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Keywords: the Siberian musk deer (*Moschus moschiferus*), caudal glands, marking, home range, structure, communication zones, heritability.

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Keywords: the Siberian musk deer (*Moschus moschiferus*), caudal glands, marking, home range, structure, communication zones, heritability.

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I. INTRODUCTION

Chemical communication, realized by odors, is of great importance for mammals, affects various vital functions. One of the main tasks of studying the communication functions is the ascertainment of its value in regulating the individual distribution relative to each other in spatial coordinates. The placement of scent marks in space is of great importance for animals, in particular, predatory, whose strategy of feeding is consistent with maintaining a certain home range ([3][22][13][17][18][2][38][29]; etc.). The study of the functions of the scent marking in ungulates ([28][7][8][9][10][6][36][12][1][5]; etc.) it is difficult often due to the specifics of ecological niches, a dynamic spatial and social organization of populations. A special complexity is the study of the results of the response of recipients to the marks, which actually determines the regulatory functions of the scent marking. However, the value of the marking can be understood by taking into account the totality of information about the movements of individuals, the marks frequency, behavioral and spatial aspects of marking and response of recipients to marks.

The musk deer has a distinction from other ungulates animals of the temperate climatic zone due of year-round individual territoriality, it marking the home ranges with specific scent marks all year [41] [27]. The many musk deer have been using compact forest areas all their lives (in the sense of “Lifetime Range” [14]), nevertheless, shifting the home ranges and changing their size in different of times periods [41][46].

We began the study of the scent marking in musk deer since 1975 [41]. The main task is to ascertainment the functions of marks in the regulation of social bonds and spatial distribution of individuals. In this article, we concentrate one's attention on the relationship between the frequency of marking by musk deer males with caudal glands and the markers density in different parts of their home ranges with the movements of males, the distribution of other individuals. For this, the results of the study are used in one of key plots in the Sikhote-Alin reserve (Far East, Russia) in 1976–1977 and 2003–2004. The results characterize the structure of the musk deer associations and the scent marks distribution in the period (January-March) after the rut (November-December), when the locomotor activity of male decreases, the marks distribution becomes more stable. In winter it is supported a communication system, which musk deer forms during the rutting period [41]. The tasks consist in determining the relationship between: 1) the structure of the grouping; 2) the marking frequency of the different parts of the home regions; 3) density and other indices of the marks distribution, it including after the time interval of 30 years.

II. MATERIALS AND METHODS

2.1 Presentation of the study area and researched species

The Sikhote-Alin State Biosphere zapovednik (reserve) (SABZ, 401,600 ha; IUCN category I; 136°20'; 45°02') and adjacent areas of the Central Sikhote-Alin have significant indicators of biological diversity [37]. Forests cover more than 95% of the reserve area. All means of hunting and chasing animals, a using vegetation have been banned for more than 50 years.

In the central part of the reserve in the river basin Serebryanka is our main key plot for the study of musk deer – "Zimoveyniy". The snow period lasts from the second half of November to the end of March-beginning of April. In January-February, temperatures down to -5°C– -15°C (up to -20°C) prevailed with the usual monsoon wind from the mainland to the Sea of Japan. The vegetation cover is dominated by cedar pine forests (*Pinus koraiensis*) of complex composition, multi-layer vertical and mosaic horizontal structure, with close crowns of forest stands of the upper tiers. Cedar pine forests are replaced by fir-spruce forests from absolute heights of 800–1100 m. The heights of the main ridge Podnebesny-Dalny reach 1222–1247 m a.s.l. On the slopes of southern exposures, cedar forests with oak (*Quercus mongolica*) are common, on the northern slopes cedar forests with Khingam fir (*Abies nephrolepis*), spruce (*Picea jezoensis*), cedar-larch (*Larix cajánderi*) associations, etc., on the bottom of the river valley there are cedar forests, poplar forests (*Populus maximowiczii*), willow forest (*Chosenia arbutifolia*). Fir, which is of great importance for ensuring the conditions for the musk deer existence [41], fills in many areas the lower and middle tree canopies of the forest, the lower and middle parts of the southern slopes, glens and forms the second tree layer.

The main habitats of musk deer are located in dark coniferous mountain forests, especially ripe and close to the stage of natural climax, which provide all the conditions for the existence of the species. These forests contain abundant arboreal fruticose lichens genera *Usnea, Evernia, Alectoria*, soft fir needles, leaves of rhododendrons (*Rhododendron sichotense*) and others, this are the main components of its nutrition, especially in winter. Thanks to the protection in the reserve, an increased animal number is maintained. The number of musk deer exceeded 3000 individuals [41] in the first period of research (1974–1983) in the reserve, its population density was more than 30 individuals per 10 km^2 in the most favorable fir-spruce forests and cedar pine forests with fir, larch, in the basin Serebryanka river – usually 11–24 musk deer. However, the musk deer population gradually decline since 1975–1980, mainly due to natural causes. In the second period (since 2003–2004), we counted in Zimoveyniy from 12–13 in 2004 to 3 musk deer per 10 km² in 2012. Outside the reserve, its population density is less. Density is affected by habitat transformation by tree felling, roads, hunting and poaching [43] [31].

2.2. Data collection

2.2.1. Key Plots, the "Zimoveyniy"

The methodology was based on snow tracking and visual observations of musk deer accustomed to the presence of an observer and their neighbors with photo and video recording, from 2011–2015 whish supplemented by radio tracking [41][19][20][46]). The studies were carried out in key plots at least 10–25 km² in the river basins of the eastern macroslope of the Sikhote-Alin ridge. We have created a network of intersecting pathways 0.5–0.6 km apart, with a total length of 35 km in Zimoveyniy. Of these, 9.5 km are marked every 20 m with scarlet paint. The main pathways run along the mountain foothills, streams, along the crests of the watersheds. Pathways and many landmarks are marked on the plans with the basis of aerial photographs in 1976–1979. From 2003-2004 we used satellite images, GPS and GPS-Glonas recorders. From the pathways, we approached the places of the previous musk deer snow tracking and continued to trail further, determining the location azimuths of the during radio tracking.

2.2.2. Tracking technique

The method of musk deer inurement, visual observations, snow tracking is described in detail in publications [41][46], popular on the website [44]. Musk deer, accustomed to us, allowed themselves to be observed from a distance of 1.5–10 m, it did not change their behavior and activity rhythm, retained this property of behavior all their lives, after long breaks. Each accustomed musk deer had special features of build, the location of spots on the fell and behavioral characteristics in relation to the observer. The intensive growth of canines in males up to the age of three years ensured the identification of several age classes: under yearlings, (0–1) year; the second – (1–2) years, the third year of life – (2–3); three years old and older (≥3). According to the shape of the head and spotting of the color, under yearlings of both sexes, females of the age of (1–2) years and older (≥2) were reliably identified. The age was determined exactly for the musk deer accustomed to an observer at the age of less than a year of life. Sex and age classes have special trace characters [45].

The tracking we carried out directly on the musk deer trails. The distances were measured with checked steps, by compasses, GPS recorder, with an orientation to known landmarks (landscape features, vegetation changes, fallen trees, etc.). A more accurate survey of the movement trajectories carried out with a surveying compass with the registration of changes in directions by natural components – the vectors **V**a (according to the average from 1.3 m to 4.0 m at different transitions) ([41] [42] etc.). We noted encountered: scent marks, latrines (accumulations of several dunghill), beds, etc., as well as noticeable eats trail of lichen, needles, rhododendron, etc., and features of the trajectory. Part of this tracks were marked with bright numbers (total 1749 in 1976–2008). Thus, we determined the period between repeated visits to these points by musk deer, since neither the compass nor the GPS recorder provided such an opportunity. The length of the daily movement (for ≈24 hours) we determined by the trajectory of movement between successive meetings of an individual every day.

2.2.3. Organization of musk deer monitoring

Some neighbors of the accustomed musk deer also gradually got used to our usual presence in the key plot. We followed each musk deer continuously from 4–5 to 17 days, then took a break and often resumed tracking. From 2–3 to 5 neighboring individuals were usually tracked per day. In the interval between a tracking some musk deer, its emergence in the places of tracking a neighbor was established at the meeting of traces. After that we to tracked it up to the meeting. This made it determine more possible to accurately the overlap size and the number of visits to the home range of musk deer by neighbors. We regularly kept records of lichen (*Usnea, Evernia, Alectoria*) and other food of musk deer on permanent (11) and episodic plots of 400 m^2 and 900 m^2. The results show a sufficient abundance of musk deer food in the Zimoveiniy key plot [41][43].

2.3. Data processing

2.3.1. Tracking schemes

Data for the winter seasons 1976–1977 and 2003–2004 collected from January to the end of March–beginning of April. We conducted 140 tracking of daily movements and their fragments of 13 individuals in 1976 –1877, and 89 for 11 musk deer in 2003–2004. Tracking data (from GPS recorders and work schemes) was transported to an aerial and space image in NextQGIS or MapInfo. Then the trajectory, meeting points of scent marks, we corrected according to work schemes, next they converted into MapInfo 7.2. Spatial data analysis we carried out in MapInfo. On the schemes (Fig. 1, 3) it is possible to determine a similar course of trajectory movement after a long tracking break within no more than 70–100 m along the horizontal of the relief and 15–20 m along the vertical. In each season, we used our footprints of previous snow tracking for orientation.

2.3.2. The size of home ranges and the allocation of their zonal structures

The author adheres to the classical definition of the "home range" term [4], adjusted in relation to the time of study and ideas about the home range as a statistical dynamic system of movements. The latter has been shown when using snow tracking [41] [46], and radio and GPS satellite tracking ([25][16][26][23]; etc.). The outer contours of home ranges, of overlapping areas of neighboring musk deer on each other, are drawn along the trajectories of individuals bordering the areas, with smoothing at intervals of at least 50–100 m of their small changes in the path [46]. Such a method was used and when identifying a common center of activity, local activity cores or kernel ([4][15][39]; etc.), and zones with different the density of scent marks, beds. The cores are identified along dense groups of closed trajectories, usually at the locations of many beds. A common center of activity brings together local cores with tracks in between. This makes it possible to determine the contours taking into account the trajectories, which does not allow the selection of polygons by the radio and satellite methods of tracking. Episodic outings of musk deer, more often females, outside the home range were not taken into account. Marking frequency indices were used: the number of MGC marks, etc. per 0.1, 0.2 km or 1 km of tracking.

2.3.4. Marking patterns

Musk deer has several specific skin glands. Sokolov and Chernova (2001) generalized the results of their structure. All of these glands are involved in marking the home range. However, the complex of caudal glands: circumcaudal and supracaudal in males, circummanal in both sexes are of particular importance. Marking by glandular excretion of this complex has been studied both in wild and in captivity ([40][41], [33][27], etc.). Adult male leave two types of marks with caudal glands.

1) Smell spots (*MGC*), no more than of 2–4 cm in diameter, on objects that rise 30–70 cm above the ground or snow (stumps, branches, roots, stems of grass).
2) Dunghills – pellet group (*PG*), which during patrols can reach a mass of only 1.1–5 g and intensely smell of glandular excreta.

All musk deer also leave large heaps of excrement (more than 20–25 g) often in latrine (some more than 20–30 piles). The number of latrines and individual pellet hills in the habitat in any period reaches hundreds of pieces. Females and under yearlings usually scrape the substrate with their forelegs after defecation. Adult males leave separate small piles, usually in a "new" place, on path, rarely on the feces of other species. Often (≥63%) males do not scrape the substrate, especially in small piles, or make one or two scrapers. The pattern of marking objects in nature consists of:

1) approach to the scent mark; 2) its study, sniffing; 3) turning, raising or lowering on the

hind legs, applying the excreta of glands by rubbing from side to side or less often from top to bottom; 4) scrapers with one or alternately two front legs of the substrate towards the object of marking; 5) going away. Sometimes the musk deer licks off the old excreta of the conspecific with its tongue, also scrapes the bark of firs on the excretory spot with incisors. A variety of objects allows the musk deer to leave marks in the coniferous forest almost everywhere. *MGC* marks are clearly visible when tracking.

2.3.5. Patterns of behavior when musk deer male movements around the home range

Males combine usually several behavioral activities along the way, among which one usually dominates [41]. Foraging A] predominates in the fragments of way with active feeding and rest (according to the frequency of eating and resting places) with many turns, short steps (up to ≥25–35 cm) it is usually in the center of the home range. The pattern B] of active patroling distinguished by a more straightened trajectory, a long stride (up to 40–45 cm), sometimes trotting, a large number of scent marks, and rare food collection. Complex patrolling C] combines active foraging with scent marking. There are movement fragments in places rarely visited by musk deer D] with a low marking frequency. At the same time, males collect food (lichen thallome scraps, etc.) from the underlying surface, branches with different activity almost all the way.

2.3.6. Statistical Methods

Statistical calculations were carried out using Statistica 8, Statgraphics Plus. Nonparametric methods were used, since many samples are small. They were verified by Kolmogorov-Smirnov (*KS*) and Shapiro-Wilk (*SW-W*) tests. The difference in individual marking parameters of musk deer at different times and in different parts of the habitat was assessed using the Wilcoxon Matched Pairs Test (*W-test*), *ANOVA Friedman*. The text also uses the following designations: *Me* – median; *CV*, % – coefficient of variation; r_s is the Spearman correlation coefficient.

III. RESULTS

3.1. The structure of the musk deer observable grouping in the Zimoveyniy key plot in the seasons of 1977 and 2004 and Parameters of home ranges

In the Zimoveyniy key plot, the musk deer uses most usually the upper halves of the northern and northeastern slopes of the watersheds along their ridges, overgrown with cedar pine forests with abundant the Khingam fir, larch and other trees, as well as areas with a similar dense forest of the bottom of the river and streams valley. The activity of home ranges cores of males were located in a forest with abundant undergrowth, a "polewood" of the Khingam fir. Females and underyearlings settled in the forest with a windfall and coniferous regrowth.

3.1.2. In 1977

We determined the presence in January-March of 11 musk deer per 4.8 km^2 of tracking area: four males, five females of reproductive age (older than a year) and two more individuals (female and under yearlings) on the outskirts, which monitored only once. In February, in a cedar forest near the Zimoveiniy stream (between *4* and *6*; hereinafter, the numbers in the rectangles in Fig. 1, 2) settled on a part of the *M4* home range, a previously unknown female ("Martian") of age (1–2). By the beginning of March, it had gone to the upper reaches along the slope. Conflicts with it other musk deer were not noticed. *M4* ("Starik" – "Old-timer"), *M8juv* ("Myshka" – "Mouse"), *F1* ("Neulovimaya" – "Elusive"), *F2* ("Mila") were accustomed to the observer presence, *M5* (1-–2), *M6* (1–2) made it possible to follow from a distance of 20–30 m. External parameters of the main structural elements (cores, common center of activity) of the area used by musk deer during the tracking period shown in Table 1. For *M6*, the parameters are given until February 27, *F3* until February 21, 1977. The lynx (*Lynx lynx*) caught these animals on these dates. The areas of females significantly (from 26–27% to ≈100%) overlapped with areas of adult males. Three of females, then two and one lived within the home range *M4* and at least two lived within the area ($S >$ 1 km^2) *M7*

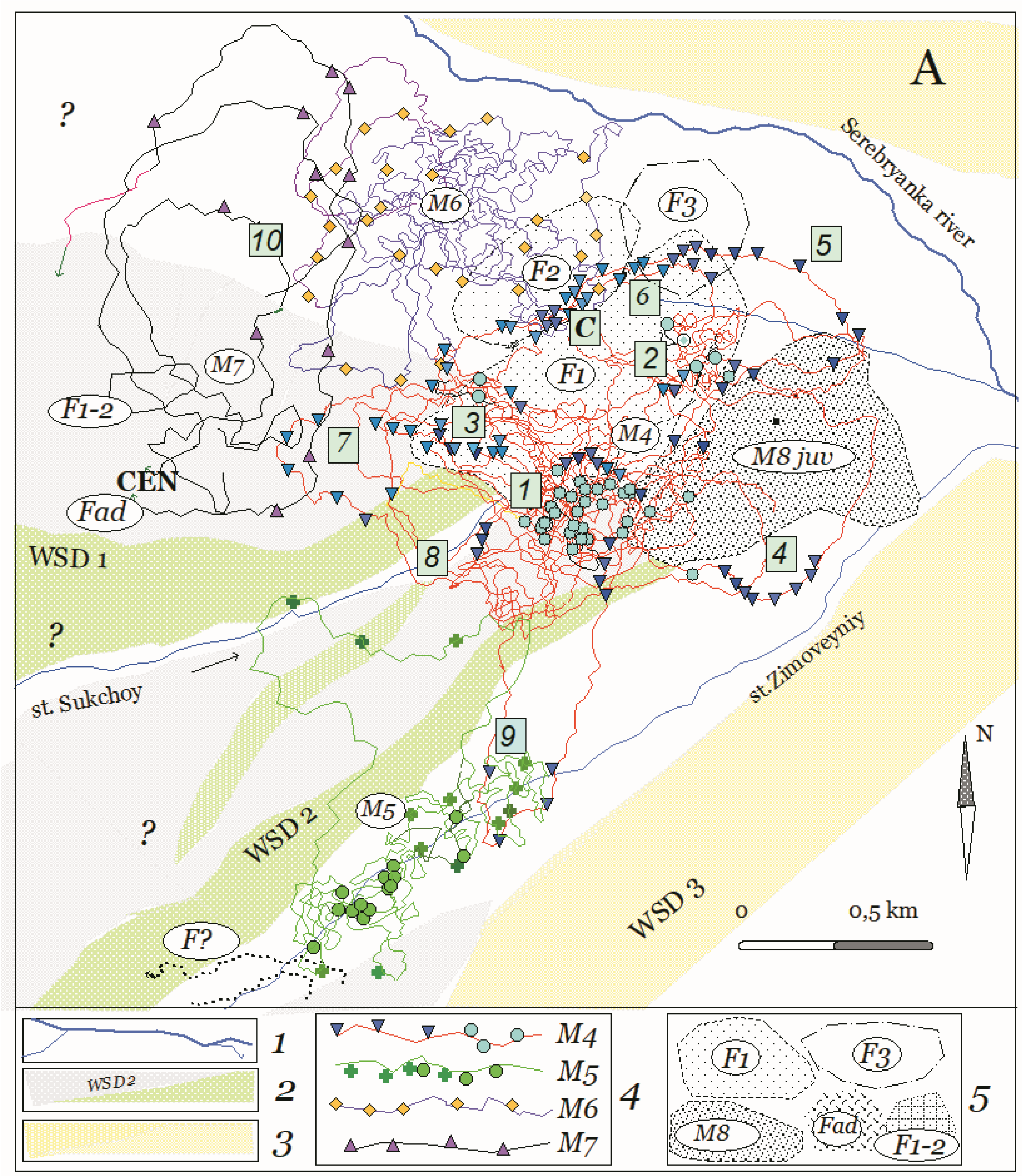
(> 2 year). The sizes of the *M7*, *F4*, and *F5* home ranges, which were observed fragmentarily, were not precisely determined. However, it was established that the center of activity of the *M7* was located in a cedar pine forest with fir along the crest of the WSH 1 watershed (Fig. 1).

Table 1: Parameters of musk deer home ranges on key plot Zimoveyniy in 01-03.1977

Musk deer, (age group)	Period, days*	Area, km²	Perimeter, km	Length and Width, km	Centre, km²	Number of the neighbors of same sex	Overlap (km²) with musk deer of the same sex
M4 (>3)	24	1,54	5,42	1,80×1,25	0,56	4	0,27
M5 (1-2)	18	≥0,78	3,97	1,0×1,4	≥0,20	2	≥0,14
M6 (1-2)	14	0,66	3,22	1,2×0,93	0,30	2	0,22
M8juv (0-1)	25	0,30	2,26	0,83×0,62	0,23	1	0,26
F1 (>3)	19	0,34	2,51	1,10×0,49	0,20	2	0,053
F2 (2)	11	≥0,15	1,45	0,62×0,46	≥0,11	2	≈0,032
F3 (2)	10	>0,16	1,33	0,48×0,44	≥0,10	2	≈0,03

Note: * – number of tracking days.

The percentage of overlapping sites of neighboring males on the site *M4* in January-February was 18–20%. *M4* appeared just a few days later in the former center of activity of *M6* after the death of the latter. Until March 11, an overlap zone of sections *M4* and *M7* was formed, with an overlap area of 28-–30% of the home range area *M4*. In this season, we did not notice visits of neighboring males to the *M4* activity center, except for one passage of *M5* to the center margin, as well as a similar visit of *M4* to the *M5* activity center. The area percentage of activity centers reached 36% of the *M4* home range, 45–46% of *M6*, and 76–77% of *M8juv*.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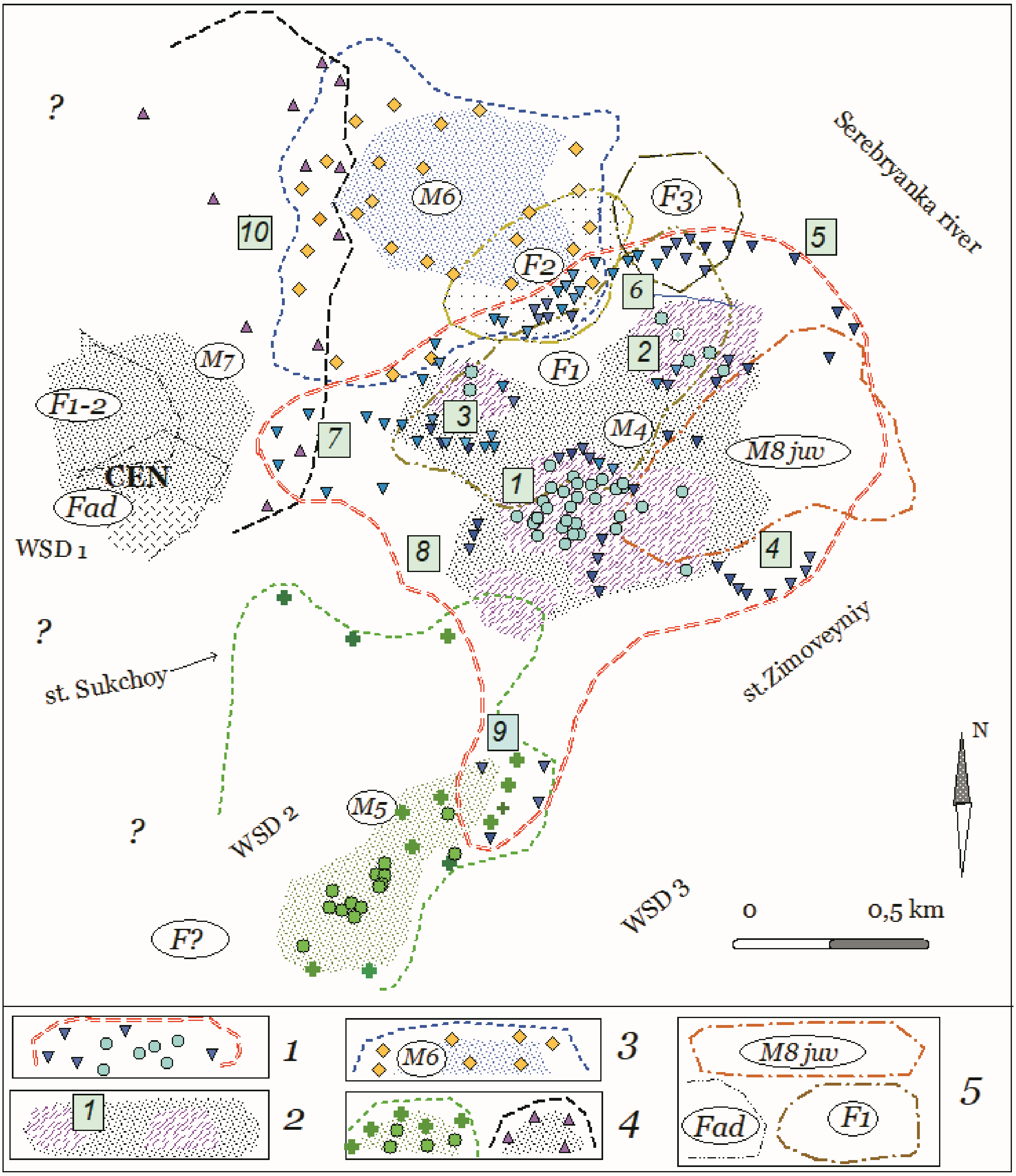


Fig. 1: Movements (Fig. A), contours of home ranges, the common center and local activity cores (B) of musk deer and the location of *MGC* marks and beds in the 1977 season, according to multi-day tracking data: in fig. A., legend: *1* – river and streams; *2* – southern and northern exposures of mountain slopes, WSH n – watersheds; *3* – valley cedar pine forests and secondary forest (yellow color) on mountain slopes; *4* – tracking trajectories of male musk deer, *MGC* marks and beds (circles); *5* – polygons for the female home ranges (individuals in Table 1 and in the text); in Figure B: *1* – contours, marks and beds of the *M4* home range in January-February 1977; *2* – center and local cores of *M4* activity; *3* -– contours, marks of *M6*; *4* – contours, centers, marks and beds of *M5* and *M7*; *5* – contours of the females and *M8juv* home ranges.

Overlap of home ranges females in phyllopatry association at point *6* (Fig. 1, 2) had lower values: for *F1* – 15%, *F2*– 21%, *F3* – 18–19%. The females occasionally ventured outside their normal ranges. *F1* in February made two exits from the valley to the slopes, also walked all night through the *M8juv* habitat, lay down twice, and then returned to its usual site. The movement of *F1* expanded after the death of *F3* and the departure of *F2* in the first ten days of March up the WSH 2 watershed and along the Zimoveiniy stream. *F1* has used many parts of the former sites of these females.

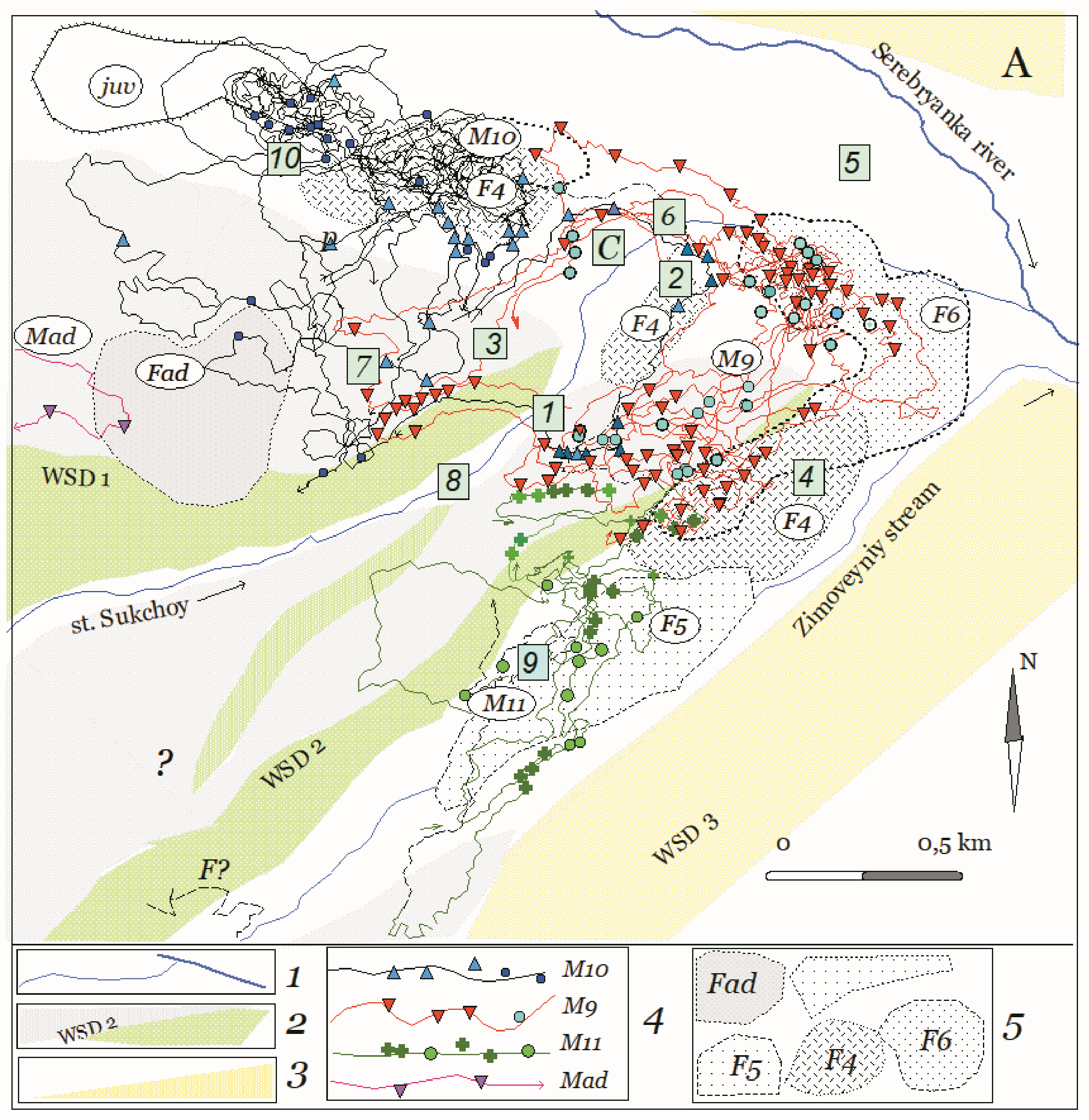
3.1.3. In 2004 г

In February, the snow depth reached 43–50 cm in the forest. In January-February, we determined the presence of 10 musk deer on 5.1 km^2 of the area surveyed by tracking. Among them, *M9* ("Iskatel" – "Fortune hunter") and *M10* ("Hero"), *F4* ("Beauty") are accustomed to our presence. Other traced individuals (Table 2) occasionally allowed themselves to be observed from distances of 20–35 m. The musk deer population density in this time was 3–1.4 times less than the average population density of this association in 1975–1982. At the beginning of the season in the dense forest of the river valley and Zimoveyniy stream, three females lived near the outskirts of home ranges *M9* and *M11* (Fig. 2). The overlap of their sites reached 23% for *F5*, 29% for *F6* and 50% for *F4*. However, the females stayed mainly in the places (6–15 ha) not overlaping by the neighbors visits. This phyllopatric females aggregation began to disintegrate in the first half of February, probably due to competition between them. However, the author noticed traces of only one pursuit by *F4* jumps of a younger *F6*, while tracking. *F4* did not fully use the vacated areas of the forest. At first, the female moved closer to the Sukhoy stream along the valley (area (0.04 km^2; *F1* lived here in 1977), but a day later it went into the forest, where *F2* lived in 1977 (0.14 km^2). Nearby was the underyearling home range, which was almost 50% overlapped by tracks of movements of *M10*.

Table 2: Parameters of musk deer home ranges in key plot Zimoveyniy in 01 -03.2004.

Musk deer, (age group)	Period, day	Area, km2	Perimeter, km	Length and Width, km.	Centre, km2	Number of the neighbors of same sex	Overlap (km^2) with musk deer of the same sex
M9 (≥3)		1,35	5,47	1,75× 1,26	0,30	3	0,66
M10 (>4)		1,58	5,21	1,85×1,31	0,59	2 (3?	0,69
M11 (2-3)		>0,82	4,13	1,50×0,76	0,18	2 (?)	0,13+
F4 (>3)		0,18	1,8	0,78×0,41	0,13	2	0,09
F5 (3)		0,21	2,23	1,1×0,35	0,15	1	0,05
F6 (2)		>0,20	2,33	0,71×0,71	0,13	1	0,058

A significant overlap of home ranges was determined for males (Table 2): *M9* – 49%, *M10* – 43–44%, *M11* – at least 16% from the *M9* site. These percentages are even higher, since for the neighbor *Mad* on WSH 1 (Fig. 2) part of the area on the watersheds remained untracked. However, in these places, footprints of musk deer of different freshness were register during tracking.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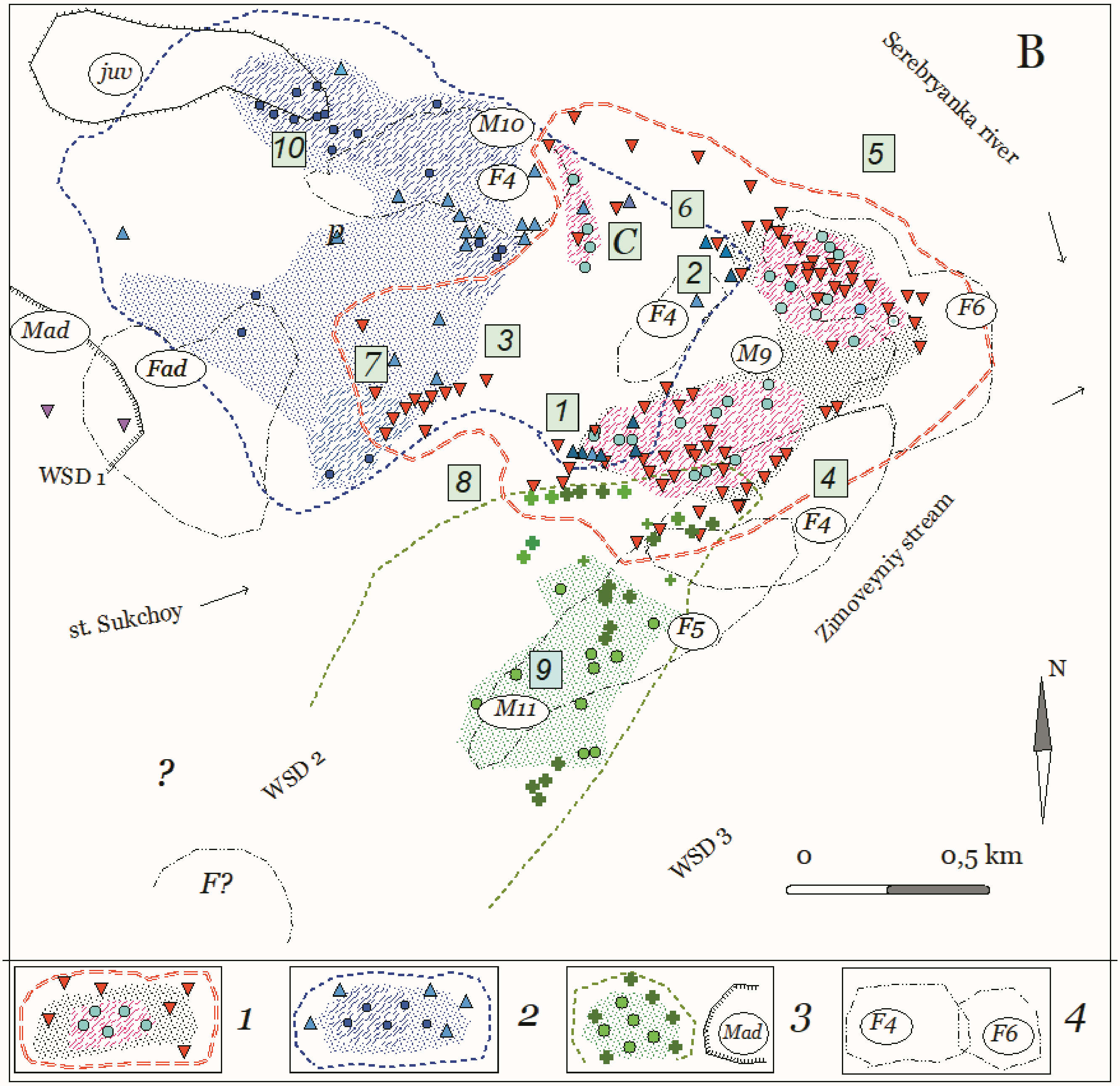

Fig. 2: Movements (Fig. A), contours of home ranges, centers and cores of activity (B) of musk deer and the location of MGC marks and beds in the 2004 season; in fig. A, the legend: *1–3* – designations in fig. 1.; *4* – tracking trajectories of male musk deer, *MGC* marks and beds (circles); *5* – female home ranges polygons; in legend of fig. B: *1* – contours, center and cores of the *M9* home range, marks and beds in January-February 1977; *2* – contours, the center of the *M10* home range, marks and beds; *3* – contour and center, marks of *M11*, contour of *Mad*; *4* – contours of females and underyearlings home ranges.

The home range size, areas of common centers of activity in males was 22–23% for *M9*, 37.3% for *M10*, and approximately 20–25% for *M11*. The general centers and, especially, the local cores of activity were located almost in the same places where centers and cores of males were located in 1977 (Fig. 1, 2). The difference from the situation in 1977 was small distances between the centers and the main local cores of neighboring males: only 150–350 m or less between *M9* and *M10*; 200–250 m between *M9* and *M11*. *M9* formed core ***C*** (Fig. 2B) almost synchronously with the movement of *F4* to neighboring areas. In March, *M10* delimiting the main place of presence of *F4* with *MGC* scent marks. At this time, we did not notice the movement of *M10* along the center of the *M9* home range (cores *1*, *2* in the rectangles and between them; Fig. 2). However, from the side of Zimoveiniy and WSH 2 traced two *M11* trajectories near the main core 1 of *M9*.

3.2.1. Frequency of MGC marking in activity centers and periphery of home ranges

The marking frequency (Tables 3, 4) differs significantly in the centers of activity and on the periphery of the home ranges of adult (>3–4 years old) males *M4* (1977), and *M10* (2004), as well as *M6* (1–2 year old in 1977) (Table 5). A male of the age class (1–2) *M5* (1977) had a similar frequency of marking the center of activity and the periphery under conditions of close location of the overlap zones of neighboring males to the center of *M5*. The difference slightly does not reach the p-value ($p < 0.05$) for *M11* (Table 5), the center of activity of which almost adjoined the home range of *M9* (Fig. 2A, B). The frequency of marking the periphery and the center of activity for *M9* (>3) had an insignificant difference. *M10* visited the center of activity of this male and its surroundings in January–February 2004 (Fig. 2A).

Table 3: Indices of the marking frequency with *MGC* scent marks (marks/0.2 km) of males followed by many days of tracking in January-March 1977.

Musk deer	Statistical index	Scent marks GC / 02 km in		
		Centre of Activity	Periphery	General
M4	*Mean*	0,23	0,82	0,48
	SD	0,619	1,214	0,984
	n	138	78	171
M5	*Mean*	0,20	0,45	0,30
	SD	0,459	0,631	0,547
	n	41	29	70
M6	*Mean*	0,22	0,28	0,24
	SD	0,422	0,461	0,435
	n	23	23	41

Table 4: Indices of the marking frequency with MGC scent marks (marks/0.2 km) of males followed by many days of tracking in January-March 2004.

Musk deer	Statistical index	Scent marks GC / 02 km in		
		Centre of Activity	Periphery	General
M9	*Mean*	0,51	0,79	0,62
	SD	0,775	1,125	0,929
	n	70	43	113
M10	*Mean*	0,12	0,59	0,28
	SD	0,379	0,931	0,658
	n	52	27	79
M11	*Mean*	0,39	0,89	0,56
	SD	0,941	1,079	0,969
	n	23	18	59

Table 5: Results of the assessment of differences (*W-test*) in the marking frequency in the center of activity and the periphery of male home ranges (according to Tables 3 and 4).

Statistical index	Male of Musk Deer					
	M4	*M5*	*M6*	*M9*	*M10*	*M11*
Z	3,718	0,338	2,628	1,150	2,934	1,804
p-value	0,0002	0,735	0,009	0,250	0,003	0,071
n	78	18	29	43	27	18

3.2.2. Frequency of marking with MGC marks in different zones of male home ranges

The results show that the frequency of *MGC* marks per 0.2 km of the way in 1977 varied somewhat in different parts of the male home ranges (Table 6). However, a significant variation in these indices (*CV* up to 194–320% with *n* up to 23–55) and a large proportion of null results allowed us to identify only a few major differences (Table 5). Comparison of data from 3 different cores of the *M4* home range showed insufficient difference between the samples in the overall continuum: *ANOVA Friedman*; $\chi^2 = 3.0$ (df = 3; p = 0.39), as in different parts of the periphery: $\chi^2 = 0.444$ (df = 4; p = 0.979). However, in the zone of active patrolling *5–7* (1.5 scent marks, *n* = 23, *SD* = 1.442) and between cores (0.62, *n* = 21, *SD* = 0.864), the difference is significant: *W-t test*, z = 2.22; *n* = 21; p = 0.026.

Table 6: Marking frequency (scent marks/0.2 km of tracking; in parentheses – *SD*) and density index (marks/ha) in different zones of male home ranges in January-March 1977

Iindices	Values of the frequency and density of marks in different zones of the home range							
	M4				*M6*			
	Core	Common Center	Periphery		Core	Common Center	Periphery	
			Whole area	Marking zones			Whole area	Marking zones
Number of *MGC*/0,2 km	0,23 (0,62)	0,33 (0,62)	0,82 (1,21)	1,52 (1,44)	0,20 (0,46)	0,45 (0,63)	0,23 (0,62)	0,33 (0,62)
Density of *MGC*/ha	0,68	0,58	0,55	1,8	0,50	0,43	0,39	0,64

In the common center and activity cores of *M4*, patterns of food gathering and resting A] prevailed over 82% of the total trajectories length (27.6 km). Only on some fragments of the way, the male left 2–3 marks per 0.2 km. The mark distribution in groups is also noticeable in other places, in particular, on trajectories along the *M8juv* area, where we observed one fragment of active marking B] in *4* (in Fig. 1). The male marked, with a slightly lower frequency, fragments of the way between cores *1*, *2*. He marked the periphery noticeably more often, especially the zones of active marking in the places of overlapping home ranges of *M4, M6*, and *M7* (Fig. 1, Table 6), with a total length along way 1, 6–1.7 km and a depth of up to 0.15–0.250 km. However, even before entering this zone from core *2,* the male began to actively marking (up to 3–4 scent marks per 0.2 km) on patterns B] (in *5* to *6* in Fig. 1) 700–800 m before overlapping with *M6.* It also marked actively after leaving the zone *7–6*. This zone is the inertial zone of the marking. This inertia is also observed in other places (in *3*, *7*, etc.; Fig. 1, 2).

In the snowy winter of 2004, many movements of the observed musk deer located in the valley and on the near slopes more compactly than in 1977. However, many features of the home ranges structure of predecessors were preserved (Figs. 1, 2). *M9*, which occupied a site similar in terms of the location of the kernels and part of the contour with the *M4* site (1977), marked the center of activity and the periphery relative evenly (Tables

4–7). However, in the overlap zone of the *M10* home range, the frequency increased significantly to 1.27 (n = 15; *SD* = 1.44) compared with the nuclear labeling (0.5; n = 24; *SD* = 0.771); *W-test*: z = 2.24; n = 15; p = 0.025, especially after *F4* moved here from Zimoveiniy stream. Each time when walking around this part of the home range, *M9* encountered fresh tracks of *F4*, walked along them (complex patrolling C], turning into pattern A]), several times it lay down near *F4* in a new nucleus in ***C*** (Fig. 2). This area was visited actively with marking and *M10*, to the home range which *F4* also moved. At the same time, *M9* marked the center of activity of its home range more intensively than the adultery *M10*: z = 2.84; n = 42; p = 0.005.

Table 7: Marking frequency (tags/0.2 km; *SD* in brackets) and index of marks density (marks/ha) in different zones of male home ranges in January-March 2004

Indices	Values of the frequency and density of marks in different zones of the home range							
	M9				*M10*			
	Core	Common Center	Periphery		Core	Common Center	Periphery	
			Whole area	Marking zones			Whole area	Marking zones
Number of *MGCs*/0.2 km	0,50 (0,77)	0,51 (0,78)	0,79 (1,12)	1,27 (1,44)	0,12 (0,38)	0,10 (0,36)	0,59 (0,93)	0,76 (0,99)
Density of *MGC*/ha	1,90	1,79	0,11	0,83	0,18	0,58	0,15	1,25

3.2.3. Density distribution of MGC scent marks in male home ranges

In key plot Zimoveiniy, aggregations of male trajectories are distinguished, uniting the cores of activities (between *1* and *2*, *1–3*, etc., Figs. 1A, 2A) and patrol (*4–9*) in the peripheral parts of home ranges. Adult males bypassed all the periphery of their territories in no less than 4–7 days (*M4* in 5–6 days), each time passing only a part of it. The next patrol usually took place in a few days. Only some males repeated visits to the same overlapping zone more frequently if the female's home range was located there (*M9* near *F4* home range in 2004).

In 1977 and 2004, we identified a similar arrangement of patrol trajectories in the overlapping of the male home ranges relative to relief and other landmarks (Figs. 1, 2). Only a slight shift of these zones was observed. The location of the main activity cores, the central system of movements that unite the local cores in a common center, was also preserved (1–2, 1–3). In 1977 and 2004, the trajectories of the central system, and especially patrol ways 5 and 6, lay along the outskirts of the female areas, between their territories. Males often did not enter the central parts of female home ranges. Since February 1977, *M4* also bypassed the main part of the *M8juv* area, which began to be marked with *MGC* marks since March. Conflicts of these musk deer at short distances from each other were not noticed. Conservatism in the schemata of ways location also determined the peculiarities of the males scent marks disposition.

There is no direct relationship between the marking frequency and the marks density (Tables 6, 7) for all males in different zones of their habitats: for *M4*, r = 0.86 (p = 0.13); *M9* – r = -0.65 (p = 0.35); *M10* – r = 0.78, p = 0.24, total for these males r = 0.35 (p = 0.26). For *M4*, M6 in 1977 and *M10* in 2004, the marks density in the marking zones was higher than in the activity core. At the same time, the ratio of marks densities in these zones is different for *M4* and *M6* (χ^2 = 5.16; df = 1; p = 0.02), for *M9* and *M10* (χ^2 = 20.09; df = 1; p < 0.001), as well as for *M4* and *M10* of different generations (χ^2 = 51.42; df = 1; p < 0.001). However, the difference is not significant for *M4* and *M9* living in the same place at different times (χ^2 = 2.40; p = 0.12), as well as for males of different age classes *M6* and *M10* (χ^2 = 2, 02; p = 0.12). The marks distributions in the males home ranges of different ages *M6* and *M9* also had similarities (χ^2 = 1.18; p = 0.28).

In 1977, we did not notice visits by neighboring males to the *M4* activity center, except for one visit to the *M5* margin, and the zones of active marking were distant from the main activity core. In the marking zone 5–7 (Fig. 1), the density of fresh marks in different places reached 1.42–2.8 per hectare, in the inertial zone 2/ha. This was different from the marks density in cores: *W-test*, z = 2.02; p = 0.043. Density indices differed in different activity cores by almost 1.5 times (from 0–0.69 marks to 1 per ha). *M4* left 16 marks in the 5–6 zone in just two patrols (1.65 km of way). In activity core 1, the male left five and four marks on only two the way fragments in places where old marks meet.

In 2004, the overlap zone between *M9* and *M10* reached 0.46 km^2. Patrol ways of males were located quite compactly almost in the same place where a similar zone stretched near *M4* in 1977 (Fig. 1, 2). *M9* had 0.83 *MGC* marks per ha, and in the inertial marking zone 5 had 1.67 scent marks, in the activity cores 1.69 (0.92–2) per hectare. Differences with mark densities in these parts of the home range are small (*W-test*, z = 1.75; p = 0.08). The increased marks density in the core of *M9* is due to the rare visits of the *M10*.

The concentration of fresh *MGC* markers in the *M9* activity core is associated with visiting the surroundings and marking by the *M11* by the end of March 2004. At a distance of up to 60 m from the *M11* trajectories, 11 marks were encountered, up to 130 m, – 18, and up to 300 m, another 7; $r^2 = 0.923$, $p = 0.009$. *M9* marked core activity mainly on pattern of complex patrolling C].

IV. DISCUSSION

The tracking methods for many days in key plot, in combination with visual observation of individually recognizable individuals, made it possible to accurately determine whether the marks belong to one or another musk deer male, accustomed to the observer. However, the full application of the method is possible in the snowy periods of the year. The study determined a significant similarity in the home ranges location, especially the main cores of activity (with the exception of their specific contours defined by motion trajectories), movement patterns of musk deer generations, separated by a time interval of almost 30 years. All this time, the grouping existed in stable conditions that are typical for coniferous forests, especially those close to the natural climax stage with sufficient food resources for musk deer [41]. The population density of the musk deer was in 2003–2004 on Zimoveiny, only 1.3–1.4 times less than in 1976–1977, the numbers of musk deer in the association are almost equal, and the sizes of home ranges of individuals of the corresponding sex and age groups are similar. The impact of the snowy winter of 2004 had a local effect. The musk deer is adapted to its usual movement in deep snow in coniferous forests [43].

The data (Fig. 1, 2; Tables 3–7) contain information about the encounter of only fresh marks during snow tracking. However, during the snow period, males leave more *MGC* marks in their home ranges, since we tracked only part of the musk deer movements. During the mating season (November-December), the intensity of marking in adult males (≥2–3 years old) reached 15–18 *MGC* marks per day, males traveled an average of 3.6 km with the prevalence of active patrolling B] on most of the way [41]. In January–March, the lengths of daily movements (to 1–3.5 km) and the scent marks number (3–8) per day decreased. Young males (1–2) left up to 4–5 marks per day in November–December, and 1–2 marks in January–March. Total, in November-December, adult males left from 750 to more than 1000 marks in their home ranges, in January-February – from 250 to more than 700; young males, respectively, about 200–300 and 90–180. After a period of active marking in November–December, males usually renewed their previous marks, the encounters number with which is much higher (>75–90%) than with the marks of their neighbors [41]. Meanwhile, the smell of *MGC* persists for a long time. We felt it 1–1.5 months after marking. Nevertheless, males renewed some marks 4–6 times in 1.5–2 weeks, and in some places of key importance for the movement organization, 5–7 marks were located in limited areas (100–200 m^2). Such activity of marking, which seems to be excessive, is probably associated with possible rapid changes in the musk deer groupings, such as the death of a neighbor, with the maintenance of territorial status and scent background by males.

The results indicate a significant relationship between the frequency of *MGC* marking and the distribution of scent marks in the male musk deer home ranges with the movements of neighboring males, the distribution of their marks, and the social situation in the musk deer grouping in different time. The movements of adult males (≥2–3 years) are coordinated, moreover, with the distribution of females, which leads to an indirect connection between the distribution of marking zones and the location of females' territories. However, the distribution of marks (Figs. 1, 2) and indices of their density (Tables 4–7) in home ranges indicate a relationship between *MGC* marking, primarily with the movements of males, with their visits to each other's home ranges, with the proximity of the main activity centers and local cores of neighbors.

The frequency of *MGC* marking is usually higher in zones of active marking at the periphery of home range than in the cores of activity, especially in adult males (Tables 3–7), but not always. There was no direct relationship between the marking frequency and marks density by the end of the tracking period ($p > 0.05$). According to the ratio of mark density indices in cores and in marking zones, two main variants in the location of markers are distinguished:

a) active marking zones are distant from the main activity core, neighboring males do not visit the activity core of the resident, males often visit the marking zones on the periphery;
b) some local cores almost adjoins the area of overlap with the home ranges of neighbors, neighboring males visit the main cores with marking.

In variant b), the scent mark density in the cores visited by neighbors was even higher than in the infrequently visited peripheral marking zones (Table 7, in *M9*), the marking frequencies of the common center of activity and the periphery did not differ much (Table 5). Alternative b) includes data of the marks distribution in the home range of the male (2–3 years old) in our other key area [46]: 54.1% of *MGC* marks were located in the common center and activity cores of this male during frequent visits to his territory by neighbors. The male formed a modular structure near the places where neighbors penetrated into the center of activity, which ensured the vital activity of the individual and the protection of the territory. Elements of the modular structure can also be notice for males on Zimoveiniy, near local cores (for *M4*, *M10*) and the female habitats.

Scent marks have dispersal over the entire area of males from the age of >1 year, especially during the mating season [40] [41]). However, the density of their distribution has different values in different parts of home ranges. Males mark after the mating season with greater frequency, mainly certain zones. These include areas visited by other males. Among them, in specific episodes, a vast zone *5–7* stands out (Fig. 1, 2) in the place of overlapping areas of male neighbors of successive generations. The location of this belt has changed only slightly since 1977. By the 2000 two of its sections are detached: the lower one (*5–6*) in the place of active B] and complex C] patrolling of *M9* and *M10*, and the upper on the mountain slope (near *7*; Fig.2), which was preserved in the place of the *M4* and *Mad* confrontation in 1977. Other zones are also maintain their approximate localization according to changes in the male movements.

Peters and Mech [24] were among the first to propose a graphical grid-and-nodal model, according to which the density of scent marks in the wolf (*Canis lupus*) increases in the border zones between the home ranges of neighboring packs. However, wolves also actively mark the environs of the den, but in a different way [2]. The location of marks in places where competitors are likely to appear is also characteristic of other predatory animals: the coyote (*Canis latrans*) [3], the African lion (*Panthera leo*) [17][18], and the cheetah (*Acinonyx jubatus*) [13]; the tiger (P. tigris) [32], leopard (*P. pardus*) [29], etc. The inertial marking phenomena that we observed in the musk deer (the inertial marking belt in 5 and others; Figs. 1, 2) violate the strict relationship between the distributions of scent marks and neighboring individuals. Musk deer males marking actively, starting bypassing belt 5–6, almost a kilometer before visiting the overlapping area with neighboring males. However, all the years there was no regular presence of males from the side of the river, where this zone is located in the forest. The activity (motion, marking) of males increased spontaneously during patrolling due to the corresponding motivation (reconnaissance, individualization of the territory, aggression). The inertial marking zones persisted for as long as well the marking zones in the overlay area. The phenomenon of inertial marking additionally indicates an excessive amount of scent marking means. In general, redundant marking contradicts, on the one hand, the principle of saving and reducing costs (which is suppose by some authors: [8][11][2]. But on the other hand, it is effective not only in creating soft "barriers", hindrances between plots of neighbors only on a part of the periphery, but it is also optimal for the individualization of the all territory by a resident. Male musk deer are able to distinguish their *MGC* marks from those of their neighbors. This has been shown both in natural conditions [41] and in captivity [27]. In the natural environment, the influence of encounters with smell marks of neighbors on the change in the movement trajectories of the recipients was also observed. Thus, *MGC* marking has diverse communicative functions; it is involved in the regulation of the dynamics and stabilization of the musk deer distribution. Such a response is observed in cheetah [13].

This conclusion adds to the hypothesis by Gosling [7] [10]. that residents mark their home ranges with scent to give recipients a means of evaluating when comparing the scent of individuals upon meeting with the mark scent. Resident musk deer neighbors are familiar with each other, but they have a small number of contacts when they meet most of the year [41] [46]. The excreta of the caudal complex glands contains various chemicals [34] [35] and they is able to indicate to the recipient several parameters of the donor. This is consistent with the concept of broad communicative properties of marking, which is also suggested by Macdonald [18] – "connection marking") for predators, by Matyushkin [21] for the Amur tiger (*Panthera tigris altaica*), this is consistent with the concept of mediated communication [30] and hypothesis by Gosling [7] [11].

Scent marking is one of the means, mechanisms for regulating the spatial distribution of individuals, however, effective. Attention is drawn to the rare visit and then avoidance of *M4* to the main site of the *M8juv* (1977) even before the young male began marking his home range with sparse *MGC* marks from mid-March. Males also did not form local nuclei in their home ranges in the places where other under yearlings and females are usually present. Thus, the very distribution of musk deer individuals is based on a certain behavior stereotype, which determines their adaptive dispersal according to environmental conditions, however, with the preservation of a single association. Marking arrange in this case spatial and social relations between individuals. This is facilitated by the maintenance for a long time, the inheritance of such elements of the structure of the used space as the main marking zones. With this continuity is probably due to the similarity (χ^2; $p > 0.05$) of the distribution of mark density indices in different parts of the home ranges of different generations males occupying habitats in the same places: adult males *M4* and *M9*, different age classes *M6* and *M10*.

V. CONCLUSION

The paper provides for the first time detailed information on the marking in musk deer males by the excretion of the caudal glands (*MGC*) in different parts of their home ranges in connection with the movements and marking by neighboring males, with location of females and underyearlings home ranges. The tracking methods makes it possible to determine exactly the belonging of the marks to one or another musk deer, accustomed to the observer and individually identifiable. The data indicate a significant similarity in the home ranges location, the system of movements, in the activity cores distribution and the main marking zones for musk deer generations, separated by a time interval of almost 30 years. This conservatism corresponds to rather stable conditions created by dark coniferous forest. Marking with *MGC* is part of a general stereotype of behavior that determines the adaptive dispersal of individuals in an association according to environmental conditions. This is an effective means of stabilization and dynamics of the group structure, regulation of the distribution of individuals, especially males, relative to each other, including the main patterns of bypassing their home ranges for a long time. The variety of scent marking communicative properties are revealed in the creation of communication zones between the home ranges of neighboring males, which also have the value of barriers, and in the individualization of the residents home ranges. Some redundancy in the means of marking (the number of marks, inertial marking phenomena) is probably associated with possible rapid changes in groupings, individualization, and the maintenance by males of a certain territorial status.

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Ethic

In the study, not a single musk deer died due to our fault. We did not influence the distribution and normal movements of the musk deer in home ranges.

Conflict of Interests

No conflicts of interest

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