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Comparison of hair coat structure between the Raccoon dog and Blue fox

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Abstract

Topographic comparison of structure of winter pelage in two different canid species, the raccoon dog (*Nyctereutes procyonoides* Gray, 1834) and the blue fox *(Alopex lagopus)* was done. Considerable site-specific variations in physical traits of pelage exist in both species. The ventral surface of the body seems to be more protected in the blue fox, which is due mainly to the greater density of hairs. In both species, density of hair is not only composed of the number of hair follicles in a bundle but also includes the number of bundle units per surface area.

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Introduction

Two quite different canid species have extended their ranges into subarctic regions of Scandinavia. One is the blue fox *(Alopex lagopus)*, a circumpolar inhabitant whose ability to stand cold environments is widely documented (SCHOLANDER et al. 1950a–c; IRVING and KROG 1954; UNDERWOOD and REYNOLDS 1980; KORHONEN et al. 1985). Another is the raccoon dog (*Nyctereutes procyonoides* Gray, 1834), a species native to Eastern Asia, originally adapted to a north-temperate climate (HEPTNER et al. 1974).

Thermoregulatory characteristics and survival strategies of both species in the cold have been compared from several points of view (KORHONEN et al. 1984a; KORHONEN and HARRI 1984; KORHONEN et al. 1985; KORHONEN and HARRI 1986). These also include descriptions of moulting and seasonal pelage variations, especially in the raccoon dog (KORHONEN et al. 1984b). The thermal insulation of fur seems to be the main factor affecting heat economy of these species. The thermal insulation, furthermore, is mainly dependent on the density of hair coat (c.f. HAMMEL 1955; TREGEAR 1965). However, attempts to determine their hair density have previously failed because of methodological difficulties (KORHONEN et al. 1984b; DIVEEDA et al. 1985a,b).

In the present paper, we are comparing hair density of winter-furred raccoon dogs and blue foxes by a method which makes it possible to evaluate, in detail, the factors of which hair density is composed. Furthermore, this paper provides a precise comparison of hair coat structure at different regions of the body. Thus, the present study gives a topographic comparison of the thermal properties of hair coat in two different canid species.

Material and methods

Subjects

In December, large numbers of raccoon dogs and blue foxes were killed, skinned and tanned according to standard methods. All animals originated from the commercial fur farm of Koillis-Savon Turkis Ltd., in eastern Finland. They were all about 8 months old, and in good condition. Their pelts were ranked subjectively by professional sorters (Finnish Fur Sales Ltd.) into one of the 10 grades (1 = poorest, 10 = best) according to mass, quality, cover, impression and purity. From these, five pelts of equal quality (quality group = 6 representing medium quality) were selected for a detailed analysis in both species.

Procedures

Pelt samples were excised from different locations shown in Fig. 1 by using a cork borer with a diameter of 19 mm. Skin pieces with hairs were weighed to an accu-

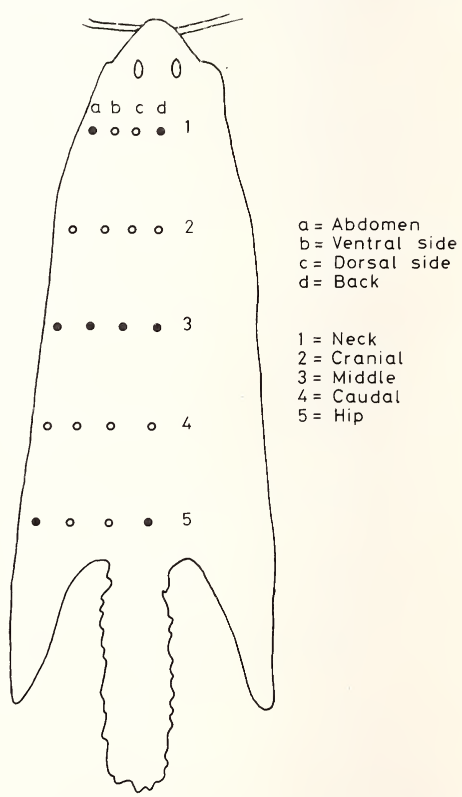

Fig. 1. Sketch showing different sampling positions for measured pelage parameters. Samples for determination of hair density were taken only from locations marked by closed circles

racy of ± 1 mg, after which the hairs were removed with a scalpel. Guard hair and underfur were weighed separately. Length of guard hair and underfur were measured with a ruler to the nearest 1 mm. Skin thickness was measured with a ROCT 577-68 dial micrometer to the nearest 0.01 mm.

For microscopic observations, skin samples were softened over night in 50 % acetic acid. After dehydration with alcohol and enbedding in paraffin, 10 µm longitudinal sections were stained with hematoxylin-eosin. Hair density was determined as follows: the number of hair follicles contained in each follicular bundle were first calculated with the aid of a projection microscope. Thereafter, the number of bundle units per surface area (mm^2) were calculated. Hair density was determined by multiplying the number of hair follicles times the number of bundle units.

Statistical treatment

All values reported are expressed as mean ± SD. Analysis of variance was employed for the statistical treatment of the data. The data were processed by the VAX 11/780 computer and SPSS (Statistical Package for Social Sciences) program.

Results

Morphological characteristics of hair coats of winter-furred raccoon dogs and blue foxes are summarized in Tables 1 and 2. Considerable site-specific variations in morphological traits of fur exist in both species. Generally the values are greatest on the back regions and tend to decrease when moving towards ventral regions. The depth of the hair layer is greatest for the back and dorsal side, and least for the ventral surface. This pattern is more pronounced in the raccoon dog. Principally measured parameters on areas of the back significantly differ from those found on the ventral surface. These conclusions hold true when surveying the hair coat transversely. As regards longitudinal scale, there exists surprisingly small variation in various fur characteristics in both species. Particularly in areas of the back and dorsal side such differences are very small. Guard hair weight, for instance, does not differ significantly at different sites of the hair coat longitudinally.

Parameters like hair and underfur weight tend to be greater in the blue fox than in the raccoon dog – particularly in sites like the abdomen and dorsal side. Length of guard hair and underfur, on the other hand, seems to be greater in the raccoon dog. Weight and thickness of skin are the parameters which are the most uniform in these species. Very interestingly, although the length of underfur is generally greater in the raccoon dog, the opposite holds true for its weight.

In both species, the number of hair follicles in a bundle unit are generally higher on the back than on the abdomen. As regards the raccoon dog, this trend is evident also considering the number of bundle units per surface area. However, number of bundle units in the blue fox do not show such statistically significant site-specific variations. Hair density is greatest on areas of the back in both species. Differences in hair density values as surveyed longitudinally are very small. Interspecies comparison reveals that hair density in the blue fox is significantly greater compared to that of the raccoon dog. This difference is evident all over the body. It is mainly due to the greater density of bundle units in the blue fox, i.e. the blue fox has about twice as many bundle units per mm^2 as the raccoon dog. However, the number of hair follicles in a bundle in both species are much more similar (Table 1, 2, and Fig. 2).

Discussion

At least since the days of BURNS and MILLER (1931) several direct and indirect methods have been used to estimate density of hair coat in mammals (c.f. KASZOWSKI et al. 1970). One of the latest is that described by ALLAIN and ROUGEOT (1980) in which hair density was estimated by counting the number of hair follicles contained in each follicular bundle. This method has been used e.g. for the determination of hair density in the American mink

Table 1

Physical traits of winter pelage of raccoon dogs at different sampling positions (see Fig. 1)
The values are expressed as means ± SD

VARIABLE MEASURED	ABDOMEN	VENTRAL SIDE	DORSAL SIDE	BACK	S
Skin weight, mg/cm^2					
neck	38.3 ± 6.4	35.6 ± 6.4	47.1 ± 8.6^{a*}	56.9 ± 5.3	***
cranial	63.2 ± 13.8^{b*}	47.1 ± 15.5	36.7 ± 1.3^{a*}	51.8 ± 4.5	**
middle	17.8 ± 5.1	23.5 ± 4.2	47.9 ± 34.7	77.9 ± 67.3	NS
caudal	19.9 ± 10.1^{a*}	19.5 ± 4.8	27.5 ± 7.7	41.9 ± 8.5	*
hip	46.3 ± 16.2^{b*}	31.2 ± 9.1	36.7 ± 5.2	42.6 ± 5.5	NS
S	***	**	NS	NS	
Hair weight, mg/cm^2					
neck	37.9 ± 4.9^{a**}	55.5 ± 9.4^{a*}	107 ± 19.7^{a*}	136 ± 24.1	***
cranial	47.6 ± 15.5	73.4 ± 11.2	88.0 ± 12.2^{a*}	131 ± 36.0	***
middle	18.3 ± 2.9^{a***}	64.5 ± 13.5	99.1 ± 15.9^{a*}	160 ± 16.9	***
caudal	15.0 ± 3.5^{a***}	47.7 ± 21.9	104 ± 21.2^{a*}	155 ± 16.7^{b**}	***
hip	59.3 ± 3.9^{b**}	98.5 ± 26.9	133 ± 12.9^{a*}	146 ± 18.9	***
S	***	**	*	NS	
Underfur weight, mg/cm^2					
neck	24.3 ± 4.4^{a**}	35.5 ± 9.1^{a***}	75.5 ± 20.2^{a**}	83.5 ± 13.2^{a**}	***
cranial	31.0 ± 10.2^{a*}	53.3 ± 11.1	60.2 ± 9.0^{a**}	68.5 ± 35.2^{a*}	*
middle	12.1 ± 2.4^{a**}	43.7 ± 11.7	66.6 ± 11.8^{a***}	105 ± 14.5	***
caudal	10.9 ± 3.0^{a***}	33.1 ± 16.1	77.7 ± 17.8^{a*}	112 ± 13.8	***
hip	39.1 ± 3.1^{b***}	74.0 ± 2.1	109 ± 13.5	107 ± 16.9	***
S	***	**	**	*	
Guard hair weight, mg/cm^2					
neck	13.6 ± 2.2	20.0 ± 3.4	30.9 ± 7.2^{b*}	52.6 ± 18.5^{b*}	***
cranial	16.5 ± 6.5	20.0 ± 2.8^{b*}	27.8 ± 5.9	62.4 ± 21.7^{b**}	***
middle	17.3 ± 3.1	21.1 ± 2.8	32.5 ± 8.7	55.0 ± 11.1^{b**}	**
caudal	13.2 ± 10.8	14.6 ± 6.1	26.6 ± 8.2	43.4 ± 10.4^{b**}	***
hip	17.7 ± 9.8^{b*}	23.6 ± 9.1	24.6 ± 6.5	39.1 ± 7.5^{b*}	NS
S	NS	NS	NS	NS	
Underfur length, cm					
neck	2.4 ± 0.4	3.6 ± 0.5	4.8 ± 0.4^{b*}	4.9 ± 0.2^{b*}	***
cranial	2.7 ± 0.1^{b*}	3.5 ± 0.3^{b**}	4.8 ± 0.3^{b**}	4.9 ± 0.3^{b**}	***
middle	2.4 ± 0.2	4.0 ± 0.3^{b**}	4.8 ± 0.3^{b**}	5.4 ± 0.4^{b***}	***
caudal	2.2 ± 0.1	3.5 ± 0.3^{b**}	5.1 ± 0.3^{b**}	5.4 ± 0.3^{b***}	***
hip	2.9 ± 0.5	4.1 ± 0.5^{b*}	5.3 ± 0.4^{b***}	5.6 ± 0.6^{b***}	***
S	NS	NS	NS	NS	
Guard hair length, cm					
neck	4.3 ± 0.4	6.3 ± 0.7	7.9 ± 0.4^{b*}	8.3 ± 0.4^{b***}	***
cranial	4.8 ± 0.7	6.1 ± 0.2^{b*}	7.8 ± 0.8^{b*}	8.5 ± 0.5^{b***}	***
middle	4.3 ± 0.5	7.1 ± 0.5	8.1 ± 0.3^{b*}	9.0 ± 0.4^{b***}	***
caudal	4.1 ± 0.2	6.3 ± 0.6	7.4 ± 0.8^{b*}	8.7 ± 0.4^{b***}	***
hip	5.0 ± 0.6	6.6 ± 0.5^{b*}	7.6 ± 0.6^{b**}	8.1 ± 0.3^{b***}	***
S	NS	NS	NS	NS	
Skin thickness, 0.01 mm					
neck	28.4 ± 4.2	27.2 ± 3.1	38.8 ± 12.6	43.0 ± 2.3	NS
cranial	41.6 ± 9.2^{b*}	31.8 ± 7.3	28.8 ± 2.6^{a*}	44.6 ± 5.6	*
middle	13.8 ± 4.3	18.8 ± 3.3	26.4 ± 4.0	42.0 ± 4.9	***
caudal	15.4 ± 4.6	15.8 ± 4.8	24.6 ± 2.7	39.0 ± 6.4	***
hip	35.8 ± 17.7^{b*}	24.2 ± 5.6	29.4 ± 3.6	36.0 ± 3.8	NS
S	***	**	NS	NS	
Number of hair follicles in a bundle unit					
neck	21.8 ± 1.6	-	-	25.2 ± 1.9^{a*}	*
middle	18.2 ± 0.8	23.0 ± 1.4	24.6 ± 3.6^{a*}	27.0 ± 2.6^{a**}	**
hip	22.6 ± 1.7^{a*}	-	-	24.8 ± 1.9^{a*}	NS
S	*			NS	
Number of bundle units/mm^2					
neck	5.0 ± 1.2^{a***}	-	-	7.8 ± 1.1^{a***}	*
middle	5.2 ± 1.1^{a***}	6.2 ± 0.8^{a***}	6.6 ± 0.9^{a***}	7.4 ± 0.5^{a***}	*
hip	7.0 ± 1.2^{a**}	-	-	8.2 ± 0.8^{a**}	NS
S	*			NS	
Hair density, hair/mm^2					
neck	110 ± 31^{a***}	-	-	196 ± 26^{a**}	*
middle	94 ± 19^{a***}	143 ± 22^{a***}	163 ± 38^{a***}	201 ± 32^{a**}	***
hip	158 ± 28	-	-	203 ± 24^{a***}	*
S	**			NS	

Significance: *$p<0.05$, **$p<0.01$, ***$p<0.001$, NS=not significant (analysis of variance), a: blue fox > raccoon dog, b: raccoon dog > blue fox.

Table 2

Physical traits of winter pelage of blue foxes at different sampling positions (see Fig. 1)
The values are expressed as mean ± SD

VARIABLE MEASURED	ABDOMEN	VENTRAL SIDE	DORSAL SIDE	BACK	S
Skin weight, mg/cm^2					
neck	33.6 ± 6.2	41.0 ± 8.8	58.8 ± 2.1	57.5 ± 2.0	NS
cranial	40.2 ± 25.9	37.3 ± 6.6	54.6 ± 13.3	51.7 ± 11.9	NS
middle	21.5 ± 5.7	19.1 ± 7.7	43.2 ± 23.8	50.0 ± 15.8	*
caudal	31.5 ± 16.1	22.6 ± 8.3	36.9 ± 10.8	50.0 ± 12.7	*
hip	20.0 ± 10.8	29.6 ± 7.7	46.9 ± 28.9	48.8 ± 6.1	*
S	NS	*	*	NS	
Hair weight, mg/cm^2					
neck	61.1 ± 11.5	86.9 ± 24.5	131 ± 6.7	131 ± 8.6	***
cranial	57.7 ± 11.0	73.8 ± 14.1	128 ± 29.6	123 ± 16.4	***
middle	36.0 ± 4.2	47.9 ± 22.9	129 ± 22.3	112 ± 26.7	***
caudal	36.4 ± 4.6	48.8 ± 14.2	134 ± 8.6	112 ± 11.6	***
hip	30.4 ± 8.3	75.6 ± 37.6	168 ± 18.4	132 ± 16.1	***
S	*	NS	NS	NS	
Underfur weight, mg/cm^2					
neck	50.0 ± 10.2	70.5 ± 23.9	110 ± 7.8	108 ± 11.6	***
cranial	47.5 ± 8.3	63.5 ± 14.9	107 ± 31.9	106 ± 17.7	***
middle	24.3 ± 9.8	37.4 ± 18.6	105 ± 22.2	92.9 ± 23.9	***
caudal	28.4 ± 3.0	37.3 ± 10.3	112 ± 17.9	95.2 ± 13.6	***
hip	22.5 ± 6.4	60.5 ± 34.4	139 ± 16.3	110 ± 15.7	***
S	*	NS	NS	NS	
Guard hair weight, mg/cm^2					
neck	12.2 ± 3.1	16.5 ± 4.6	20.2 ± 3.6	23.1 ± 8.6	*
cranial	10.2 ± 3.1	10.3 ± 1.4	21.8 ± 9.3	17.3 ± 6.8	*
middle	26.1 ± 40.3	10.5 ± 4.7	23.9 ± 3.4	19.1 ± 1.8	NS
caudal	8.1 ± 1.9	11.5 ± 4.0	22.2 ± 11.8	16.9 ± 3.4	*
hip	7.9 ± 2.7	15.1 ± 4.6	29.4 ± 5.9	22.2 ± 1.8	***
S	NS	NS	NS	NS	
Underfur length, cm					
neck	2.8 ± 0.3	3.0 ± 0.3	3.5 ± 0.3	3.6 ± 0.3	**
cranial	2.0 ± 0.2	2.1 ± 0.2	3.3 ± 0.3	3.3 ± 0.3	***
middle	2.3 ± 0.3	2.8 ± 0.3	3.6 ± 0.3	3.5 ± 0.3	***
caudal	2.3 ± 0.3	2.8 ± 0.3	3.5 ± 0.3	3.6 ± 0.2	***
hip	2.5 ± 0.4	2.7 ± 0.4	3.9 ± 0.2	3.5 ± 0.2	***
S	*	*	*	NS	
Guard hair length, cm					
neck	4.9 ± 0.5	5.4 ± 0.5	6.0 ± 0.2	4.9 ± 0.5	**
cranial	4.0 ± 0.3	3.5 ± 0.7	5.2 ± 0.5	4.6 ± 0.4	***
middle	4.8 ± 0.6	6.0 ± 0.6	6.0 ± 0.5	4.3 ± 0.3	***
caudal	4.9 ± 0.6	5.9 ± 0.4	5.4 ± 0.4	3.9 ± 0.3	***
hip	5.6 ± 0.4	5.1 ± 0.4	4.7 ± 0.3	4.2 ± 0.1	***
S	**	**	*	*	
Skin thickness, 0.01 mm					
neck	28.0 ± 4.6	34.8 ± 5.2	40.8 ± 8.4	44.6 ± 8.8	*
cranial	27.2 ± 7.5	30.0 ± 6.4	42.8 ± 4.1	44.2 ± 4.1	***
middle	17.8 ± 3.9	15.6 ± 2.9	33.0 ± 9.8	38.0 ± 9.2	***
caudal	21.8 ± 6.4	19.0 ± 4.8	31.6 ± 4.3	39.8 ± 8.3	***
hip	18.6 ± 6.7	25.4 ± 6.1	33.8 ± 13.3	40.0 ± 4.4	**
S	*	**	*	NS	
Number of hair follicles in a bundle unit					
neck	22.8 ± 4.1	-	-	28.6 ± 2.3	*
middle	22.0 ± 2.5	24.6 ± 0.9	31.4 ± 3.0	32.8 ± 2.2	***
hip	28.2 ± 3.6	-	-	30.8 ± 4.8	NS
S	*			NS	
Number of bundle units/mm^2					
neck	11.2 ± 1.4	-	-	14.0 ± 2.4	NS
middle	12.2 ± 0.6	12.8 ± 1.9	11.8 ± 1.6	11.6 ± 0.6	NS
hip	12.2 ± 2.4	-	-	12.4 ± 1.7	NS
S	NS			NS	
Hair density, hair/mm^2					
neck	251 ± 27	-	-	402 ± 88	**
middle	268 ± 48	315 ± 51	368 ± 38	380 ± 23	*
hip	345 ± 81	-	-	382 ± 73	NS
S	NS			NS	

Significance: *$p<0.05$, **$p<0.01$, ***$p<0.001$, NS=not significant (analysis of variance)

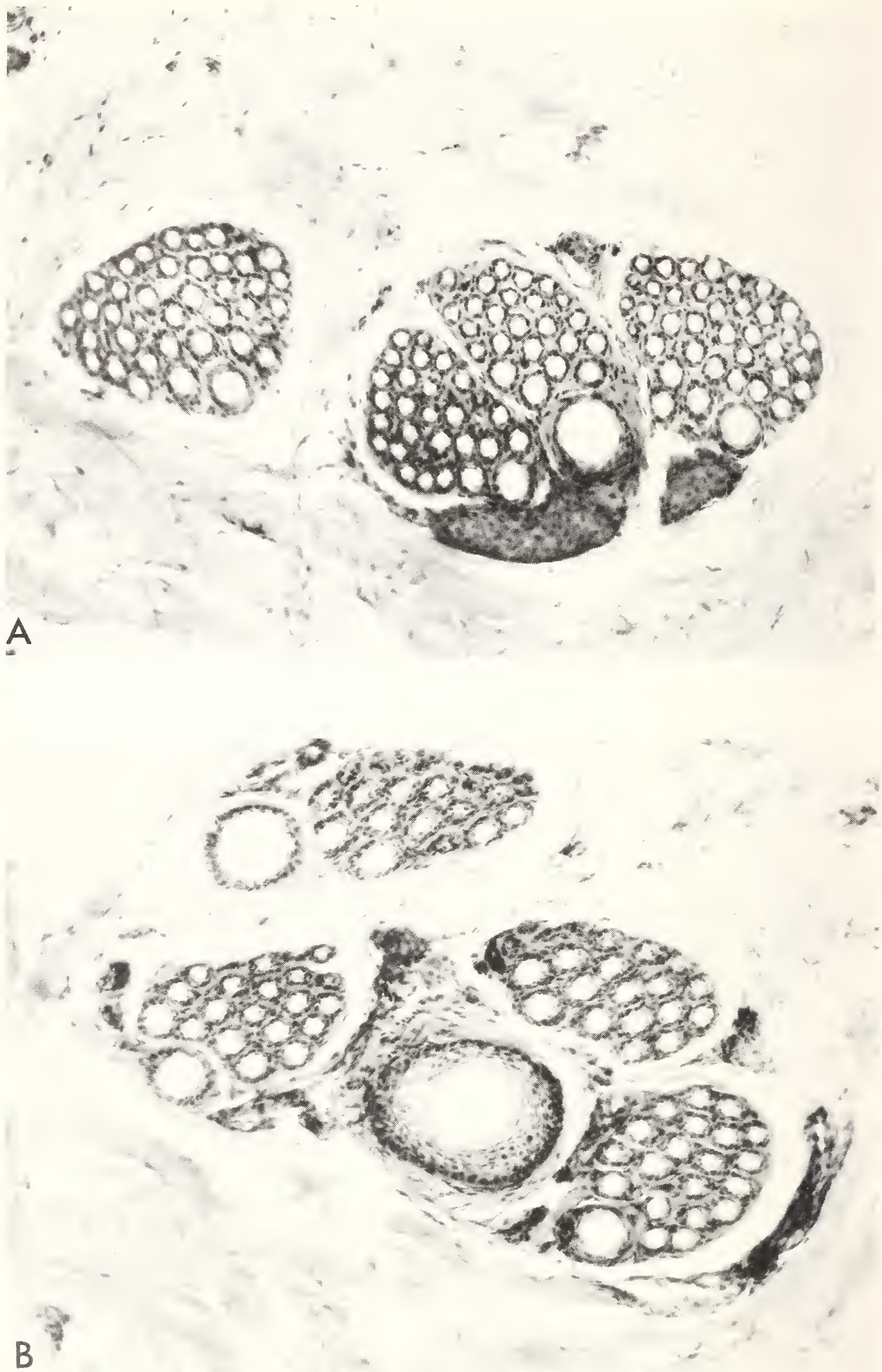

Fig. 2. Transverse section of the skin taken from the area of neck (position 1d, see Fig. 1.). A: Blue fox, B: Raccoon dog. Note the interspecies differences in numbers of hair follicles in bundle units. (Magnification 400-fold)

(Mustela vison) (ALLAIN and ROUGEOT 1980). The present results, however, reveal that density of the hair coat is not only composed of the number of hair follicles in a bundle, but also includes the number of bundle units per certain surface area. As can be seen, the number of bundle units differed drastically between blue foxes and raccoon dogs. Interspecies differences in number of hair follicles in a bundle, on the other hand, were much smaller. Thus, at least in the species studied, the density of hair essentially depends on the number of bundle units per surface area.

The air layer trapped by the hair coat provides the main resistance to heat transfer between the animal's body and the environment. Insulative properties of the hair coat are thus highly dependent on the density of hair (TREGEAR 1965), although the length of the insulative layer has importance also (SCHOLANDER et al. 1950a; HART 1956). The present results support the conclusion that the hair coat of the blue fox possess somewhat better insulative power than that of the raccoon dog. Furthermore, although site-specific variations exist in insulative value of hair coat in both species, this holds true to a lesser extent for the blue fox. Also the total density of hair allover the blue fox's body is significantly greater than that of the raccoon dog. As winter is the critical period for survival of both species, conductive heat loss also has great importance in regulation of their thermal balance. Thus, thermal properties of ventral and dorsal sites of the coat are of pronounced importance. As the results showed, these regions are better protected in the blue fox. Parallel findings were evident also in our previous works. Our body cooling measurements on the raccoon dog (KORHONEN et al. 1983; KORHONEN and HARRI 1984) emphasized the importance of the ventral surface as a significant route of heat loss by animals lying on an unprotected base, but also in standing position heat is markedly lost from the regions of chest, abdomen and feet. As our infrared thermographs showed, this is evident to a lesser extent for the blue fox (KORHONEN and HARRI 1986).

Previous metabolic measurements also support the conclusions of the thermoregulatory properties of both species drawn in the present paper (KORHONEN et al. 1985). However, although the raccoon dog has longer hairs (both underfur and guard hairs), especially on its dorsal and lateral surfaces, and accordingly a thicker hair coat, its metabolic response to cold is even more marked than that of the blue fox. Therefore the uniformity of the hair coat thickness is even more important than the maximal thickness at a certain place. This is especially important under farm conditions in which both raccoon dogs and blue foxes are caged outside, including the coldest part of the subarctic winter. Due to the importance of the ventral heat loss, raccoon dogs even in curled position cannot satisfactorily protect themselves against cold on bare wire-mesh net. Blue fox, on the other hand, can even in such conditions withstand cold better. Thus, as were suggested already in our previous works, a simple rest-shelf can provide marked energy savings for the raccoon dogs, particularly during the coldest part of winter (KORHONEN et al. 1983; KORHONEN and HARRI 1986).

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Zusammenfassung

Vergleich der Fellstruktur von Marderhund mit Blaufuchs

An determinierten Regionen der Körperdecke wurde die Struktur der Winterfelle bei den beiden Canidenarten Marderhund (*Nyctereutes procyonoides* Gray, 1834) und Blaufuchs *(Alopex lagopus)* vergleichend untersucht. Bei beiden Arten konnten in physischen Merkmalen der Haut beträchtliche lagespezifische Variationen nachgewiesen werden. Die Ventralseite des Körpers scheint beim Blaufuchs in stärkerem Maße geschützt zu sein, hauptsächlich bedingt durch eine größere Dichte von

Haaren. Bei beiden Arten wird die Haardichte nicht nur gebildet durch die Anzahl von Haarfollikeln in einem Bündel, sondern auch durch die Anzahl von Bündeln pro Oberflächeneinheit.

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