D3.3 – Drone Operations Requirements for Digital Nature Conservation

WP3, T3.3 Drone requirements analysis

[Version 1.0 – 28/06/2024]

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WildDrone is an MSCA Doctoral Network funded by the European Union's Horizon Europe research and innovation funding programme under the Marie Skłodowska-Curie grant agreement no. 101071224.

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Technical References

Grant Agreement n°	101071224
Project Acronym	WildDrone
Project Title	Autonomous Drones for Nature Conservation Missions
Project Coordinator	Ulrik Pagh Schultz Lundquist, Professor University of Southern Denmark ups@mmmi.sdu.dk
Project Duration	January 2023 – December 2026

Deliverable No.	D3.3
Dissemination level*	Public
Work Package	WP3 – Effective Computer Vision for Conservation
Task	T3.3 – Drone requirements analysis
Lead beneficiary	FBK
Contributing beneficiary/ies	EPFL, FBK, WWU, UB
Due date of deliverable	30/06/2024
Actual submission date	28/06/2024

V	Date	Author(s)	Reviewers	Comments
0.1	20/06/2024	Fabio Remondino, Vandita Shukla	-	Report Writing
0.2	26/06/2024	Vandita Shukla	-	Assimilation of partner inputs
1.0	28/06/2024	Elzbieta Pastucha	-	Minor edits, submitted Version

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Executive Summary

The report aims to outline and summarize the drone requirements for data-acquisition based fieldwork. From the lens of Theme 3 innovation requirements, we address the data collection and drone-build specifics for maximal collaboration and data re-usability within WildDrone. We describe the Theme 1 project goals and scope, creating a context for the data needs that will contribute parallelly to advancements in the projects within Theme 3 for vision-based habitat and wildlife monitoring related tasks.

Keywords: data acquisition, wildlife monitoring, large-scale census, habitat analysis, pose estimation, tracking, path planning

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1. Introduction

1.1. Purpose, scope, and target group

This deliverable aims to identify drone operations requirements to maximize data acquisition efficiency for the PhD projects of Theme 3 "Effective Computer Vision for Conservation". The document is targeted to assist all doctoral candidates and supervisors in fieldwork and secondment planning for realizing maximum collaborative potential for effective computer vision in conservation practices. The findings of this report can be used also in the PhD projects of Theme 1 and 2. The requirements have been identified by considering the anticipated technical innovation goals of Theme 3 projects. Challenges and gaps identified from research literature review along with the latest project results form the groundwork outcomes of this deliverable.

1.2. Contributing partners

Did any partners contribute to this deliverable?

Table 1: Contribution of partners

Partner	Contribution
Syddansk Universitet (SDU)	Review and comments
Westfaelische Wilhelms-Universitaet de Muenster (WWU)	Review and comments
Fondazione Bruno Kessler (FBK)	Overall main text and contribution
Ecole Polytechnique Federale de Lausanne (EPFL)	Review and comments
University of Bristol (UB)	Review and comments

1.3. Relation to other activities in the project

Table 2: Relation to other activities in the project

Task	Description
Task 1.1	Fieldwork for Data Acquisition

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1.4. Delays and obstacles

N/A

1.5. Potential for dissemination, exploitation, and communication activities

The report mainly addresses and covers the planning and requirements of data acquisition activities within the WildDrone lifetime and their link to Theme 3 projects. This report can be useful for field work activities and possible review of data acquisition in the wild.

1.6. Ethical and security considerations

No ethical or security issues were encountered in preparing this report.

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2. Drone Operations Requirements for Theme 3 innovation goals

The doctoral projects of Theme 3 rely extensively on the quality and suitability of drone-based data acquisition in the field and the advancements in drone technology in various stages of research, including experiment design, software development and validation of results. Table 3 shows the link between the research focus of individual Theme 3 projects and the impact of drone elements from projects of Theme 1 and 2.

Table 3: Theme 3 PhD topics in relation to the other topics and themes.

		PROJECT NAME	**DC9**	**DC10**	**DC11**	**DC12**
Theme 1 Drone-based Data Acquisition	DC1	Livestock-Wildlife Interaction	X	X		
Theme 1 Drone-based Data Acquisition	DC2	Migration Analysis				
Theme 1 Drone-based Data Acquisition	DC3	Predator-Prey Response	X	X		X
Theme 1 Drone-based Data Acquisition	DC4	Coastal Monitoring	X		X	
Theme 1 Drone-based Data Acquisition	DC8	Real-Time Census	X		X	
Theme 2 Drone Design, Operations and Control	DC5	Calm Drones		X		
Theme 2 Drone Design, Operations and Control	DC6	Automated Planning	X			X
Theme 2 Drone Design, Operations and Control	DC7	Flexible Deployment			X	
Theme 2 Drone Design, Operations and Control	DC13	Mutualistic Drones	X			X

This deliverable covers only the data acquisition requirements linked to Theme 1, but this table additionally links Theme 2 collaboration possibilities. This is because projects within Theme 1 involve a fieldwork component which focuses directly on monitoring animals and their habitats and thus integrates into the Theme 3 data requirements. In contrast,

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innovation goals of Theme 2 are focused more on the facilitation of autonomous drone missions. The theme 2 fieldwork will be carried out by conducting trial flights for testing drone operations and the main goal will not be data acquisition but hardware centric. The doctoral candidates from Theme 3 will have the scope to conduct their own fieldwork for data acquisition and test onboard or offline performance of developed software. However, identifying drone operation requirements with respect to other themes will enable faster iterations from a collaborative and direct application standpoint.

In the following sections, data acquisition requirements are elaborated based on Theme 1 topics in order to better interlink Theme 3 activities with them and allow technological developments with end-users needs.

2.1 Drone-based Data Acquisition

2.1.1. Scouting Drones to Prevent Human-wildlife Conflict in Livestock Grazing Systems (DC1)

2.1.1.1. Project Goals and Scope

The population of the African Lion has been reducing critically and one of the major reasons is known to be retaliatory killings due to conflict with neighbouring human communities (Nicholson et al., 2023). The encroachment of habitat spaces, bushmeat poaching, trophy hunting and killings both preventative and in retaliation are some of the main causes for human-wildlife conflict. This conflict requires data and research to back-up the policies and methods with which the protection of lion species in harmony with human communities can be taken forward. A harmonious co-existence will have its roots in mitigating human-lion conflicts that arise due to lion predation on livestock (Robertson et al., 2020; Patterson et al., 2004). The potential of using drones to gain understanding on such conflicts is huge (Schad & Fischer, 2023). Using cameras on board of drones provides the benefits of cost-efficiency and researcher safety while creating scope for unobtrusive and widespread monitoring of animals to gauge underlying patterns. While drones are currently used to monitor wildlife populations and detect threats in anti-poaching efforts (Olivares-Mendez et al., 2015), their ability to study animal behavior in detail suggests that they could play a crucial role in shaping conservation strategies related to human-carnivore conflicts (Olivares-Mendez et al., 2015). By offering insights into carnivore habitat use and livestock responses to predator threats, drones may contribute to reducing conflicts such as instances of lions preying on livestock.

The outcomes of the project will focus on determining several key insights and firstly, lions' response to the presence of drones will be investigated to minimize disruptions and offer valuable recommendations for planning drone applications in biodiversity conservation. The data collection protocols for the remainder of the project will be informed by the insights gained from this primary investigation. The observability of lions from an aerial perspective across different habitats and times of the day, including nighttime, will be assessed to determine their aerial visibility. Patterns of lion distribution, combined with critical behaviors and nocturnal movements will be used to predict encounters with livestock herds. Cattle behavior will also be monitored (with geo-referenced locations through collars) using drones, to understand distribution of cattle

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relative to lion locations. This comprehensive approach will enhance the understanding of predator-prey dynamics, considering habitat variations and prey encounters.

2.1.1.2. Drone Operation Requirements

The detection and identification of African lions and their prey will be carried out using drone imagery, with species identification for all animals and individual identification for lions where feasible. The imagery also needs to be utilized to categorize the behavioral states of both lions and their prey which involves the understanding of posture. For lions, behavioral analysis will focus on their reactions to drone activity, employing posture tracking to ascertain head and body orientation (DC9). The drone flights therefore should be conducted from varying altitudes between 20-100m altitudes using multi-rotor equipped with RGB and/or thermal cameras. The flying height is also depending on the camera focal length and trying not to disturb the animals. The varying altitudes will help in determining the minimal flight height with efficient postural tracking with minimal disturbance. The project also aims at identifying the fine-scale movement behaviour and deciphering the behaviour patterns based on vegetation (density and height) which requires habitat reconstruction. For the landscape reconstruction (DC10), including vegetation height determination, oblique view flights will need to be conducted with GCPs for accurate metric measurements.

2.1.2. On the Wings of a Stork: Revealing the Dynamics of Soaring Environments (DC2)

n/a

2.1.3. Differences Between Responses of Prey to Predators and Humans (DC3)

2.1.3.1. Project Goals and Scope

Drones can help in deepening insights into the anti-predator behaviors of African herbivores while advancing technological applications in ecological studies. The primary objective of this project is to investigate the capabilities of African mammalian herbivores to scientifically underpin the differences between disturbances originating from natural predators and those induced by human activities. Utilizing drones and advanced deep learning techniques will provide an opportunity to create quantifiable insights in the consistency of individual variations in spatial behavior (Koger et al., 2023). The project therefore aims to incorporate drones for data acquisition and computer vision for analytical processing, leveraging cutting-edge technology to advance ecological research (Corcoran et al., 2021). The research will also examine how group size and composition affect these behaviors (Fryxell & Berdahl, 2018), focusing on the impact of the social environment and inter-individual interactions on predator-prey dynamics. Additionally, the study aims to assess the role of individual variability (del Mar Delgado et al., 2018) in movement behaviors to understand how specific traits affect predator detection, escape tactics, and risk assessment (Domenici et al., 2011; Domenici et al., 2011). The anticipated outcomes include significant scientific contributions and the development of sophisticated methodologies that will enhance both academic knowledge and practical wildlife conservation initiatives.

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2.1.3.2. Drone Operation Requirements

To accomplish project aims, drone flights should be conducted from varying altitudes between 60-100m altitudes using multi-rotors equipped with one or more RGB cameras. The data collection, from a collaborative point of view will co-facilitate the research of DC10 and DC12. Habitat reconstruction and landscape 3D modeling (DC10) for enabling creation of geo-referenced tracks through automated tracking (DC12) should be used to answer several of the research questions within this project including the effect of habitat complexity on predator-prey behaviour (Costa-Pereira et al., 2022).

2.1.4. Tracking Cetaceans in Coastal Areas (DC4)

2.1.4.1. Project Goals and Scope

Recent technological advancements, particularly in infrared imagery, offer innovative solutions for marine mammal research. Infrared cameras can enhance detection of marine mammals by capturing their thermal signatures, and potentially detect indirect signs like fluke prints. This project shall seek to advance technological methods for wildlife conservation and management by improving the use of drones and remotely acquired data to detect, identify, and track large aquatic mammals in challenging environments (Woolcock et al., 2022). Using machine learning models and multi-sensor systems, one of the primary goals will be to investigate new techniques for understanding the behaviour of these animals and mitigating human-wildlife conflicts. This research will explore the use of infrared-equipped drones for fine-scale identification and behavioural analysis of semi-aquatic species like hippopotamus, aiming for individual recognition and behavioural observations in natural and disturbed contexts (Inman & Leggett, 2022) (Lhoest et al., 2015). The potential combination of visual and acoustic sensors on drones for simultaneous above and below water monitoring will be examined for such species.

Drones have shown promise for non-invasive wildlife observation, yet their impact on animal behaviour varies by species and environment (Schroeder et al., 2020). Existing research has developed guidelines to minimize disturbance, such as recommended flight altitudes, but these are often context specific. Additionally, it remains unclear whether drone disturbances are consistent throughout the day and night, considering the varying natural soundscapes and lighting conditions. This project will also aim to fill this gap by investigating Burchell's zebras' tolerance to drones during both day and night using thermal imaging technology. As drone technology advances, especially with autonomous flight planning and real-time data processing, it becomes crucial to minimize disturbances. This project proposes also to develop a "detect and avoid disturbance" (DAAD) system, which would adjust drone flight paths in real-time based on animals' reactions, using 3D pose estimation and artificial intelligence.

2.1.4.2. Drone Operation Requirements

The drone flights shall be conducted from varying altitudes between 30-120m altitudes using multi-rotor equipped with RGB and/or thermal cameras. To understand behaviour, oblique viewpoint flights will provide for maximal computer vision-based insights.

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2.1.5. Drone-based Behavioral Studies and Abundance/Body Condition Estimates of Marine Mammals and Birds (DC8)

2.1.5.1. Project Goals and Scope

The significant technological advancements and increased availability of drones in recent decades have facilitated their use in monitoring and studying large terrestrial and marine mammals (Pollicelli et al., 2020). However, using aerial photogrammetry to measure smaller cetaceans, such as harbor porpoises, remains challenging. Moreover, the potential for drones in photo-identification has not been fully harnessed for many species (Vincent et al., 2001), where it could offer substantial benefits; one of these species being harbour porpoises (Elliser & MacIver, 2016). The PhD project will aim to address these gaps and to extend aerial photogrammetry techniques to harbor porpoises, evaluating their body condition and age class distribution. Accurate assessment of these parameters can provide crucial information on population health and demographics. Utilizing drones for this purpose can make monitoring less intrusive. Existing growth curves and body mass indices from porpoises in human care will guide this research. The study will test UAV photogrammetry's precision in measuring porpoises at the Fjord & Bælt facilities in Denmark, using three porpoises with regularly recorded physical measurements. Monthly drone flights at various altitudes will capture images throughout the year, allowing the estimation of length and width, which will be compared with direct measurements. This will help establish protocols for wild populations and large-scale census practices, focusing on precision, statistical biases, and potential calibration methods. Another element of this project will be to study the application of drones for the photo-identification of grey seals, by improving data collection in hard-to-reach locations and reducing animal disturbance. This study will investigate if drones can capture sufficient identifying features, often located on the throat, flanks, or underside. Initial research will use images of three captive seals to identify permanent features and their seasonal changes. Subsequent tests will determine the optimal drone settings for capturing these features in the wild, aiming to create a photo-identification database. Photo-identification will be extended to individual rhinos, zebras, and giraffes in Ol Pejeta Conservancy. This will be done by studying whether ground-based identification methods (features e.g., ear notches, horn shape) are discernible from drone footage. The study will develop protocols for image acquisition and create catalogs of individuals, potentially enhancing monitoring programs and behavioral studies. Overall, this project aims to validate drone-based photogrammetry and photo-identification techniques, develop practical protocols, and contribute to the broader use of drones in wildlife research. These advancements will support future collaborations in automating individual animal identification through computer vision.

2.1.5.2. Drone Operation Requirements

Automatized photo-identification will require high-resolution images of target animals from multi-view viewpoints with minimal disturbance. The drone flights will need to be conducted with oblique shots using RGB cameras at a flying height of 50-100 m, depending on focal length. Estimation of body condition metrics over certain fixed periods will also benefit from way-point based nadir data acquisition that ensures maximal repeatability of missions especially in controlled environments at Fjord & Bælt.

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2.2. Table Summarizing Drone Operation Requirements

Table 4: Drone Operations Requirements

	Project Name	Type of Drone	Sensors	Altitude Range(m)	Perspective	Stereo
DC1	Livestock-Wildlife Interaction	Quadrotor	RGB , Thermal	20-100	Nadir, oblique	yes
DC2	Migration Analysis		n/a	n/a	n/a	n/a
DC3	Predator-Prey Response	Quadrotor	RGB	60-100	Nadir, oblique	yes
DC4	Coastal Monitoring	Quadrotor	RGB, Thermal	30-120	Nadir, oblique	no
DC8	Real-Time Census	Quadrotor, Fixed-Wing	RGB	50-100	Nadir, oblique	yes

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3. Conclusions

This document lays out the primarily identified drone operations requirements for digital nature conservation mission through the lens of some PhD projects. The technological impacts of drones in the wild are multi-faceted and are thus planned to have an overarching contribution to the automation of wildlife conservation practices using drones. The reported operational requirements considered project aims although there could be some possible adjustment during field works due to unexpected situations typical of wild scenarios.

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