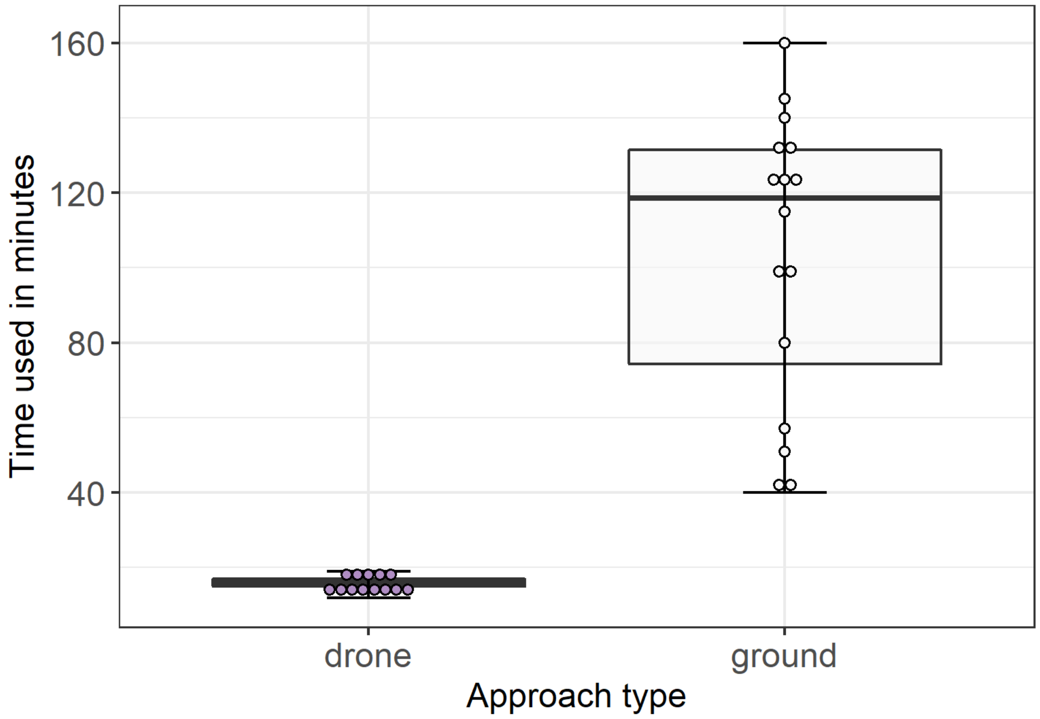

Figure 10. Time (minutes) used for drone approaches and ground approaches on wild female moose.

3.4 Fleeing distance

Of 40 adult female moose approached by drone, 14 (35%) left the site. For ground approaches 22 of 37 (59,5%) left the site (Figure 11).

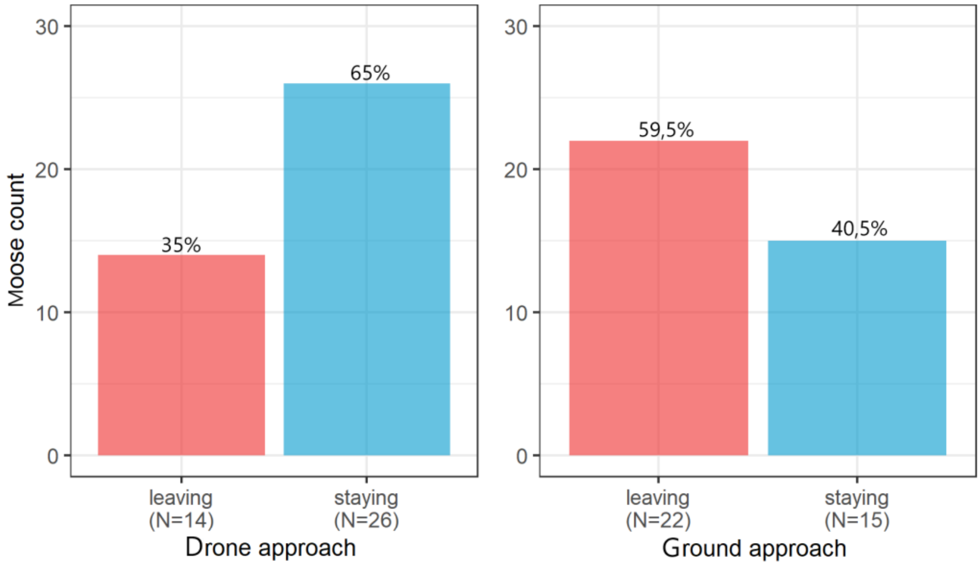

Figure 11. Number of moose staying or leaving the site during two types of approaches.

Moose that left the site during the drone approach had an average fleeing distance of 353 meters (95%CI: 172 – 725 m, df= 28, n=13) before going back to a normal movement pattern. The average fleeing distance for moose that left the site during ground approach was 1420 meters (95%CI: 757 – 2665 m, df= 28, n=17) (Figure 12).

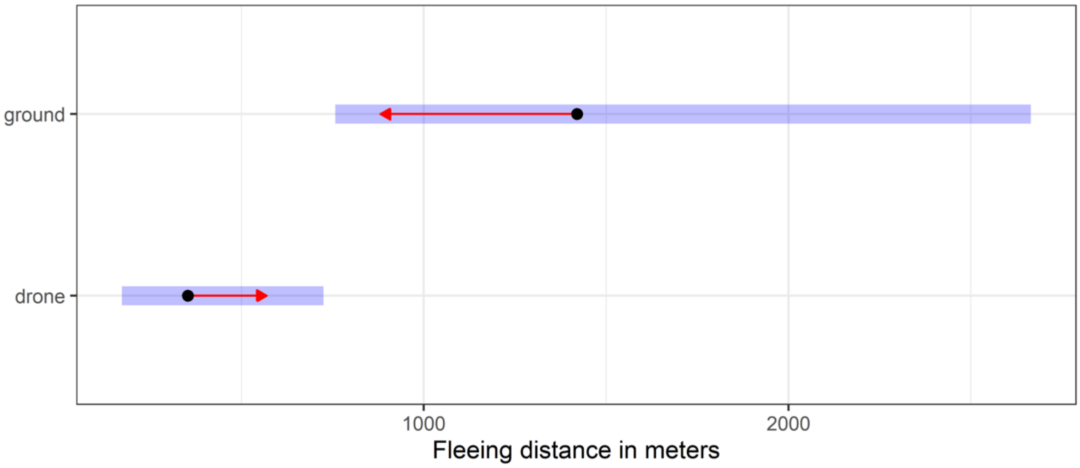

Figure 12. Estimated marginal mean of fleeing distance for each type of approach. Blue bars illustrate 95% CI, black dots the average, and red arrows is showing a significant difference since the red arrows are not overlapping.

3.5 Habitat effects on distance moved during drone approach

I tested six generalized linear mixed models with random effects and different variables taken during drone approaches. The AIC table shows that the variable ''habitat'' influenced distance moved for adult females the most, with the lowest AIC score and highest AIC weight (Table 3). The habitat ''open forest'' had a positive effect on distance moved before going back to a normal behavior pattern. Habitat "dense forest" were excluded since there were only two observations (Figure 13).

Table 3. AIC table of the distance moved by moose during drone approach.

Model	**K**	**AICc**	**AICc weight**
distance_moved_approach ~ habitat + (1|moose id)	**4**	**299.58**	**0.57**
distance_moved_approach ~ habitat + calf + (1|moose id)	5	301.61	0.21
distance_moved_approach ~ habitat + weather + (1|moose id)	5	302.32	0.15
distance_moved_approach ~ calf + (1|moose id)	3	304.64	0.05
distance_moved_approach ~ weather + (1|moose id)	4	307.12	0.01
distance_moved_approach ~ 1 + (1|moose id)	4	307.19	0.01

The distance moved during a drone approach was 6,63 meters in intermediate forest (95%CI: 2,15 – 20,38, df= 28, n= 23) and 91,96 meters in open forest (95%CI: 14,90-567,78, df= 28, n= 9) (Figure 13).

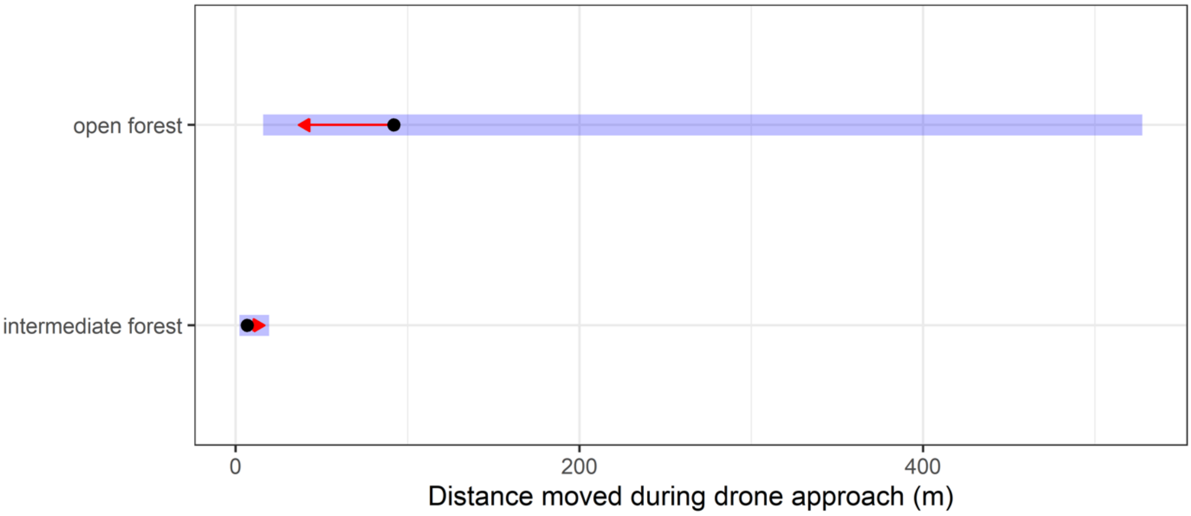

Figure 13. Estimated marginal mean of fleeing distance moved during drone approach for the two types of habitat; open- and intermediate forest. Blue bars illustrate 95% CI, black dots the average, and red arrows is showing a significant difference since arrows are not overlapping

3.6 Distance moved for 24 hours with 2-hourly positions

The model with moose-id as random effect predicts that the average distance moved by the moose during drone approaches was 1.25 km (95%CI: 1.01 - 1.55, df= 132, n= 42), ground approaches 2,05 km (95%CI: 1.68 - 2.49, df=132, n= 54), no approaches 1.31 km (95%CI: 1.06 - 1.63, df= 132, n= 41). There is a difference between ground approaches and the two other groups; no approaches and drone approaches (Figure 14).

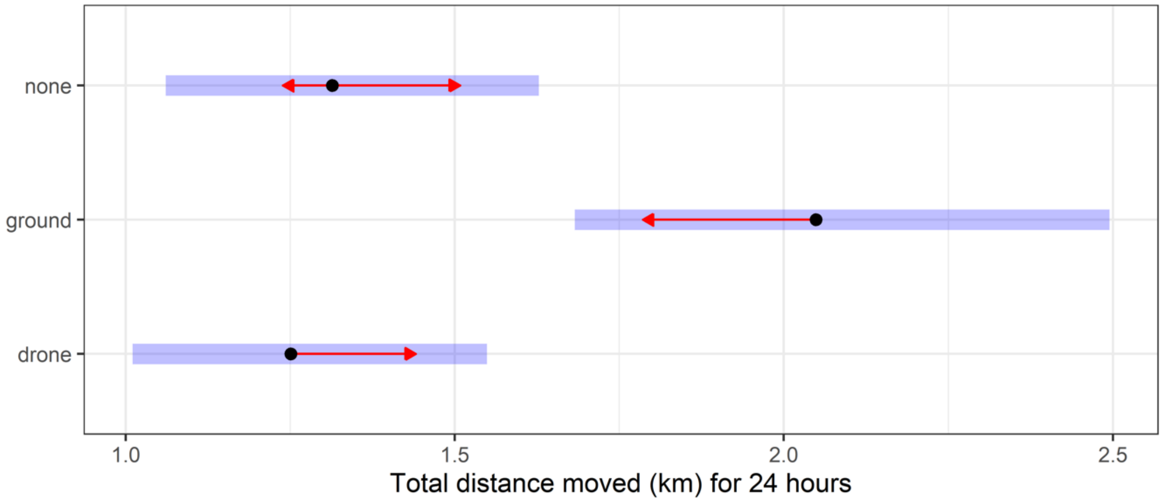

Figure 14. Estimated marginal mean of total distance moved through 24 hours (00:00-24:00) for drone approach, ground approach, and no approach. Blue bars illustrate 95% CI, black dots the average, and red arrows is showing a significant difference when arrows are not overlapping with one of the groups.

4. Discussion

I studied the behavior and reproduction rate of 24 GPS collared free ranging female moose, comparing the method of using a drone to sneaking on ground by foot with an VHF-receiver. The drone detected 43 of 44 adult female moose and ground approaches detected 28 of 36 adult female moose. For my first prediction, I did find more calves with the use of drone versus ground approach, but only with one in difference. The drone found 15 out of 17 (88,2%) known calves, and the ground personnel found 14 out of 17 (82,4%) known calves. The results show little to no difference in detectability of calves and could change with more samples. My second prediction is supported, as the drone was much more time efficient than ground approaches with almost one sixth of the time spent on average. The drone used 17 minutes ±12-22 and the ground approaches 97 minutes ±26-244. In accordance with my third prediction, fewer moose were disturbed by the drone, and those that were disturbed fled shorter distances. None of the moose did run away when the drone was hovering for two minutes at a 100-meter altitude. Through the whole drone approach from 100 meters down to 20 meters hovering altitude, 14 out of 40 moose (35%) did respond with moving from the site with an average on 353 meters (95%CI: 172-725). For ground approaches, 22 of 37 (59,5%) adult females moved from the site during the approach with an average on 1420 meters (95%CI: 757-2665). For detecting the number of calves, lowering the drone to 20 meters will almost never be necessary, and hence, a high detectability can be reached with a much lower disturbance rate.

To my knowledge, no other studies have quantified how GPS-collared free ranging moose respond to a drone during and after an approach and compared it to behavioral responses to humans doing reproduction surveys from ground with use of a VHF-receiver.

There have been studies with GPS collared moose where they have studied the behavioral effect of skiing, the use of moose hunting dogs, and the effect of ground approaches for calf checking (Græsli, Le Grand, et al., 2020; Johnsen, 2013; Viljanen, 2019). In the following, I will discuss the weaknesses and strengths of using a drone as a tool for reproduction studies on GPS collared moose.

4.1 GPS-collar intervals and sending frequency

The study based the localization of moose on the positions sent from the GPS on the collar. After analyzing the data, a more frequent positioning schedule, preferably at 1-minute interval would be ideal to tell more precisely how far the individuals moved away from site if they got scared when using a drone. For the ground approaches, the reaction was more severe and would probably be detectable with 10-minute intervals and a changepoint analysis since they moved a lot longer over a short time. We also set the GPS collars to send every third position (30 minutes), and this position was what we used to localize the moose. If drone approaches are to be used in the future, it is not necessary to have 10-minute positions since we only got the third position sent to us in real time. The 10-minute positions in this study were only for analyzing the movement pattern.

Earlier years, doing ground approaches for reproduction studies on the same individuals have been done without changing the GPS positioning schedule. Only VHF-receivers have been used to localize the moose and is a lot cheaper relative to using the battery capacity and shortening the collar's battery life by having a positions recorded and sent more frequently. Shorter lifetime of the collar also means that in order to be able to follow the individuals through several years, we need to recapture them more often and this is costly.

Comparing the drone and the ground approach will be difficult since there are different trade-offs for both methods. For drone approaches, the advantages are that they are quick, give a good overview, few individuals get scared, and if scared they have a relative short fleeing distance compared to ground approaches, and it does not demand a lot of experience to do. The disadvantages are that they are costly due to a higher frequency of GPS positions recorded and that we are dependent of GSM coverage to let the collar send the positions and let the field personnel receive them.

Advantages of the ground approaches are that they do not consume more battery than normal from the GPS collar and do not require GSM coverage when using VHF-signals. The disadvantages are that trained personnel is needed to sneak close enough to determine if a moose has a calf in May/June, and this requires a lot of experience. Even with trained field personnel doing ground approaches, my results show that almost 60% of the moose chose to leave the site. Ground approaches also take a lot more time and will cost more if field personnel are paid by hour, but on the other hand they save money by not using battery capacity of the collar.

Summarized, the drone approach is faster, has less impact on the moose and could show signs of a higher detectability rate than the ground approach. It is also easier to teach someone to use a drone than having to teach someone to sneak up close to a moose unseen.

4.2 Monitoring calving success and calf survival

The drone is less disruptive than the typical approach for monitoring the calving success and calf survival. There have also been studies of the behavioral response of GPS collared free ranging adult moose during calf checking in the same area back in 2013, and our results only differ by 53 meters in fleeing distance (Johnsen, 2013, pp. 6–7). When calves are new-born and an easy target for predation, it is even more important to not disturb them. We do not know the survival rate of new-born calves when the mother runs away during a ground or drone approach, but we know from other studies when collaring calves with GPS or VHF collars (Ballard et al., 1981; Patterson et al., 2013; Severud et al., 2015), that 18,4% of the calves were left behind within 48 hours post capture (DelGiudice et al., 2015). A study also showed that disturbance by human towards elk from ground approaches during calving season decreases the calf-cow ratio (Phillips & Alldredge, 2000). If this is relatable to moose is unknown but could be likely.

As a response I used behavioral change as evidence of no disturbance by the drone. It is important to have in mind that animals can have an unseen response as heart rate changes or physiological stress that is not apparent in behavior towards drones (Ditmer et al., 2015). Other studies with drones have used the same method as this study and found no evidence of disturbance on elephants (*Loxodonta africana*) (Vermeulen et al., 2013) and penguins (*Pygoscelis spp.*) (Goebel et al., 2015).

4.3 Improving the drone platform

Based on my results the drone detected 92% of the calves at seventy meters hovering height and only 1 of 40 choose to walk away from site. The drone ''DJI Mavic 2 Enterprise Dual'' do have a digital zoom which helps the pilot to crop the picture/video when flying and works as a ''zoom''. This function does only work when recording in 1920x1080 resolution, and results in a bit grainy picture/video when cropping and looking for a calf at hundred- or seventy-meters height. To improve this, I would recommend using the exact same drone platform, but with another camera that support optical and digital zoom. The drone ''DJI Mavic 2 Enterprise **Zoom**'' has the same dimension, propellers, and software as the drone used in this study, but with the ability to zoom closer and still maintain a sharp picture (optical). This mean that the drone could hover at hundred meters altitude and zoom towards the moose and get the same picture the drone in this study got at lower altitudes.

This study detected thirteen single calves, two twin calves and missed two single calves. Where the two missed calves were during the drone approach is unknown, but likely close by. Some drones are equipped with thermal cameras. Thermal camera could aid the detection rate of calves if the drone have this option (McMahon et al., 2021). The drone used in this study had a thermal camera but was not used since it does not have a high enough resolution to detect moose at summer. There is also a challenge using thermal imagery at summer since the sun heats up rocks and other objects that absorb solar energy and would make a lot of disturbance for the pilot. There is software for automatic detection of moose when doing surveys like this, but solar energy could lead to false positive detections because of rocks, trees etc. (Chrétien et al., 2016; Dunn et al., 2002; Lethbridge et al., 2019). Therefore, it is limited to weather conditions but a good option to have.

4.4 Regulations and laws

According to Norwegian law and regulations for UAS (Unmanned Aircraft Systems) it is required for all operators to have an online theoretical exam and insurance. Operating the drone in this study required A1/A3 online course with an exam of 40 questions (Forskrift om luftfartøy som ikke har fører om bord, 2016, § 18). When the exam is passed, you are allowed to fly the drone maximum 120 meters above ground and within sight (VLOS - visual line of sight). To improve the study design and be more time efficient, flying BLOS (beyond visual line of sight) could in many cases reduce time used to get into five hundred meters range of the moose before take-off. Having the possibility to fly BLOS could mean that the pilot does not need to get close and in many cases fly from the car or other more convenient places for time efficiency, as long as it is within the range capacity of the drone. To be able to fly BLOS the operator needs further online courses and an risk assessment for this type of flying (Forskrift om luftfartøy som ikke har fører om bord, 2016, § 37).

4.5 Conclusion

Drones can replace traditional ground approaches for reproduction studies on GPS-collared free ranging moose. The results show higher time efficiency and less disturbance on moose with the use of drone in a period that is critical for calves that are dependent on the maternal care from their mother. The antipredator behavioral response towards the drone is lower than toward field personnel doing ground approaches, which should be emphasized. However, the study design of using drone is depending on GSM coverage, without high resolution in positioning intervals it would be difficult to conduct approaches by drone. Furthermore, the research goal will also be important when it comes to choosing type of method. If saving battery-life is of high value to the research project, drone approaches may potentially be too costly. An example could be looking at cow survival where you want the collar to work for a longer period, the cost of changing positioning interval could be too high. In summary; this is a context-dependent method and has pros and cons needs to be considered in the design of the study. Weather, GSM-coverage, economic cost, research goal and field personnel will be an important aspect to consider.

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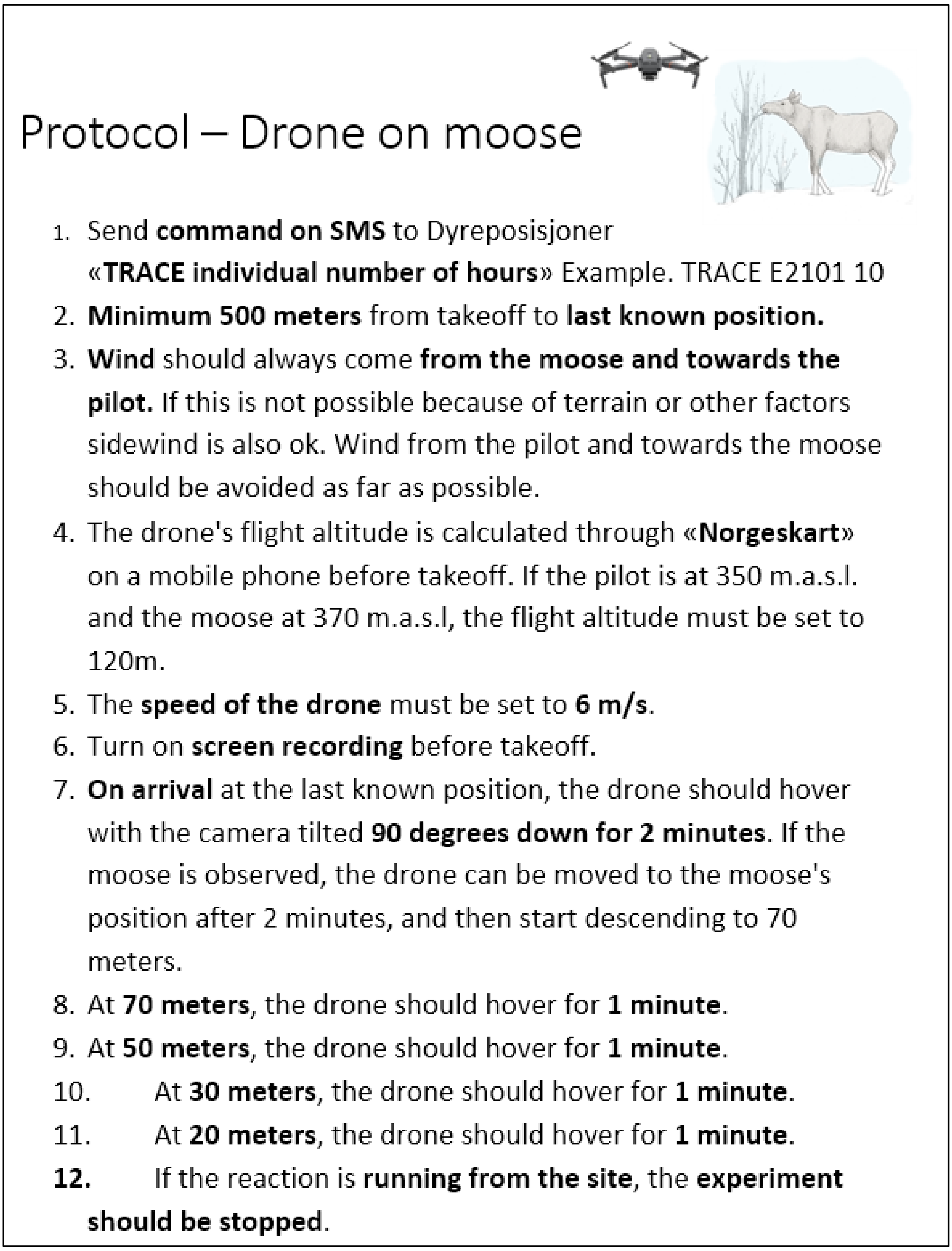
SUPPLEMENTARY

S1

S1. *Protocol for drone approach on GPS collared moose (Alces Alces).*



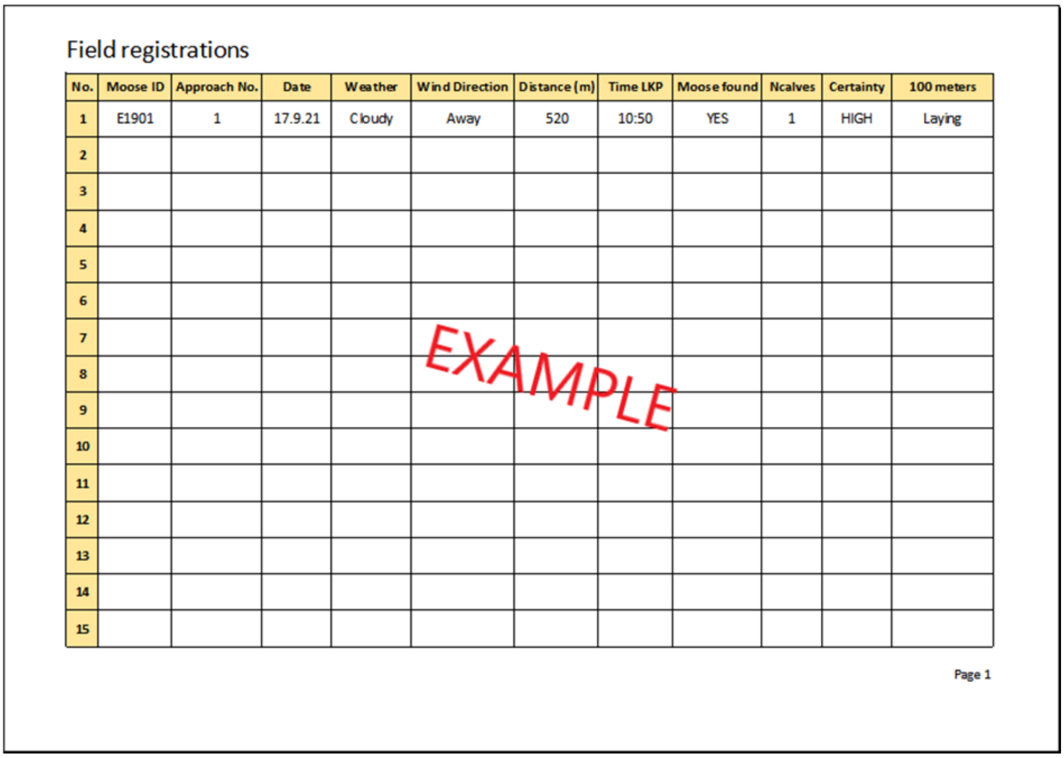
Protocol – Drone on moose

1. Send **command on SMS** to Dyreposisjoner «**TRACE individual number of hours**» Example. TRACE E2101 10
2. **Minimum 500 meters** from takeoff to **last known position.**
3. **Wind** should always come **from the moose and towards the pilot.** If this is not possible because of terrain or other factors sidewind is also ok. Wind from the pilot and towards the moose should be avoided as far as possible.
4. The drone's flight altitude is calculated through «**Norgeskart**» on a mobile phone before takeoff. If the pilot is at 350 m.a.s.l. and the moose at 370 m.a.s.l, the flight altitude must be set to 120m.
5. The **speed of the drone** must be set to **6 m/s**.
6. Turn on **screen recording** before takeoff.
7. **On arrival** at the last known position, the drone should hover with the camera tilted **90 degrees down for 2 minutes.** If the moose is observed, the drone can be moved to the moose's position after 2 minutes, and then start descending to 70 meters.
8. At **70 meters**, the drone should hover for **1 minute**.
9. At **50 meters**, the drone should hover for **1 minute**.
10. At **30 meters**, the drone should hover for **1 minute**.
11. At **20 meters**, the drone should hover for **1 minute**.
12. If the reaction is **running from the site**, the **experiment should be stopped**.

SUPPLEMENTARY

S2

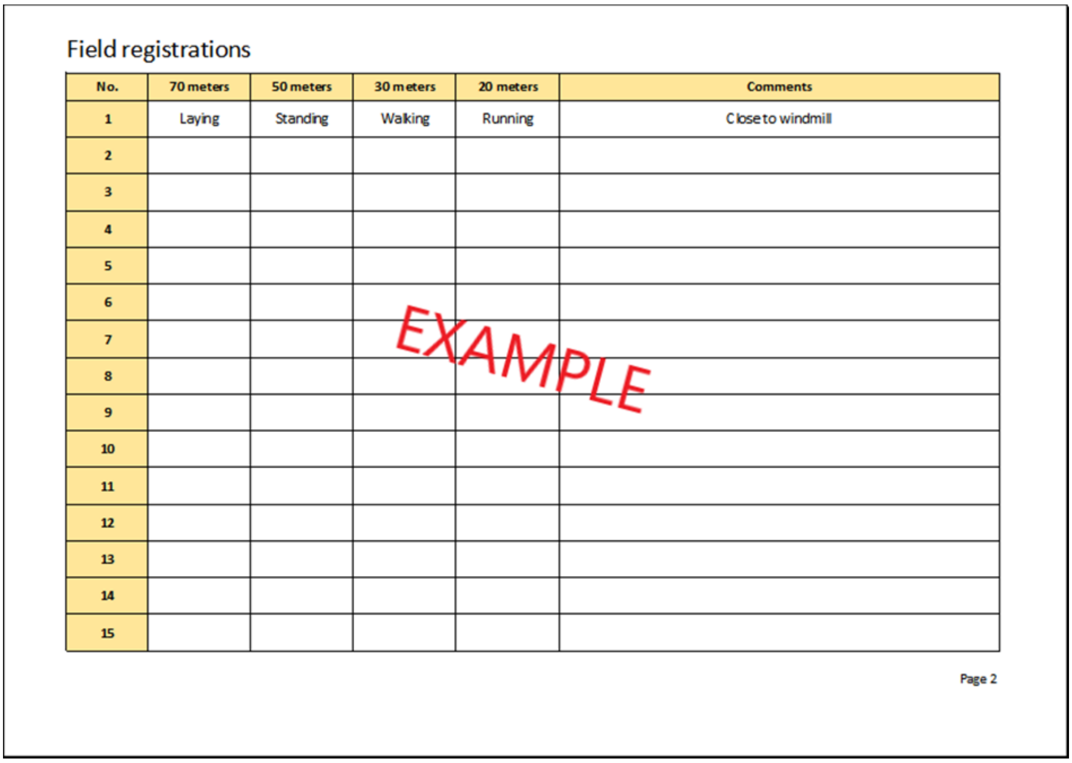
S2. Field schedule for drone approach.



Field registrations

No.	Moose ID	Approach No.	Date	Weather	Wind Direction	Distance (m)	Time LKP	Moose found	Ncalves	Certainty	100 meters
1	E1901	1	17.9.21	Cloudy	Away	520	10:50	YES	1	HIGH	Laying
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											

Page 1



Field registrations

No.	70 meters	50 meters	30 meters	20 meters	Comments
1	Laying	Standing	Walking	Running	Close to windmill
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

Page 2