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ASSESSING THE EFFECTIVNESS OF THERMAL IMAGING AND UAV TECHNOLOGY FOR SUMMER WILDLIFE DETECTION

Rafal Frackowiak[1], Zdobyslaw Jan Goraj [2]

[1]Department of Aircraft Design, Warsaw University of Technology, Warsaw, Poland
[2]Department of Aircraft Design, Warsaw University of Technology, Warsaw, Poland

Abstract

The paper presents the results of practical tests of an UAV aggregated with a thermal imaging camera for detecting animals in forested areas during the vegetation season (specifically in summer). The study focused on estimating the likelihood of detecting eurasian elk, red deer, european roe deer, and eurasian wild boar.

The UAV's flight altitude was 80 meters above ground level, providing a ground sampling distance of 7 cm. The tests were conducted between June 4 and September 26, 2022. A total of 21 flights were completed, covering a surveyed section approximately 110 kilometers long. The width of the inventoried transect was approximately 45 meters. Based on the total length of the route, the surveyed area was approximately 495 hectares, representing around 7% of the forested area in the Czarna Białostocka sub-district, where the research was conducted.

In conclusion, the results indicate that summer is not the optimal time for conducting animal inventory flights. This is evidenced by the fact that approximately 60% of all thermal signatures detected by the observer could not be attributed to specific species. The dense tree foliage during this season likely contributed to this challenge. It's also important to highlight that the forest habitats in the study area are highly fertile, featuring not only a canopy of trees but also thick undergrowth and second-growth forests, which can suppress the heat radiation emitted by animals. In less fertile areas, where understory vegetation is absent and the tree cover is primarily composed of coniferous trees (which have foliage year-round), the season of observation may have less impact on data quality.

Keywords: Animal detection, UAV, Hexacopter, Thermovision

1. Introduction

The range of technologies currently employed in nature conservation is remarkable, with many modern applications being adapted from other fields and tested in real-world environments. Among these, Unmanned Aerial Vehicles (UAVs) are becoming increasingly popular [15]. UAVs are now widely used across various sectors, including natural resource inventory.

Data collected using UAVs, when combined with specialized equipment, is often more accurate than that obtained through traditional ground-based surveys. UAV-based surveys also tend to be less stressful for animals compared to conventional methods [4, 22]. Even in ground-based inventories, monitoring multiple species presents challenges, as different animals typically require distinct monitoring techniques. It is crucial to consider the behavior of the species being surveyed [11]. Before undertaking a population survey, it is essential to establish both the purpose of the inventory and the manner in which the data will be applied [10]. In addition to direct methods, such as counting individual animals, indirect methods can also be employed to detect their presence [7, 8, 23]. These indirect methods do not require directly seeing or hearing the animal but involve identifying traces of their presence, such as tracks or droppings. The use of UAVs for estimating animal populations is generally considered a direct method, as the goal is often to detect individual animals. However, this is not always the case.

UAVs equipped with cameras operating outside the visible light spectrum can enhance the effectiveness of wildlife surveys [2]. Thermal sensors, for instance, detect temperature differences between the target and its surroundings [16]. The use of thermal imaging cameras (TIR) on drones is particularly effective for wildlife detection, as these cameras capture heat emitted by animals, unlike traditional cameras, which rely on visible light reflected from objects. The key factor in utilizing thermal imaging is the animal's body temperature being higher than its environment (thermal contrast). While atmospheric distortions may occur when measuring temperatures from UAVs, these distortions are typically negligible at low altitudes [1], which is significant when using UAVs equipped with thermal imaging.

Efforts are underway to automate the analysis of images for animal detection. Research indicates that automatic detection using RGB sensors on UAVs is highly feasible for large species inhabiting open, homogeneous environments with minimal vegetation or topographic variation. Infrared sensors, integrated with multi-rotor UAVs, are more effective for detecting smaller, elusive species in complex habitats. Corcoran et al. provide valuable insights into this subject [6].

During the summer season, the presence of foliage and undergrowth can limit the detection of animals [21]. The readability of thermograms is also affected by wind, which not only impedes UAV flights but also lowers the animal's body temperature by reducing thermal contrast. This makes it difficult to detect animal signatures in thermal images and videos [20]. A significant challenge in using UAVs for wildlife observation is that animals often seek shelter under vegetation [12, 18], which can block emitted radiation. However, precise temperature readings of the entire animal are not necessary for detection; it is sufficient for the animal to appear as a hotspot against the cooler background [5].

UAV imagery is not the only useful tool for animal detection. Camera traps also play an important role in this process [13, 14]. The automation of species identification using camera traps shows promising results [3]. With camera traps (whether ground-based or tree-mounted), individual animals are more likely to be identified using deep learning or YOLO algorithms, as camera traps have the advantage of capturing the full figure of the animal, unlike UAVs, which typically provide an overhead view. Consequently, automatic species identification is expected to be more challenging with UAV images than with photos from camera traps. There is significant potential in automated object detection, though no current algorithm is yet fully applicable. For instance, research by Chao Mou et al. [17] on real-time animal detection yielded encouraging results, but theirs study (according to the article) was limited to species found in open or sparsely wooded areas, so the method may not be applicable in other environments.

The proportion of fertile habitats in the area is also relevant, as these habitats typically support dense canopies and substantial ground cover. Additionally, the structure of forest stands in such areas is often more complex, with dense upper-storey canopies and significant understorey vegetation. An interesting study by Pagacz et al. examined the degree of ground cover by tree and shrub canopies during the winter period [19].

1.1 Definitions, acronyms and abbreviations

Definitions, acronyms and abbreviations

AGL = Above Ground Level;
GSD = Ground Sampling Distance;
RGB = Red-Green-Blue;
UAV = Unmanned Aerial Vehicle.

2. Research site and main research interest

UAV tests with a thermal imaging camera were conducted in the Czarna Bialostocka Forest District during the summer of 2022. These tests of the unmanned aerial vehicle are a continuation of the research previously described by the authors [9]. For the 2022 summer season discussed in this article, the flight methodology was modified compared to earlier seasons

2.1 Purpose

The aim of the study was to assess the usefulness of thermal imaging camera data collected from UAVs during the summer for detecting wildlife in forested areas. The research focused on the following species: red deer, eurasian elk, roe deer, and wild boar.

2.2 Research area – Czarna Bialostocka Forest sub-district

The Czarna Białostocka area was selected as the research site. The Czarna Białostocka precinct covers approximately 6,980 hectares. Figure 1 shows selected flight transects within the Czarna Białostocka precinct, where the flights were carried out.

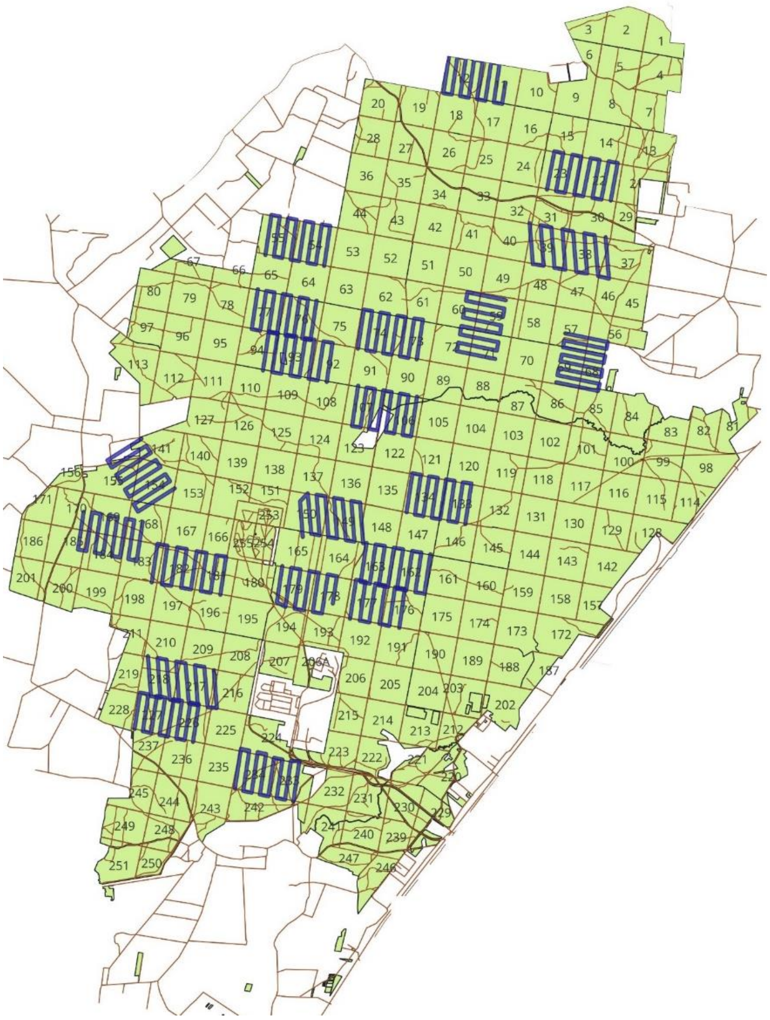

Figure 1 – Selected flight transects (marked in blue) in the Czarna Białostocka precinct of the Czarna Białostocka Forest District, where research flights were conducted

2.3 Equipment

The selected equipment included the following:

a) E20Tvx, Yuneec:

Justification: The camera's low viewing angle (33° x 26.6°) allows for the acquisition of high-quality images due to the smaller Ground Sample Distance (GSD) compared to cameras with a larger viewing angle. Additionally, it offers high sensitivity and a high-resolution thermal sensor matrix (650 x 512). Nevertheless, it should be noted that there are cameras of much higher quality then the one used in this study. However, some of mentioned cameras may by used only under military restricions.

b) Hexacopter Yuneec H520E:

Justification: This UAV was chosen for its compatibility with the selected camera.

2.4 Flight conditions

The flights were conducted during the summer season, from June 4 to September 26.

Additional flight conditions included:

• one battery was used per mission, with no battery changes during a single mission,

• the centres of adjacent transects were spaced 120–150 metres apart,

• flight altitude was maintained at 80 metres above ground level (AGL),

• horizontal flight speed was set at 10 m/s,

• the take-off and landing site for the multi-rotor was located at least 200–300 metres from the surveyed area to minimise the impact of noise on the animals being inventoried,

• the survey area was inventoried starting from the point nearest to the operator and progressing through the surveyed area.

3. Findings

A total of 21 flights were completed, covering a surveyed section approximately 110 kilometres in length (Table 1). Based on the horizontal field of view of the thermal imaging camera (33°) and the flight altitude (80 metres AGL), the width of the inventoried transect was approximately 45 metres. Given the total length of the route, the surveyed area covered approximately 495 hectares, representing around 7% of the forested area in the Czarna Białostocka sub-district.

As a result of all 21 UAV flights, only one red deer was detected. No moose were identified during the summer flights. Based on tests conducted in previous seasons, it can by stated that the quantity of animals detected during summer perioid is low [9]. Six european roe deer and seven eurasian wild boar were detected. However, it is important to note that previous tests have shown that the equipment used did not provide reliable identification of these species (european roe deer and seven eurasian wild boar) [9]. A total of 21 thermal signatures were recorded but not classified. Approximately 60% of all thermal signatures detected by the observer could not be attributed to specific species. The main reason for the inability to identify the species was dense vegetation. A summary of the number of recorded individuals is presented in Table 2.

Table 1 Summary of flights conducted during the summer of 2022

Date	Start time	End time	Duration of the mission	Flight speed	Approximate flight location - Inventory branches		Length of the inventoried route	Number of infrared photos	Sunrise	Sunset	Wind speed	Cloud cover	Precipitation	Temperature
-	UTC time		min.	m/s	-		m	no	UTC time		m/s	%		C
04.06	20:06	20:18	12	10	22	23	5 240	736	02:02	18:48	5	100	lack	16
	20:30	20:44	14		38	39	5 661	793						
05.06	19:15	19:25	10		176	177	4 006	549	02:02	18:49	3	3		15
	20:04	20:18	14		181	182	5 321	728						
	20:48	21:01	13		217	218	5 411	743						
06.06	19:14	19:29	15		149	150	5 386	726	02:01	18:50	5	100		18
	19:43	19:56	13		178	179	4 469	602						
	21:06	21:22	16		92	93	5 349	737						
13.09	15:08	15:23	15		162	163	5 379	653	03:56	16:48	4	3		13
	15:26	15:41	15		133	134	5 386	656						
	16:23	16:37	14		233	234	5 355	689						
14.09	17:18	17:31	13		54	55	5 389	692	03:58	16:45	5	70		12
	17:40	17:54	14		76	77	5 362	715						
	18:54	19:08	14		154	155	5 554	736						
16.09	17:48	18:00	12		68	69	5 539	741	04:01	16:41	9	42		11
	18:05	18:18	13		59	71	5 231	690						
	19:15	19:29	14		226	227	5 085	669						
17.09	16:43	16:56	13		73	74	5 307	681	04:03	16:38	8	64		12
	16:58	17:11	13		106	107	5 383	662						
	18:00	18:13	13		11	12	4 936	639						
26.09	16:44	16:57	13		169	184	5 256	732	04:19	16:16	3	32		13
Total							**110 005**	**14 569**						

Table 2 Summary of flights conducted during the summer of 2022

Date	european roe deer	red deer	eurasian wild boar	eurasian elk	not marked	**Sum**	Approximate flight location		**Inventoryed area (surface)**
	number of individuals						numbers of divisions		ha
4 VI						**0**	22	23	23,58
					1	**1**	38	39	25,47
5 VI			2		1	**3**	176	177	18,03
						0	181	182	23,94
			1		2	**3**	217	218	24,35
6 VI					2	**2**	149	150	24,24
						0	178	179	20,11
						0	92	93	24,07
13 IX					3	**3**	162	163	24,21
					1	**1**	133	134	24,24
			1			**1**	233	234	24,10
14 IX	2					**2**	54	55	24,25
	4	1			1	**6**	76	77	24,13
					4	**4**	154	155	24,99
16 IX					0	**0**	68	69	24,93
					1	**1**	59	71	23,54
					2	**2**	226	227	22,88
17 IX						**0**	73	74	23,88
			2		3	**5**	106	107	24,22
						0	11	12	22,21
26 IX			1			**1**	169	184	23,65
Sum	**6**	**1**	**7**	**0**	**21**	**35**			**495,02**

The only instance of a recorded red deer is presented in Figure 1. The results from the summer UAV flights are considered less effective compared to those from previous seasons [9].

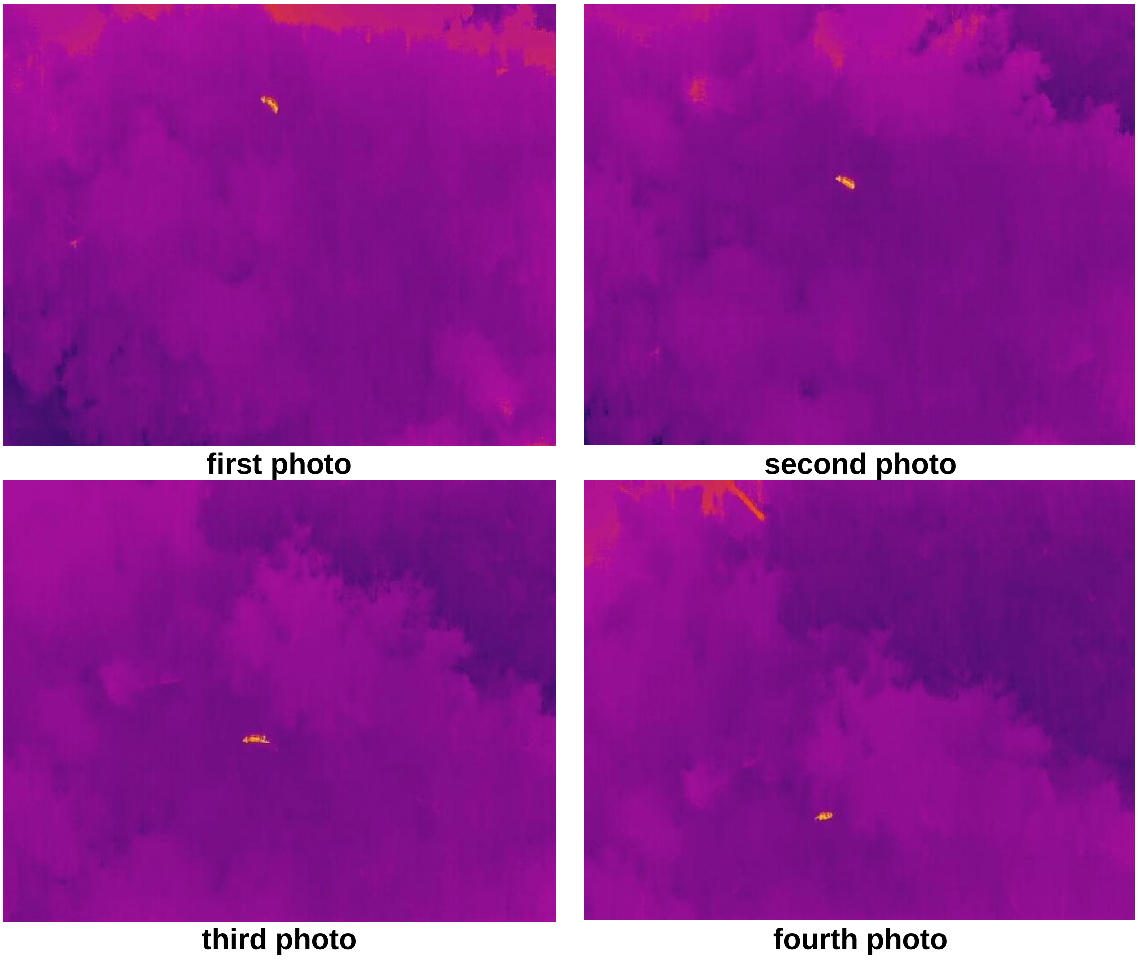

Figure 2 – Red deer recorded with a thermal imaging camera on September 14, 2022, during the second mission completed that day.

Examples of unrecognizable signatures are shown in Figure 3. The sample photos are from September 14 (a) and September 26 (b).

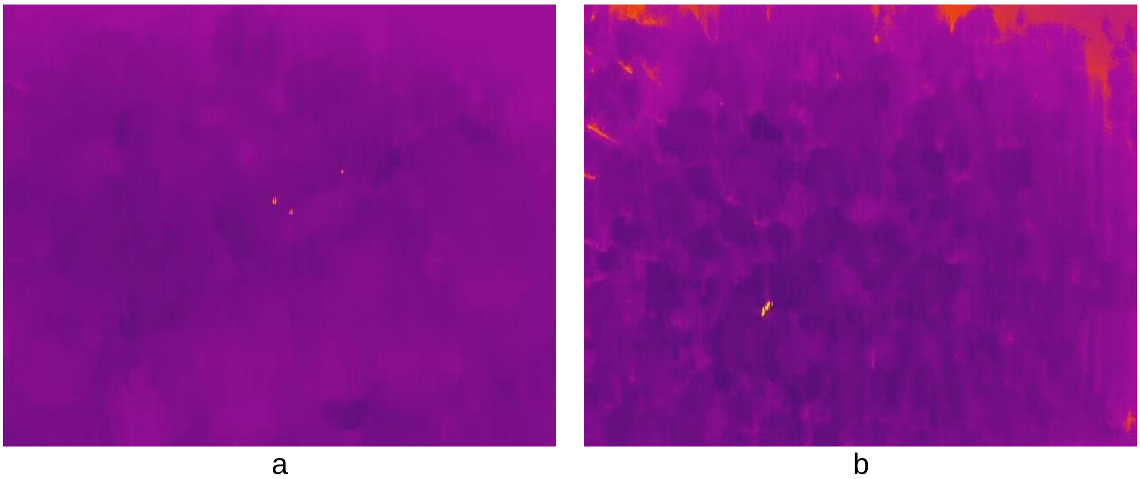

Figure 3 – Heat signatures detected that were not assigned to a species
(a - 14 September, b - 22 September)

4. Discussion. Why the effectiveness of summer flights is so low?

According to Figures 4 and 5, it can be observed that most of the inventoried area was located in forest habitat types classified as mixed broadleaved (LM) and broadleaved (L) forests, covering approximately 76%. Together with the forest habitat type Mesic mixed coniferous (BMśw), where undergrowth is also often present, this accounted for around 97% of the total area. The dense and expansive tree canopies, together with the presence of understorey vegetation, account for the invisibility of animal heat signatures in the images taken by the UAV. It may be the case that in less fertile areas (coniferous habitat types), summer flights could be as effective as those conducted later in the autumn (after leaf fall) or in winter.

The forest habitat classified as "not specified" (Figure 5) includes elements such as fragments of forest roads, open areas directly adjacent to forests, small patches of private forest, or forest fragments for which there is no habitat types layer on the digital map used for spatial analysis (minor inconsistencies in the boundary lines of vector layers representing forest divisions and habitat types). We emphasize that the mentioned errors are negligible.

SOIL FERTILITY GRADIENT →

SOIL MOISTURE GRADIENT ↓

Moisture groups of forest habitats	Fertility (trophic) groups of forest habitats			
	CONIFEROUS (B)	MIXED CONIFEROUS (BM)	MIXED BROADLEAVED (LM)	BROADLEAVED (L)
DRY	Dry coniferous Bs	-	-	-
MESIC	Mesic coniferous Bśw	Mesic mixed coniferous BMśw	Mesic mixed broadleaved LMśw	Mesic broadleaved Lśw
MOIST	Moist coniferous Bw	Moist mixed coniferous BMw	Moist mixed broadleaved LMw	Moist broadleaved Lw
SWAMP	Swamp coniferous Bb	Swamp mixed coniferous BMb	Swamp mixed broadleaved LMb	Alder Ol
FLOODPLAIN	-	-	-	Riparian Lł \ Alder-ash OlJ

Figure 4 - Percentage of forest habitat types over which a drone inventory was carried out (range from 0,03 % to 43 %)

The analysis of forest habitat types over which UAV flights are conducted is particularly important during the growing season, as more fertile habitats often have a more complex vertical forest structure. In single-storey stands within fertile habitats, the ground may also be covered by dense, expansive tree crowns (e.g. hornbeam). The thermal radiation detected in infrared images is suppressed not only by the upper canopy layer but also denser thickets than those found in poorer habitats. However, in this study, no detailed analyses were carried out on the impact of tree crown coverage on the results of game detection. In future research, this is undoubtedly a factor that should be included in the analysis, as it is directly linked to the probability of detecting animals. Many other parameters should be considered, such as the height and age of the growing vegetation. The matter is further complicated by the fact that in the conditions of larger forest complexes, we are not able to determine the exact number of animals. There is no precise method, even a laborious one, that would allow obtaining accurate, reliable reference data.

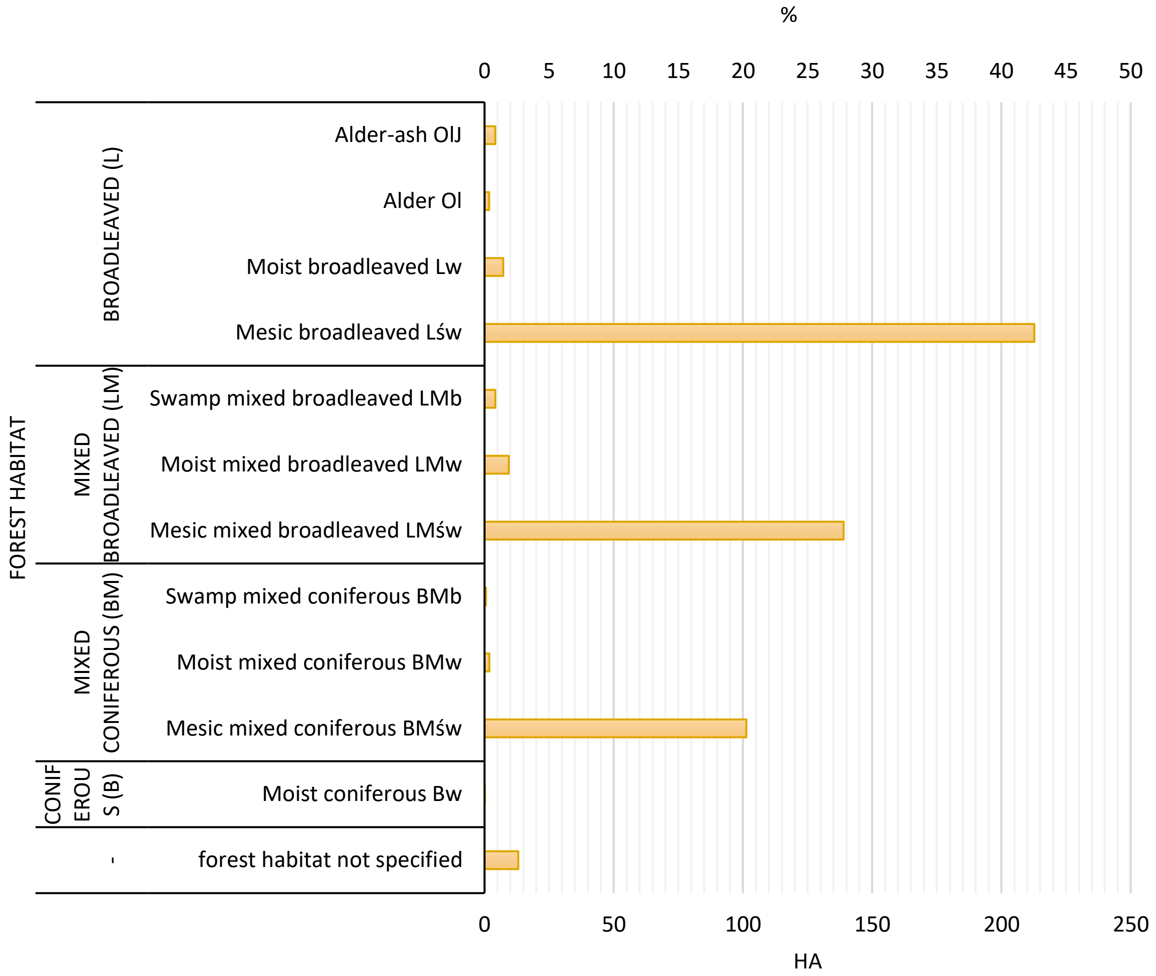

Figure 5 - Percentage of forest habitat types over which drone surveys were conducted

In addition, it should be emphasized that the equipment used is commercially available. With a higher-quality thermal imaging camera, the results would certainly be much more satisfactory (e.g. clearer thermal signatures). The hardware solution used here should rather be considered affordable.

5. Contact Author Email Address

Rafał Frąckowiak can be contacted at: rafal.frackowiak93@wp.pl

6. Copyright Statement

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