The Applicability of Thermography During the Breeding Season and Early Nursing in Farmed Fallow Deer

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ABSTRACT

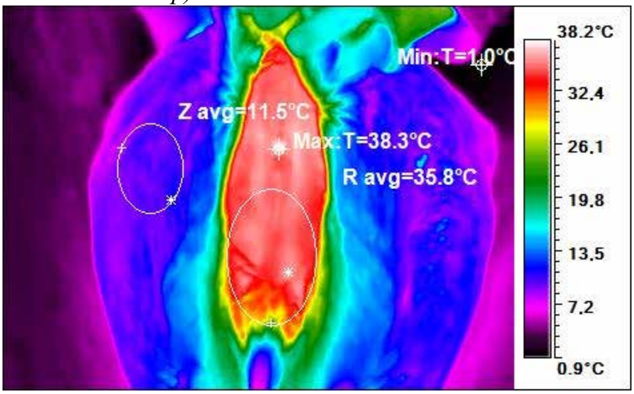
To get to know the health condition of cervids often requires the use of other diagnostic methods than those used in other farm animals. The aim of this study was to determine the applicability of thermal imaging in different stages of the breeding season and during early nursing in farmed fallow deer does and fawns. The study was carried out at a cervids farm in north-eastern Poland, where around 200 fallow deer are kept. A ThermoPro TP8 thermographic camera was used.

The results of the study demonstrated that thermal imaging supports oestrus detection, but with significant limitations. Thermal imaging does not support early pregnancy detection in fallow deer. Temperature differentials between the examined body parts are reliable indicators of pregnancy only in the last trimester when foetal development is most rapid. Thermal imaging is a potentially useful non-invasive method for studying lactation in cervids, and can be applied to monitor lactation stages in farmed cervids, but only those that are tamed. This method is also potentially useful for localising hiding fawns in farms, but only when the observations are carried out at a distance of up to 20 m.

INTRODUCTION

In farmed and wild animals, thermal imaging is used to diagnose disorders of locomotive organs[16,17], in particular lameness in horses[10, 43] and dairy cattle[1, 33,] to detect early signs of viral and systemic infections[8, 9, 36, 37, 44] in order to assess animal welfare levels[22, 40, 41], analyse the processes by which animals regulate their body temperature[21, 23, 24, 26, 39, 45], observe animal behavior[18, 25, 32, 35], investigate animal responses to various treatment regimes[6], and evaluate animals raised for meat.30 In cervids, thermal imaging methods are also applied to observe changes in antler temperature during growth.[3,5]

***Figure 1**. Thermogram of a doe's rump acquired on 8 November 2011 (Min:T – minimum temperature, Max:T – maximum temperature; Ravg – average temperature of the marked area; Zavg – average temperature of the control area on the rump).*



Thermal imaging systems are also used in research studies investigating the reproduction of farmed and wild animals. The physiological processes linked with oestrus, pregnancy, spermatogenesis, and ejaculation are energy consuming, and they require the supply of additional nutrients and oxygen via the bloodstream. The areas of the body where these processes are intensified emit heat. Thermal imaging devices measure differences in temperature between body organs, and can be used to control reproductive processes in farm animals.[27]

The aim of this study was to determine the applicability of thermal imaging in different stages of the breeding season and during early nursing in farmed fallow deer does and fawns.

MATERIALS AND METHODS

The study was carried out in a cervid farm of the Institute of Parasitology of the Polish Academy of Sciences in Kosewo Górne (north-eastern Poland; N: 53°48'; E: 21°23').

The ThermoPro TP8 thermographic camera, a Forward Looking Infrared (FLIR) device with an uncooled FPA microbolometer array, 384x288 pixels, 35 µm, was used. The camera had thermal sensitivity of 0.08°C to 30°C and measurement accuracy of 1±°C or ±1%. Emissivity was set at ε=0.98, which corresponds to the emissivity of bare skin or skin covered with dry fur.[2, 25] Images were also acquired with the use of the Canon EOS 550D digital camera for comparison with thermal images, which is a recommended procedure in thermal imaging.[27] Thermal images were analysed in the Guide IR Analyser programme (v. 2010-04-05).

The results were used to determine the applicability of thermal imaging for detecting oestrus and pregnancy, monitoring lactation and localising hidden fawns.

Oestrus Detection

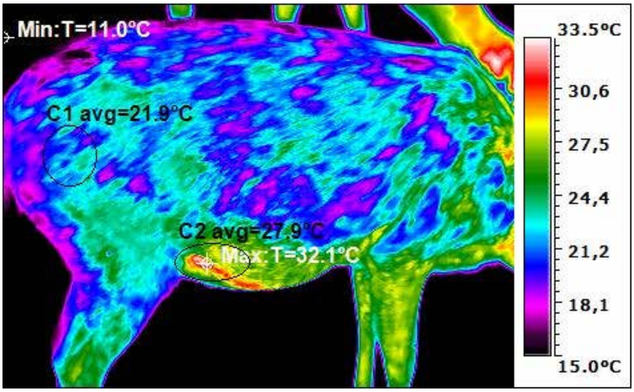
The applicability of thermal imaging for oestrus detection was evaluated on 8 November, 2011, and 17 November, 2011, in an animal handling facility where does were immobilised in a crush. Thermographic measurements were performed from a distance of around 1 m from the rump. The tail was held up during the procedure to expose reproductive organs. The average temperature in the area of the reproductive organs (R) (excluding the anus) and the average temperature on the surface of the hair coat on the rump (Z) as the control value were measured. Measurements were performed by ellipse fitting.[3, 28] Maximum and minimum temperatures were indicated in each thermogram. An exemplary thermogram is presented in Figure 1.

Pregnancy Detection

Thermograms for pregnancy detection were acquired regularly between 25 January and 13 July 2012, in weekly intervals on average (a total of 14 diagnostic days). Thermal images were acquired before sunrise and after sunset or during the day on cloudy days, from a distance of around 1.5 m.

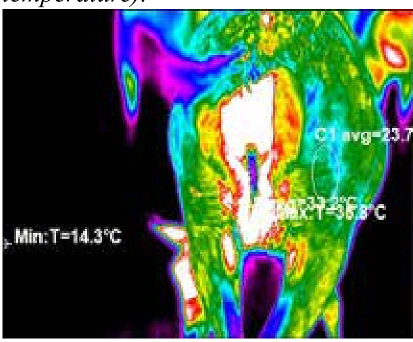
A total of 133 thermograms acquired on 14 diagnostic days and depicting the right flank of pregnant females were used in analysis. The underbelly area (B) and

***Figure 2.** Thermogram of a doe's right flank, acquired on 23 May 2012 (B avg – average temperature of the marked underbelly area; Z avg – average temperature of the marked rump area; Min:T – minimum temperature; Max:T – maximum temperature).*



the rump control area (Z) were marked in thermograms by ellipse fitting. The average temperature in the analysed areas was measured (Fig. 2) using the earlier methods.[3, 28] Differences in the average temperatures of the underbelly and the rump from three measurements were calculated. The observed changes in the average underbelly and rump temperatures were analysed in different stages of pregnancy (different thermogram dates) in view of average ambient temperature (measured by the thermographic camera) on the day of the measurement.[3]

***Figure 3.** Thermogram of the rump area acquired on 8 August 2012 (W – average temperature of the udder area; Z – average temperature of the rump area; Min: T – minimum temperature; Max: T – maximum temperature).*



Lactation Control

Lactation was monitored with the use of thermograms acquired between 15 May and 15 August 2012 in weekly intervals (a total of 14 diagnostic days). Thermograms of the rump area were acquired before sunrise or in the evening, when the tail was raised to expose the reproductive organs. Thermographic measurements were performed from a distance of 0.5-1.0 m.

A total of 153 thermograms of the rump area acquired on 14 diagnostic days were used in analysis. The average temperature of the udder area (U) and the rump control area (Z) was measured (Fig. 3). Differences in the average udder and rump temperatures from three measurements were averaged, and the results were analysed in view of the day of measurement (lactation stage) and average ambient temperature registered by the camera on the day of the measurement.

Localisation of Hidden Fawns

Hidden fawns were localised with a thermographic camera between 15 June and 15 August 2012, and in June 2013 and June 2014. Thermograms were acquired before sunrise, in the evening or during the day on cloudy days. Farm enclosures were scanned

***Figure 4**. Thermogram of a farm enclosure, acquired on 29 June 2012, depicting a potential fawn hiding site (K) (K: T – temperature in a potential hiding site: Min: T – minimum temperature; Max: T – maximum temperature).*

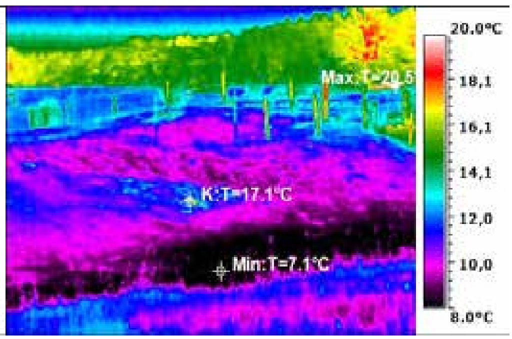


Table 1. Temperature measurements performed during oestrus [°C]

Doe	8 November 2011				17 November2011				Difference 2-1
	R1	Z1	Difference1 R-Z	Ambient	R2	Z2	Difference R-Z	Ambient	
2	35.8	11.5	24.3	10	36.7	9.8	26.9	9.2	2.6
25A	36.6	11.1	25.5	10.3	36.3	10	26.3	9.1	0.8
27A	37	13.2	23.8	10.2	38	10.2	27.8	9	4
198	35.5	9.6	25.9	10.1	37	8.9	28.1	9.1	2.2
287	36.7	10.3	26.4	10.5	38.2	x8.7	29.5	9.3	3.1
785	36.7	10.3	26.4	11.7	37.8	9.8	28	9.1	1.6
Average	-	-	-	10.5	-	-	-	9.2	2.4

localised with a thermographic camera.

Temperature was measured in locations identified as potential hiding sites. The effectiveness of thermal images was compared with digital images to determine whether the warm spots identified in thermal images were fawns or heated objects, such as stones or soil.

Statistical Analysis

Thermographic data were compiled in spreadsheet tables and analysed by calculating temperature differentials between reproductive organs and the control area, and by comparing the results with average ambient temperature registered by the thermographic camera on the respective measurement days. The results were analysed statistically in the Statistica v. 10 programme by computing a matrix of correlations between temperatures measured in the underbelly area and the control area vs. ambient temperature

RESULTS AND DISCUSSION

Oestrus Detection

Thermograms of the reproductive organs of fallow deer does were acquired on 8 November and 17 November 2011. The difference between the average temperatures in the area of the reproductive organs (R1, R2) and the control area on the rump (Z1, Z2) was greater during the second measurement by 2.4°C on average (Table 1).

In does, an increase in the temperature of the reproductive organs could point to oestrus or its onset.[15, 17, 19, 38, 42] In all females, the difference between the temperature of the reproductive organs and the control area was greater during the second measurement, which could be partially attributed to lower ambient temperature (by 1.3°C) on that day. The above contributed to greater differences in the temperature of bare skin, in particular in bodily crevices, less exposed areas (underbelly, groin, area under the tail) and fur-covered skin in exposed areas (back, rump, flanks, limbs).[3]

The results indicate that thermal imaging supports oestrus detection in cervids, but with certain limitations. For oestrus to be effectively detected in farmed fallow deer, thermal images of the reproductive organs have to be acquired from a small distance. Therefore, the degree of animal tameness is a very important consideration. Thermographic measurements should be performed daily over a period of several days to produce the most reliable results. For this reason, thermal imaging can be particularly useful in small animal farms and zoos where the animals are relatively tame. The method proposed in this study could also be applied to diagnose hidden oestrus and fertility problems in farmed does. In large cervid farms where animals are relatively untamed, thermographic detection of oestrus could be more difficult for practical reasons. In such locations, the discussed technique requires herding, capturing and immobilization, which could decrease the animals' welfare and require greater effort on behalf of farm personnel.

Table 2. *Average differences in temperature (T) between the underbelly (B) and the control area (Z) in pregnant fallow deer does [°C].*

Date of measurement	Temperature differences (B-Z) in does				Average ambient T
	2	3	neo 3605	neo 11202	
25 January	-1.4	N/A	N/A	N/A	9.9
20 March	-0.4	-1.2	-1	-1.2	11.2
4 April	0.8	0.2	0.1	1.1	7.0
26 April	1.4	3.4	1.7	1.5	17.0
9 May	6.6	4.0	3.6	4.7	19.0
15 May	9.2	2.9	7.6	6.2	14.5
23 May	7.4	9.1	7.7	9.1	20.5
3 June	3.9	-2.2	3.5	1.8	18.2
6 June	3.4	1.5	2.5	2.4	15.3
15 June	3.4	-2.0	6.0	5.6	20.9
22 June	2.6	3.1	3.6	2.5	20.7
4 July	0.9	2.3	2.9	2.4	22.3
13 July	N/A	2.8	2.3	2.6	20.1

Thermal imaging is a non-invasive diagnostic method which does not compromise animal welfare, therefore, it should be researched in greater detail. Similar conclusions were formulated by authors who used thermal imaging devices to detect oestrus in cattle,[15, 19, 42] pigs,[38] Asian elephants, and black rhinoceroses.[17]

Pregnancy Detection

Thermal images of the flanks of pregnant and postpartum does were used to calculate changes in temperature between the underbelly area (B) and the control area on the rump (Z) (Table 2). Between 25 January and 9 May, temperature differentials between the above areas continued to increase steadily and ranged from -1.4°C to 6.6°C. The average ambient temperature registered by the thermographic camera in the above period ranged from 7°C to 19°C. Temperature differentials between the analysed areas were greatest from 9 to 23 May, ranging from 3.6°C to 9.2°C. The highest values were noted on 15 May in does No. 2 and neo3 605, and on 22 May in does No. 3 and neo11 202. During that period, the average ambient temperature ranged from 19°C to 20.5°C. The greatest decrease in temperature differentials between the examined areas was observed on 3 June, and it ranged from -2.2°C in doe No. 3 to 3.9°C in doe No. 2. The average ambient temperature on the above date was 18.5°C. Between 6 and 22 June, the temperature differentials between the underbelly and the rump ranged from -2°C to 5.6°C. In successive weeks, the observed differences in temperature were less pronounced, ranging from 0.9°C to 3.6°C. The average ambient temperature between 6 June and 13 July was 15.3°C to 22.3°C. The measurements performed on 15 June revealed that doe No. 3 had recently given birth. The exact parturition dates of the remaining does could not be established, but it can be assumed that all pregnant does had already given birth to fawns by 22 June.

The observed differences in the examined areas of the body were not correlated with the average ambient temperature. Similar conclusions were derived from an analysis of the correlation matrix. Our findings differ from the earlier results in whose study, the temperature differentials between the flank and the control area in mares increased when ambient temperature was lower.3 It

Table 3. *Average differences in temperature (T) between the udder (W) and the control area (Z) in pregnant fallow deer does [°C]*

Date of measurement	Temperature differences (W-Z) in does				Average ambient T
	2	3	neo 3 605	neo 11 202	
15 May	13.4	5.4	10.9	5.5	13.5
23 May	8.2	14.0	10.7	8.2	20.6
6 June	5.5	7.9	7.1	9.9	15.7
15 June	6.4	7.0	5.9	7.4	20.8
22 June	8.6	7.4	7.0	9.2	20.9
30 June	10.4	10.1	10.1	9.5	18.0
4 July	7.7	6.9	6.9	7.1	22.2
13 July	10.3	9.0	9.5	9.4	18.9
18 July	9.6	7.3	8.8	9.9	19.1
25 July	7.6	5.6	7.9	6.5	26.2
1 August	9.4	6.8	8.9	8.5	20.5
8 August	7.9	8.7	8.7	8.9	20.3
15 August	8.4	10.4	9.0	9.9	18.8

should also be noted that the cited authors conducted measurements only in the last stage of pregnancy in mares, whereas the results presented in our study cover nearly the entire period of pregnancy in fallow deer does. The greatest differences in temperature between the analysed areas were noted on 15 and 23 May, and they could be linked to rapid foetal development. It should be stressed that the observed increase in temperature differentials was not correlated with a decrease in ambient temperature. On 9 May, when temperature differentials between the examined areas were lower in all does, ambient temperature was 1.5°C lower than on 23 May when the difference in temperature between the underbelly and the rump exceeded 7°C.

The results indicate that temperature differentials between the examined body areas were greatest in the last trimester of pregnancy (April to June) when foetal development is most rapid (Asher 2007, Mulley 2007). After 22 June, the noted differences in temperature were small in all does, which could suggest that all pregnant females had given birth to fawns by that date. The above findings support the conclusion that in fallow deer does, high temperature differentials between the underbelly and the control area (side of the rump) are observed during pregnancy, in particular in the third trimester.

Our results also indicate that thermal vision is not a highly reliable method for detecting early pregnancy in fallow deer. In this animal species, the winter hair coat effectively insulates the body. Therefore, the temperature measured on the surface of the body can differ from actual skin temperature in the evaluated areas. It should also be noted than in early stages of pregnancy, foetal development proceeds at a slower rate, so the changes in temperature on the surface of the body are less pronounced.

Lactation Control

Thermograms of the udder area were acquired between 15 May and 15 August 2012, and the average differences in temperature between the udder area (W) and the control area on the rump (Z) were calculated (Table 3). The correlation matrix revealed a negative non-significant correlation between the observed temperature differentials and ambient temperature. The above implies that the lower the ambient temperature, the greater the difference in temperature between the udder and the control area. The average temperature differentials between the examined areas were determined between 5.5°C and 14°C, ranging from around 5°C to 10°C in most cases. The greatest variations in temperature differentials between the udder and the control area were observed between 15 May and 6 June. In successive weeks, until the end of the study, the differences in temperature were less pronounced and less varied in all does, and they were correlated with ambient temperature. Temperature differentials between the udder and the rump increased steadily between 6 and 30 June. This could be attributed to the fact that most females had given birth during the above period;. Therefore, the onset of lactation could have provoked the observed increase in udder temperature.

The influence of ambient temperature on temperature differentials between the examined areas of the body, noted in our study, is consistent with the earlier results.[3] The absence of distinct variations in the average temperature differentials in all does could indicate that none of the evaluated animals had suffered from mastitis or other udder disorders that could increase surface temperature.

There is a general scarcity of published data about mastitis in farmed cervids. However, mastitis is unlikely to be frequent in female cervids which, unlike dairy cattle, goats, and sheep, are not milked (the only exception are the moose farmed in Kostroma, Russia[29]). The mammary gland is thus kept injury-free, excluding the injuries caused by nursing fawns. According to observations of nursing behaviour in fallow deer, deer does determine the duration and frequency of sucking and allosucking.[11, 24] Younger and weaker does are often reluctant to feed non-filial fawns. Intensive lactation can deteriorate the female's condition before the mating season, which can lead to fertility problems in a given year or delayed fertilization.[11] These observations indicate that does control lactation by modifying their behaviour toward fawns.

The obtained results indicate that thermal vision can be a potentially useful, non-invasive method in studies analysing lactation in cervids. Thermographic measurements can be used to monitor lactation in various wildlife species, but only in individuals that are relatively tame, for example in small farms and zoos.

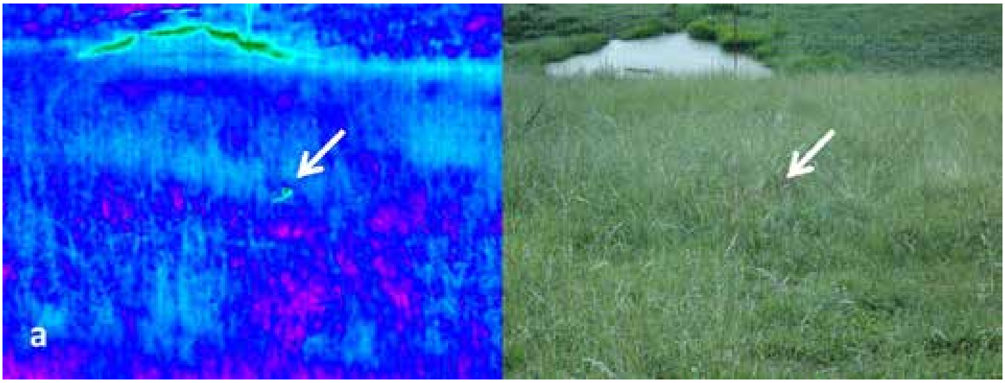
Localisation of Hidden Fawns

Hiding fawns are localised to obtain information about the beginning of the fawning period, the number of born and hiding fawns, and to protect offspring against danger (for example, when fawns are left alone in an empty enclosure after herding). An effective method of localising fawns/calves in fawning/calving enclosures would considerably improve the welfare of farmed cervids.

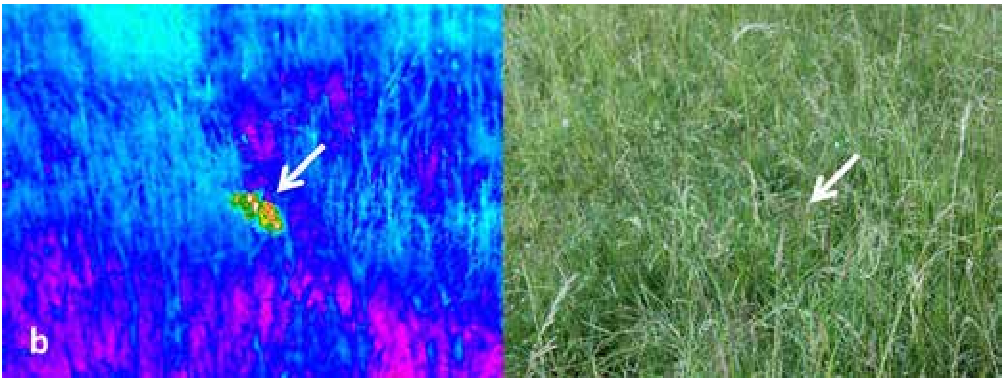
The results of this study show that thermal vision is an effective localisation method despite certain limitations. Fawns hidden in vegetation were identified with the use of a thermographic camera from a distance of up to 20 m. The effectiveness of visualisation increased with a reduction in distance. However, at a greater distance, the heat emitted by fawns made it increasingly difficult to distinguish the animal from its surroundings (Fig. 5a, b, c). Tall and dense vegetation between the camera lens and the fawn was the greatest obstacle in the localisation process. Very dense vegetation blocked the heat emitted by the animal even at a distance of several meters from the thermographic camera. Bare soil and stones were also strongly visualised in thermograms, and they could be mistaken for hiding fawns at a greater distance (Fig. 6a, b, c).

Our results are consistent with other the findings of other authors,[4, 7] who found that thermal vision was a useful method for localising white-tailed deer calves, but its effectiveness was significantly limited by dense vegetation. The cited authors

***Figure 5**. Thermograms of hiding neonatal fawns and images of the observed area captured with a digital camera:*
***5a)** distance of around 20m,*



***5b)** distance of around 13m,*



***5c)** distance of around 4m (arrows point to a hiding fawn).*

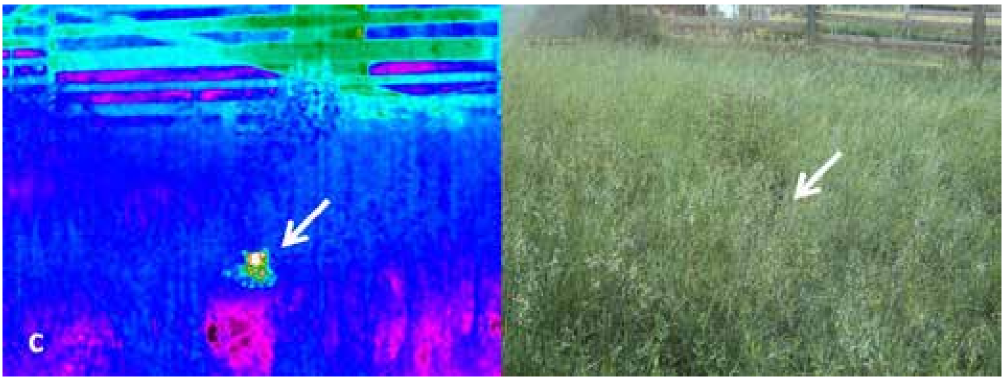
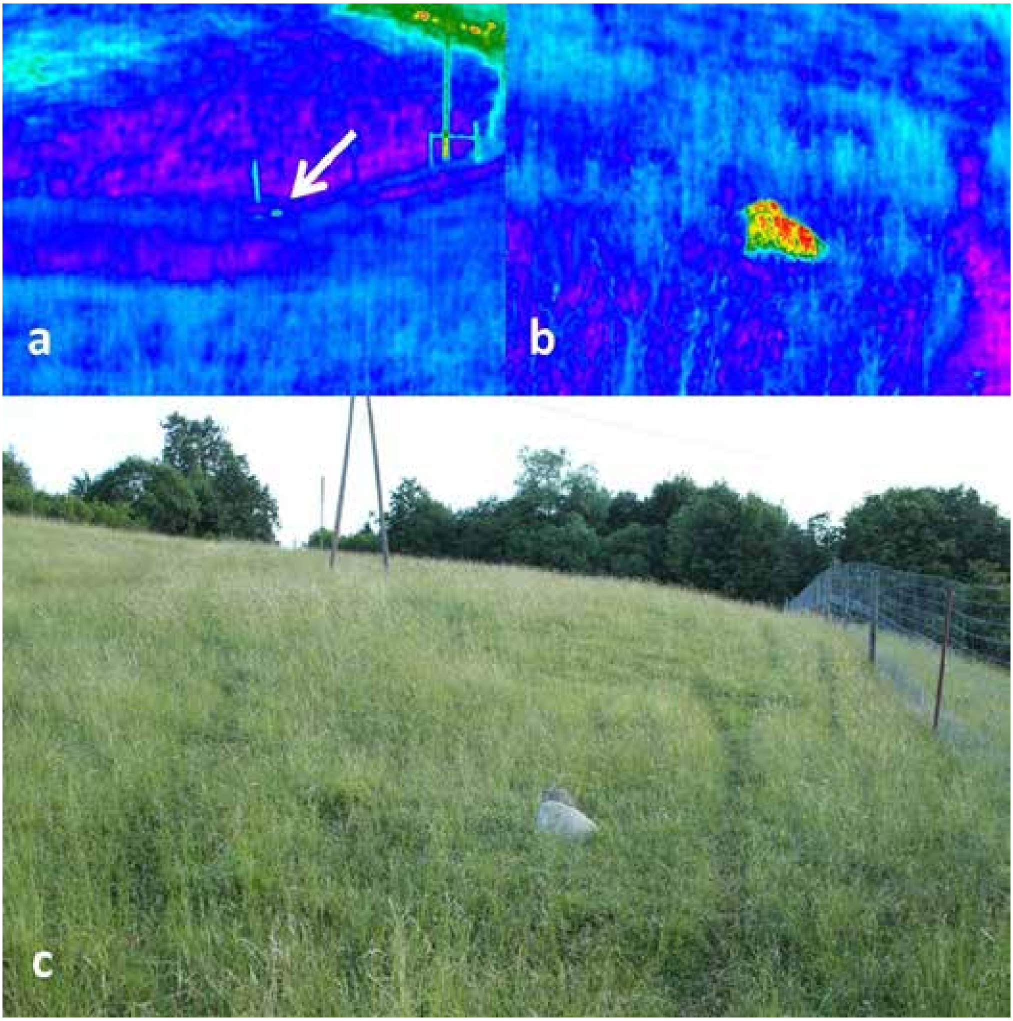


Figure 6. *Thermogram of a stone (a), close-up view (b), and a digital image of the same stone (c).*



observed that thermally active surfaces (heated ground, stones, sites previously occupied by deer) can be mistaken for hiding calves. Some authors also found that dense vegetation, high humidity, and hilly terrain can pose significant obstacles to thermal imaging of hiding animals.[12, 13, 14, 20] One of the greatest drawbacks of thermal imaging is that measurement error cannot be reliably estimated because the ratio of detected individuals to the actual number of animals in the surveyed area is unknown.

Despite the above limitations, thermal imaging is an effective tool for preventing dangerous situations that might arise when does with older fawns are herded into a different enclosure and neonatal fawns are left alone in the deserted enclosure. Thermographic cameras can also be used to study the animals' hiding preferences and determine whether fawning enclosures in a farm have a sufficient number of suitable hiding sites. When fawns, in particular very young animals, hide in inappropriate locations (by the fence, in low grass in the sun, etc.), it is highly likely that the number of suitable hiding sites in the fawning enclosure is insufficient. The resulting information can be used to increase the availability of suitable hideouts during the breeding season. Fawning enclosures can be set up in other locations that are overgrown with tall vegetation, selected plants can be planted in autumn and artificial shelters can be introduced to create visual barriers and shaded resting places.

CONCLUSIONS

Thermal vision systems can be used to detect oestrus in farmed cervids, but they are most effective when the surveyed animals are relatively tame. In fallow deer does, thermographic cameras do not support detection of early pregnancy, and reliable information is obtained only in the last trimester of pregnancy (April to June) when foetal development is most rapid. The results of this study indicate that thermal vision is a potentially useful method for monitoring lactation in cervids, but only in tamed animals. The analysed method can also be used to localise hiding fawns, but it produces reliable results only when observations are performed at a distance of up to 20 m.

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