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THE ROLE OF ANTHROPOGENIC INFLUENCE ON BIOLOGICAL SIGNAL FIELD (BSF) CHARACTERISTICS OF THE WOLF, *CANIS LUPUS LUPUS* (CANIDAE, CARNIVORA)

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The Role of Anthropogenic Influence on Biological Signal Field (BSF) Characteristics of the Wolf, *Canis lupus lupus* (Canidae, Carnivora). Shkvyria, M. G., Yakovlev, Ye. B. — The main goal of the current research includes studying the biological signal field (BSF) characteristics of the wolf (*Canis lupus lupus* Linnaeus, 1758) at different values of anthropogenic load on territories with conservation (Białowieża National park (Poland)) and hunting status of the species (Chornobyl Exclusion Zone (Ukraine)). The research in Białowieża Primeval Forest was conducted in two stages: study of the BSF characteristics of the wolf and finding correlation between data acquired from Ukraine (the first stage), and over-time study of intensity of the biological signal field (the second stage). In result of the first stage, there was no significant dependence on the characteristics of the territory and the differences between the behavior of wolves in the Białowieża Primeval Forest (conservation status of the species) and the Exclusion Zone (game status). During the second stage it was determined that provided variance of the intensity between territory groups was insufficient, the degree of significance to animals of area categories varied with the stages of the pack's life. It was found that the main factors which govern the character of wolf activity are not the level of the anthropic load and hunting pressure, but periods of the life cycle and spatial structure of groups.

K e y w o r d s : Biological signal field; Białowieża National park; Chornobyl Exclusion Zone; wolf behavior.

Introduction

Biological signal field of mammals (BSF) is "a total sum of mammals influence on the environment, changing its structure" (Naumov, 1977). Although the term "Biological signal field" was proposed by Naumov in 1977, there are not so many studies in this direction. Only recently researchers begun more detailed and in-depth studies of animal behavior are focused on BSF.Biological signal field (also known as Information sign field ISF) is considered to be a combination of specific and non-specific animal-induced changes of the environment of inter- and trans-specie importance (Mozgovoy, 2005). The term may also cover the environment changed by animals. Signal fields of animals are hereditary and multifunctional that is they are intended for transferring information within the population, between several populations and species; the fields are the evidence of environment changes, creating and sustaining the spatial structure of the animal population. The main function of the signal field — the accumulation and conservation of information about the features of habitat use in row of generations. BSF study provides the description of degree of population organization and order of the study species (Vanisova and Nikol'skii, 2012).

Despite the seeming simplicity of ISF classification parameters, there are difficulties in applying this method in field studies. In addition, the number of such a plan studies is very small for a generalized analysis of the BSF features not only on interspecific, but also intraspecific level, so actuality this subject is obvious.Biological signal field may be defined by the following characteristics (adapted from Mozgovoy and Vladimirova, 2005):

1) anisotropy stands for the total number of all environmental objects and events to which animals respond and defines the degree of intensity of objects and events in the environment of functional value to an animal; the BSF anisotropy that characterizes the volume of individual perception;

2) intensity stands for the number of movement responses, which animals generate while traveling a certain distance; the tension of the field characterizes the intensity of individual-environment informational interchange;

3) magnitude of a field stands for the number of different kinds of environmental objects to which animals interact; the size of the field characterizes the diversity of perception;

4) the number of drives associated with object perception showed the object valuation.

Białowieża National park (abbr. BNP) is a unique model territory with a high restriction rate. The wolf is one of the guarded species. The number of the native prey species is high enough (Jędrzejewski and Jędrzejewska, 2004). Ecology and behavior of the studied species are generally ordinary.

The Exclusion zone of Chornobyl Nuclear Power Plant (abbr. in text — Chornobyl Zone, CZ) was chosen for comparison as a territory with similar characteristics: the conservation territorial status of wolves and high portion of wild animals at the wolf ration. As an important difference characteristics are the facts of regular poaching and the level of using anthropogenic resources (food and spatial).

The comparison of Białowieża National park to the Exclusion Zone by the biological signal field (BSF) parameters was provided with the intent to analyze the intensity of using territories with different anthropogenic load and the different status of species, those guarded in Poland and hunted in Ukraine.

Material and methods

Research method involved researchers tracking the study animals and making thorough records of any activity indications of the study subject. Straight individual movement vectors from objects to objects, marking reactions, orientation reactions etc. were recorded as an elementary motor activity (drive). Drives of all animals were recorded. The reaction of each specimen was registered as a separate drive. Collected data were examined using mathematical methods.

In Białowieża Forest (BF) depending on anthropogenic burdening studied territories were divided into a low-level (LL) and medium-high-level (MHL). Low-level territories are characterized by absence of automobile transport, cattle, domesticated animals with rare human activity and the low number of anthropogenic constructions; the medium-high-level territories are characterized by moderate or frequent automobile traffic, presence of covered roads or anthropogenic constructions like bridges, fences etc., agricultural activity, and close location of human settlements.

In the Chornobyl Zone (CZ) we divided as low-level settlements and roads that are rare visited, forest and bog massives. As medium-high-level were divided Chornobyl and Prypyat' towns, industry and strategic targets with the surrounding area, settlements with a relatively large number of illegal settlers with livestock and frequently used roads.

All objects which caused the reactions we recorded were classified into the following categories:

1) natural territorial landmarks that structured movement of specimen (forest trails and roads, and their intersections, rivers, ditches, marshes…);

2) intraspecific communication objects (mark points, scratches…);

3) natural objects (animal tracks, prey remains…);

4) man-made objects (haystack, traces of people and pets, man-made food sites…);

5) anthropogenic territorial landmarks (asphalt roads, bridges…).

These categories were further compiled in table 1. The field size (the sum of object variants) was compared for BPF (natural — 10, anthropogenic — 15) to CZ (natural — 13, anthropogenic — 12).

Studies were conducted in different periods of the pack's life. On the average the highest value was characteristic for the territorial landmarks. Search of activity reactions in the BF was provided on the territories with the permanent territorial status of wolves in two phases:

1) two periods — October and February 2012–2013. The first period was characterized by the increase of hunting and a territorial activity. Another one — by the increase of mating and a territorial activity. These periods were chosen due to aiming to get a view of some aspects of packs' distribution, the parameters of activity, data about a diet and a mating season;

2) one period — December–January 2014–2015. Data collected during this period (6 tracks routes for each type of territory (12 tracks totally)) were used to identify overtime changes of the animal field intensity.

The previous literature sources with such data for earlier periods (Jędrzejewski et al., 2004; Zub et al., 2003) have been analyzed. During the first period 3 (Leśna-1, Leśna-2, BNP) packs were observed, during the second — 2 (Leśna-2, BNP) according to Jędrzejewski and Jędrzejewska (2004).

Tracking the animals was carried out on three types of soil: on snow, sand and on dirt. In CZ we collected material from 5 packs mostly in periods: December–March, June, August–September during 2009–2013.

We also separately analyzed marking activity on these territories. 96 mark drives were registered. For medium-high-level AT loci 59 feces, abrasion marks and urination points were calculated. For low level AT loci 35 mark drives were calculated.

The final route length was 700 km. We analyzed the content of 108 feces, the urinary marks of wolves were recorded too. 89 behavioral drives were registered.

The estimation of the wolf informational-signal field parameters (anisotropy, tension and size) was implemented for 1000 meters of tracks (similar to equivalent distance). All the objects and events percepted by motor reactions were summarized. Similar by motivational characteristics and response reactions objects registered as identical.

The BSF anisotropy (A) was calculated as;

$$A = O/L.$$

The size of the field calculated by the sum of objects variants.

The tension (T) of the field was calculated as:

$$T = R/L.$$

General sum of tensions was calculated as:

$$\Sigma T_{(I\text{-}V)} = \Sigma R_{(I\text{-}V)} / \Sigma L.$$

An attempt was made to establish correlation between groups since in this case we're dealing with quantitative data rather than events. For the level estimation of correlation between groups Spearman rank correlation coefficient from nonparametric statistical analysis pack of STATISTICA v.10 was chosen (StatSoft, 2011). This coefficient was selected since it's the most appropriate for finding correlation between two ranked sequences. The null hypothesis (H0) was assumed that features of different area groups are interrelated and differences between the said are insufficient.

Results and discussion

During the first stage of the research 208 behavioral drives and 132 object-induced movement responses were reported. The final route length in Białowieża Forest was 353.6 km. 50 feces of wolves were analyzed for their distribution, structure and were collected for parasitological studies (Yakovlev, Kołodziej-Sobocińska, 2013).

In the Exclusion Zone of 108 excrements — 64 were found in an area of the low anthropic load, most of on abandoned asphalt roads. Urinary marks (23 of 32) and scratches (18 of 22) were more common also on the territories with a low load. Also most of the marks during mating season were registered in the border parts of the patches.

Research findings of the first stage are presented in table 1.

Locomotion and marking reactions were main parts of behavioral activities (tables 1, 4). Hunting and nutrition-search activity are less distinct.

For medium-high-level territories the highest rates of individual-environment informational interchange is characteristic due to response to roads and objects of interspecies communications. Value of such objects consists was to 3 reactions for 1 object. It's caused by the intensive use of anthropogenic territorial markers by wolves for rising of movement speed in processes of hunting, nutrition-search and

Table 1. Reactions and objects for different groups of the studied territories, October, February 2012–2013

Categories	Białowieża Forest (BF)				Chornobyl Zone (CZ)			
	MHL		LL		MHL		LL	
	R	O	R	O	R	O	R	O
I	23	11	52	24	6	3	16	9
II	16	10	23	12	9	4	9	5
III	29	21	29	29	3	2	5	3
IV	8	6	3	2	9	7	8	5
V	12	9	13	8	10	7	14	4
Σ	88	57	120	75	37	23	52	26
L	38		26		16		15	
FS	15		10		12		13	

Note. I–V — categories of objects; MHL — medium-high-level territories; LL — low-level territories; R — reactions; O — objects; Σ — summation of the values in variables; L — total tracking route length, km; FS — size of the field, n.

territoriality activity. On the territories with prominent anthropogenic burdening wolf doesn't avoid anthropogenic objects in processes of active interaction with environment.

The wolf includes such objects in its signal field. On the territories with low intensity of burdening the wolf prefers native territorial markers. The value of natural objects was increasing during hunting and mating periods for account of increasing the number of mark and nutrition-search drives — to 2 per object.

Higher parameters of marking activity in the medium-high-level AT loci can be explained by the fact that borders between pack patches often match with large anthropogenic formations such as roads and big settlements. We registered big county of marks during mating season so it was high activity of wolves at the borderlines of wolf patches.

Table 2. Anisotropy and tension for different groups of the studied territories, per 1000 meters

Categories	Białowieża Forest (BF)				Chornobyl Zone (CZ)			
	MHL		LL		MHL		LL	
L	38		26		16		15	
	T	A	T	A	T	A	T	A
I	0.29	0.61	0.92	2.00	0.19	0.38	1.07	0.60
II	0.26	0.42	0.46	0.88	0.25	0.56	0.60	0.33
III	0.55	0.76	1.12	1.12	0.13	0.19	0.33	0.20
IV	0.16	0.21	0.08	0.12	0.44	0.56	0.53	0.33
V	0.24	0.32	0.31	0.50	0.44	0.63	0.93	0.27
Σ	2.32	1.5	4.62	2.88	2.31	1.44	3.47	1.73
FS	15		10		12		13	

Note. I–V — categories of objects; MHL — medium-high-level territories; LL — low-level territories; T — tension; A — anisotropy; Σ — summation of the values in variables; L — total route length, km; FS — size of the field, n.

Table 3. Spearman's rank correlation coefficient and respective values

Groups	Tension	r_s	p (r_s)	Anisotropy	r_s	p (r_s)
BF. MHL vs. BF. LL		0.90	0.037		1.00	0.000
BF. MHL vs. CZ. MHL		-0.82	0.089		-0.97	0.005
BF. MHL vs. CZ. LL		-0.10	0.873		-0.21	0.741
BF. LL vs. CZ. LL		0.30	0.624		-0.21	0.741
BF. LL vs. CZ. MHL		-0.72	0.172		-0.97	0.005
CZ. MHL vs. CZ. LL		0.36	0.553		0.13	0.833

Note. The left-most column shows comparison of two groups at a time according to the following parameters: tension, anisotropy; Spearman's rank correlation coefficient (r_s) and respective probability (p (r_s)) are provided for each pair.

Cells highlighted dark- grey show high probability of strong correlation of respective parameters between the study groups. Light-grey highlighted parameters indicate significance of correlation.

Earlier studies of marking features were done by K. Zub (Zub et al., 2003) and also had shown high importance of seasonal periods in the life cycle of the wolf pack. Usage of asphalt roads is normal feature for predators in Chornobyl Zone (Shkvyria, Vishnevskiy, 2012).

As much as the total route length and size of the field in groups of territories are different, on the basis of the results of the research the tensions and anisotropies for each category in groups of territories were calculated (table 2).

According to table 3, a high significant strong correlation in tensions and anisotropies between Medium-high-level and Low-level territories of Białowieża Forest was found, as well as for the anisotropies of Medium-high-level and low-level territories of Białowieża Forest and medium-high-level territories of Chornobyl Zone.

Table 4. Reactions for different groups of the studied territories for each day of experiment, December–January of 2014–2015

	Categories	Days						$\Sigma R_{(n)}$
		1	2	3	4	5	6	
					LL			
Reactions	I	2	1	3	2	3	1	12
	II	2	10	6	7	5	13	43
	III	–	–	3	2	–	–	5
	IV	–	–	1	1	–	–	2
	V	–	–	1	1	–	2	4
	Σ (days)	4	11	14	13	8	16	66
	L	1.2	12.3	3.6	3.6	13.1	17.8	ΣL = 51.6
					MHL			
Reactions	I	1	1	2	–	–	–	4
	II	3	1	3	1	–	–	8
	III	2	1	–	–	–	–	3
	IV	1	–	–	–	1	–	2
	V	3	1	3	1	–	1	9
	Σ (days)	10	4	8	2	1	1	26
	L	1.1	2.6	1.2	12.3	0.9	3.6	ΣL = 21.7

Note. I–V — categories of objects; MHL — medium-high-level territories; LL — low-level territories; Σ (days) — summation of the values in variables per day of tracking; $\Sigma R_{(n)}$ — general sum of reactions per category; L — route length, km.

Tension in groups of Białowieża Forest (MHL, LL) correlates with the medium-high-level group of the Chornobyl Zone closely to significance. Similarity of conditions in the territories with different anthropogenic level of load in Białowieża Primeval Forest, and similarity of aforementioned territories with Medium-high level territories of the Chornobyl Exclusion Zone related to the tension (and, respectively, the reactions of the chosen species) due to the different distribution of anthropogenic load and objects of environment in both types of territory in Białowieża Forest.

Probably, absence of significant results in other groups (white cells in table 3) was combined with constrained character of distribution of objects in categories. Since there are limits to Spearman's rank correlation coefficient regarding the sample size, correlation strength cannot be considered for these ranks.

A negative Spearman's coefficient expresses a negative trend of correlation.

Thus, significant results show that there are no dependence between the characteristics of the territory and the differences between the behavior of wolves in the Białowieża Forest (conservation status of the species) and the Exclusion Zone (game status). Thus, the main factors that regulate the activity of wolves are not in the level of anthropic load and hunting pressure, but in periods of the life cycle and a spatial structure of groups.

Hence, by ignoring such factor as the conservation status of the specie, we've decided to carry out a separate stage of research focusing on overtime movements on the territory during the period of highest interest — December–January. We were interested in the time

Table 5. Calculated tension for each day of second period

Categories		Days						$\Sigma T_{(n)}$
		1	2	3	4	5	6	
LL								
Tension (T)	L	1.20	12.30	3.60	3.60	13.10	17.80	$\Sigma L = 51.60$
	I	1.67	0.08	0.83	0.56	0.23	0.06	0.23
	II	1.67	0.81	1.67	1.94	0.38	0.73	0.83
	III	0.00	0.00	0.83	0.56	0.00	0.00	0.10
	IV	0.00	0.00	0.28	0.28	0.00	0.00	0.04
	V	0.00	0.00	0.28	0.28	0.00	0.11	0.08
	Σ (days)	3.33	0.89	3.89	3.61	0.61	0.90	$\Sigma T_{(I\text{-}V)} = 1.28$
MHL								
Tension (T)	L	1.1	2.60	1.20	12.30	0.90	3.60	$\Sigma L = 21.70$
	I	0.91	0.38	1.67	0.00	0.00	0.00	0.18
	II	2.73	0.38	2.50	0.08	0.00	0.00	0.37
	III	1.82	0.38	0.00	0.00	0.00	0.00	0.14
	IV	0.91	0.00	0.00	0.00	1.11	0.00	0.09
	V	2.73	0.38	2.50	0.08	0.00	0.28	0.41
	Σ (days)	9.09	1.54	6.67	0.16	1.11	0.28	$\Sigma T_{(I\text{-}V)} = 1.20$

Note. MHL — medium-high-level territories; LL — low-level territories; 1–6 — days of tracking; L — route length, km; Σ (days) — summation of the values in variables per day of tracking; $\Sigma T_{(n)}$ — general sum of tensions per category.

pattern of animal interactions with different object on territories with a different degree of anthropogenic transformation.

According to research findings of the second stage in Białowieża Primeval Forest 92 drives with the total distance of 101.6 km and total covered land of track of 73.3 km were reported. Findings of the second stage are presented in table 4.

Also calculated data for the following table on the field intensity for 12 tracks routes from second period of study were collected (table 5).

Spearman's rank correlation coefficient between two groups LL and MHL was 0.40 with p (r_s) 0.50. In this case it's not feasible to suggest whether the correlation actually exists.

Upon closer observation of pack's movements during the switch of two different functional periods animals appeared to join into groups with the beginning of winter hunting and estrus.

Categories of areas attributed to animal movements during the observation period varied. As mating season approached the number of area categories on territories with a high/average level of anthropogenic transformation decreased (table 5, group MHL"), and on territories with a low level of anthropogenic transformation closer to family territories remained high (table 5, group "LL") Average intensity ranges during the observation period were almost the same for both territories with low and average/high level of anthropogenic transformation — 1.28 and 1.20, the difference made up about 6.7 %.

In general, high degree of movement was a common for animal behavior, as seen by the amount tensions separately on days of the experiment (table 5), once again supporting the assumption that seasonality and the period-specific pack life are the key factors defining movements and the use of functional territories.

The analysis of feces in BF showed that the most part of feces includes rests of the red deer (more than 65 %), wild boar, elk, mice's, apples from apple orchards, green parts of plants and insects.

The study of wolf ration in CZ during 2002–2013 showed that in general it is typical for this part of Ukraine (Shkvyrya and Kolesnikov, 2008). Worth noting is a small share of anthropogenic food (mostly domestic animals) in the diet and minor differences in the forest region as a whole in the share of a wild boar (Shkvyria and Vishnevskiy, 2012). Feces were analyzed in 2009–2013 and showed the prevalence of the wild boar and roe deer in wolf ration.

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