Koshev Y. 2009. Distribution, isolation and recent status of European ground squirrel (*Spermophilus citellus* L.) in Pazardzhik district, Bulgaria. – *Annual of Shumen University "Konstantin Preslavsky", Faculty of Natural Sciences*, Vol. XIX B6: 97-109. ISSN: 1311-834X [In English with Bulgarian summary]

DISTRIBUTION, ISOLATION AND RECENT STATUS OF EUROPEAN GROUND SQUIRREL (*SPERMOPHILUS CITELLUS* L.) IN PAZARDZHIK DISTRICT, BULGARIA

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ABSTRACT

Distribution, connectivity, isolation and major threats to European ground squirrel (*Spermophilus citellus*) in Pazardzhik district have been investigated. We have found 55 colonies, ten of which were inactive. The biggest part (67.3%) of colonies occurred in lowlands up to 300 m. Probably the habitats around rivers Maritza, Topolnitza and Luda Yana represented dispersal corridors for the species. The average distance of active European ground squirrel colonies was 3.25±1.4 km and 5.95±2.37 km of inactive ones. The isolation (t =3.51, $p<0.01$, d.f.=53) and connectivity (t=4.07, $p<0.01$, d.f.=53) indices were significantly different between active and inactive colonies. The main cause for colonies extinction probably was the destruction of the natural dispersal corridors between colonies with high Isolation index. Probably this factor had a stronger influence on the colonies with small area and population density.

***Key words*:** European ground squirrel/ souslik, *Spermophilus citellus*, distribution, connectivity and isolation index

РАЗПРОСТРАНЕНИЕ, ИЗОЛАЦИЯ И СЪВРЕМЕНЕН СТАТУС НА ЕВРОПЕЙСКИЯ ЛАЛУГЕР (*SPERMOPHILUS CITELLUS*) В ПАЗАРДЖИШКА ОБЛАСТ, БЪЛГАРИЯ

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РЕЗЮМЕ

Изследвани са разпространението, свързаността и изолацията между колониите на Европейския лалугер (*Spermophilus citellus*) в Пазарджишка област и главните заплахи за вида. Открити са 55 колонии, 10 от които са неактивни. По-голяма част от колониите (67.3%) се намират в низината до 300 м н.в. Вероятно хабитатите намиращи се около реките Марица, Тополница и Луда Яна са естествените биокоридори за вида. Средното разстояние между активните лалугерови колонии е 3.25±1.4 км и 5.95±2.37 км между неактивните. Изолационния индекс (t=3.51, $p<0.01$, d.f.=53) и индекса на свързаност (t=4.07, $p<0.01$, d.f.=53) са достоверно различни между активните и неактивните колонии. Главна причина за изчезването на колониите вероятно е разрушаването на естествените коридори за миграция между колониите с висок изолационен индекс. Вероятно този фактор има по-силно влияние при колонии с по-малка площ и популационна плътност.

Ключови думи: Европейски лалугер, *Spermophilus citellus,* разпространение, индекси на свързаност и изолация

INTRODUCTION

The concept of metapopulation has served as a basis of many theoretical and empirical studies on the effect of habitat fragmentation on populations. The three major components of the metapopulations dynamics are: 1) process of local extinction; 2) movements between patches and 3) process of the colonization. All the three depend on landscape structure and dynamics [1]. Some species are very vulnerable to habitat destruction and interruption of natural corridors between matapopulations.

The European ground squirrel/souslik (*Spermophilus citellus* L.) is one of these species, it is endangered worldwide and its area in Europe constantly decreases. Because of its conservation status is unfavorable (Bern Convention- Appendix II; European Community Directive 92/43 - Appendix II and IV; Bulgarian Biological Diversity Act - Appendix II) and it is included in the IUCN Red List with status vulnerable. The main threats to this species are the conversion of steppe-grassland and pasture to cultivated fields or forestry [2]. The habitat loss and degradation because of the extending agriculture is considered to be the main threatening factor of European importance. At the same time there is absolutely no information about the species condition in Bulgaria, about the territories it inhabits and threatening factors.

Pazardzhik district combines almost all typical habitats (plain and mountainous) of the European Ground Squirrel (**EGS**) in Bulgaria. At the same time this region is expected to be one of the most intensified agricultural regions of the country after Bulgaria became an EU member [3].

Therefore our objectives were to assess the current distribution, isolation and connectivity between colonies of the EGS in Pazardzhik district (Bulgaria) and to evaluate factors that may influence the size and activity of EGS's colonies.

MATERIAL AND METHODS

Study area. Pazardzhik district is situated in the central part of South Bulgaria and covers over 4458 км^2. Bigger part of its territory is woodland (56.07%) and 36% are agriculture lands. The district includes parts of mountains Rila, West Rhodopes, Sredna Gora and

Thracian valley and represents a natural eastern corner of Thracian EGS population in Bulgaria [4]. The climate is moderately continental in lowlands and mountainous in east slopes of Rila and the high parts of West Rhodopes. The average annual temperature is 11.3°C. The surrounding mountains form a "precipitation shade" and the annual precipitation sum is 550 mm (the average for Bulgaria is 650 mm).

Only for a period of five years (1997-2001) the pasture territory has decreased from 25.33% (1997) to 20.09% (2001). They represent semi-natural grasslands with large biological diversity of vegetation and important habitats for protected animals. At the same time the area of cultivated lands has increased from 60.74% (1997) to 65.35% (2001) [3].

Pazardzhik district was chosen as a model studied area because of following causes: EGS is distributed in habitats with various landscapes (plain, semi-mountain and mountain) and different type of agriculture, mostly intensive. Regional agencies of the Ministry of Environmental and Water, the Ministry of Agriculture and Food etc., which are among the decision makers in the field of biological diversity, are presented in the district as a separated administrative unit. In this way the results of the present study could be used as a basis for future monitoring of distribution and threats for EGS not only in Pazardzhik district, but all over Bulgaria.

Field study. In Central and Southeastern Europe EGS occurs in loosely structured populations, or "aggregations" as Armitage (1981) termed them. In Landscape ecology this aggregations are called local population (or only population, subpopulation, deme). This is a set individuals that live in the same patch and are thus in interaction [1]. In Bulgaria these EGSs local populations popular are named colonies and we use the term "colony" without the social and behavior features.

We estimated the range of EGS colonies from literature, field accounts from biological surveys, personal communications with field biologist, and specimens from museum collections. During the period 2005-2008 we verified historical localities by visiting them once or several times and looking for new localities.

A database of the records included in present study was consigned to conception for conservation of EGS's habitats in

NATURA 2000 [6]. We took the GPS coordinates with Garmin *e*Trex Legend and classified colonies as active (EGS present) and inactive (only old moulds and blocked burrows observed).

Local topography, altitude, and land-use patterns according to Corine Land Cover 2000 code were determined. We used GIS software (AcrView GIS 9.2, ESRI) for estimation of distance between colonies. We assessed the colony density using transects (with counting of souslik holes) and visual methods [6]. In order to make our results more easily applicable for different type of National Monitoring Biodiversity schemes and according to Bulgarian conception for conservation of EGS's habitats in NATURA 2000 zones [6] we classified the relative colony EGS abundance into four categories (with our complement): **A**: 100–15 individuals/ha; **B**: 14–2 individuals/ha; **C**: <2 individuals/ha; **D**: insignificant (only single individuals and/or holes observed over all the surface of the studied localities; **E**: none (without EGS or active holes) [6].

We considered the dispersal corridors as linear landscape elements, near which there are or were situated EGS colonies without topographic or vegetative barriers.

Statistics. We calculated indices of isolation and connectivity for each active and inactive colony using following formulas:

$$\text{Isolation of the colony } (r_i) = \frac{1}{n}\sum_{j=1}^{j=n} d_{ij} \ ;$$

$$\text{Connectivity of the Patch } (a_i) = \sum_{j=1}^{j=n} d_{ij}$$

where n is number of neighboring colonies considered and d_{ij} is the distance between the nearest edges of colony i and any colony j [7].

We included only active colonies as possible neighbors for each active colony, but we included all colonies as possible neighbors for each inactive colony. In all cases we included in the calculations only distances among local populations not separated by current topographic or vegetative barriers. In order to describe the past and recent species distribution, threat factors and possible conflicts we used questionnaires with 62 local people.

A comparison of active versus inactive colonies with regard to mean isolation, connectivity and altitude was carried out using

Student's *t*-tests. All the analyses were performed by Statistic for WINDOWS 7.0. Release 2004. StatSoft.

RESULTS AND DISCUSSION

Distribution. EGS occurs in East Rila and Sredna Gora mountain, Thracian valley and doesn't occur in West Rhodopes. We have found 55 EGS's localities in Pazardzhik district. Ten of them are inactive (in comparison with previous data or questionnaires) or disappeared during the period of investigation (Fig. 1). There could be some existing colonies that we have not found.

Distribution in regard to altitude and land-use. The lowest colony was situated at 117m a.s.l. and the highest one (№53) - above 2500m a.s.l. (Belmeken peak, Rila Mountain) with average altitude of 2200m a.s.l. The biggest part of the colonies was found in lowlands: at 100 – 300m a.s.l. – 37 (67.3%), at 300 – 600m a.s.l. – 12 (21.8%), 600 – 1000m a.s.l. – 4 (7.27%) and above 1000m a.s.l.– 2 (3.63%). Most of them were situated in pastures – 48 (87.27%); only 4 (7.28%) in agriculture fields; and 3 (5.45%) in urban territories. The three urban territories were located within Pazardzhik city including the city park "Ostrova".

Core areas and dispersal corridors. The main core areas were in the region of the Ovchepoltzi hills, Besaparski hills and East Rila Mountain. The half of the colonies – 28 (51%) were near (less than 2.00 км) one of the three major rivers in the district. Close to Maritza river were situated 16 of them (29.1%), near Luda Yana river – 6 (10.9%) and near Topolnitza river – 6 (10.9%). Thus the habitats along rivers appear to be the only dispersal corridors for species in district. Probably this is due to the land type use in Thracian valley. There are many private vegetable gardens, orchards, vineyards, etc. in this region, which are intensively irrigated. Thus the only suitable habitats for the species are the public and municipal lands near a river, which are not cultivated (in many cases used as pastures). This situation is abnormal for a species vulnerable mostly to floods [8].

Relative population density. Only tree local populations belong to category ***A*** (5.45%), 20 to category ***B*** – 36.36%, 26 to category ***C*** – 47.27%, 2 to category ***D*** – 3.65%, and in 4 (7.27%) we

didn't find EGS – category ***E***. The some from of categories **C** and **D** during investigation were despaired.

Isolation, connectivity, and altitude of EGS colonies. We found significant differences between isolation (t=3.51, P>0.05, d.f.=53) and connectivity (t=4.07, P>0.05, d.f.=53) of active and inactive colonies. The isolation index between active colonies in Pazardzhik district was in average 3.25km±1.44, whereas between inactive colonies it was 5.95km±2.37. The Connectivity Index for active colonies was 7.57±4.75 and 17.17±7.12 for inactive ones (Table 1). Although 8 of the inactive colonies were in semi-mountain habitats with many forests and others barriers, no differences between there altitudes were found.

Unfortunately the information about EGS's migration is insufficient. Zidarova (in prep.) had investigated the dispersal of semi-adults, and established an average distance of dispersal of 17.7m (n=17; range 6.4–25m), unfortunately on too small study plot with area only 0.4ha. Alivizatos & Goutner (1997) reported that in Northeastern Greece the average distance between 10 EGS's colonies in Evros region were 1.03 ± 0.40 km from one another (range 0.40-1.55 km). The situation was similar between colonies near Maritza river (on Greek: Evros river) in Pazardzhik district, where were the most number of EGS colonies in this region (figure 1). Hulova *et al*. 2008 assumed that the migrations of the EGS are possible, if there are not unsuitable characters of the surrounding landscape: i.e., fields, forests, highways, etc. The migration pattern is restricted by the EGS's biology and social structure of the colony.

Migration is possible, if the population is growing and the adjacent areas are suitable. A migration of a single individual is not considered to be successful. It could be expected that the migration pattern of EGS is very similar to those of *S. brunneus* – about 0.02–1.00 km [12] and *S. mohavensis:* 2.9km (0–6.23km) for males and 0.753km (0–3.862 km) for females [13].

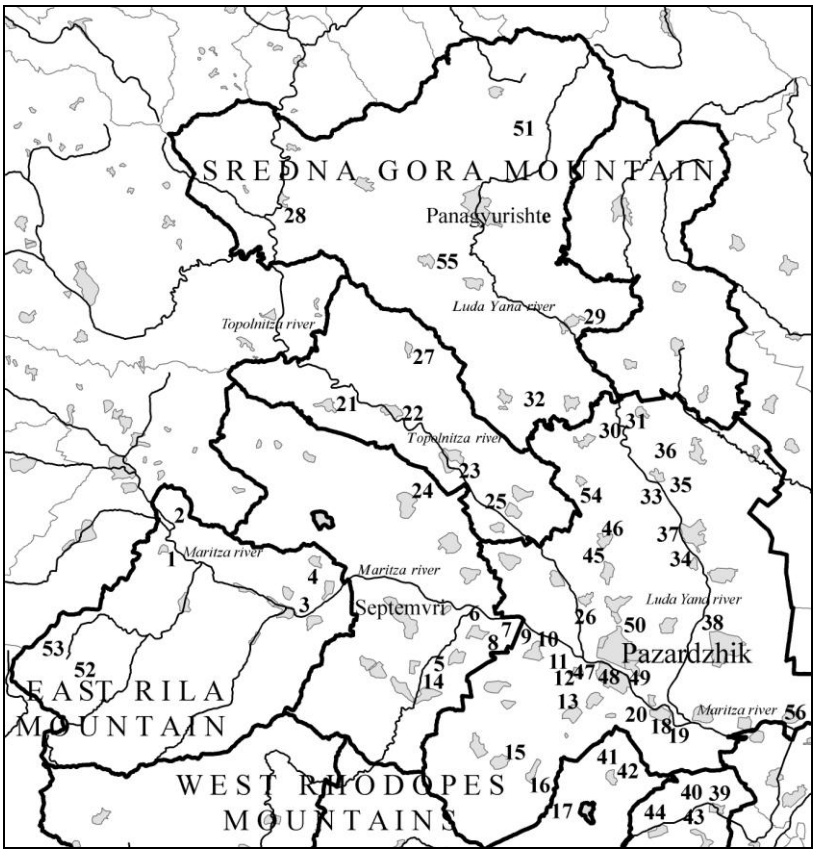

Figure 1. Distribution of European ground squirrel (*Spermophilus citellus*) colonies in Pazardzhik district, Bulgaria. Solid lines indicate district boundaries, slim line indicate major rivers and with gray indicate settlements. Colonies (with star – inactive): 1 – Menenkievo; 2 – Akandzhievo; 3 – Zlokuchene; 4 – Boshulia; 5 – Lozen; 6,7,8 – Kovachevo 1,2,3; 9,10,11 – Zvanichevo 1,2,3; 12 – Mokrishte; 13 – Alek. Konstantinovo; 14 – Vetren dol; 15 – Tzrancha; 16 – Debrashtitza; 17 – Radilovo; 18, 19 – Ogninovo 1,2; 20 – Sinitovo; 21* – Tzerovo; 22 – Lisichovo; 23* – Kalugerovo; 24 – Vinogradetz; 25 – Dinkata; 26* - Dragor; 27* - Borimechkovo; 28 – Poibrene; 29 – Popintzi; 30* - Sbor; 31* - Tzar Asen; 32* - Levski; 33 – Rosen; 34*

- Krali Marko; 35,36 – Ovchepotzi 1,2; 37 – Chernogorovo; 38 – Malo Konare; 39,40 – Izperihovo 1,2; 41,42 – Kap. Dimitrievo; 43 – Krichim; 44 – Biaga; 45,46 – Saraia 1,2; 47,48,49,50 – Pazardzhik 1,2,3,4; 51 – Panagyurski kolonii; 52 – Kurtovo; 53 – Belmeken; 54* - Apriltzi; 55* – Bania; 56 – Hadzhievo

Table 1. Means (± SD) and ranges of isolation, connectivity, and altitude of active and inactive European ground squirrel colonies. Test statistics comparing active versus inactive colonies also are presented

Character	Active colonies		Inactive colonies		Statistical comparison		
	$\bar{X}$ ±SD	Range	$\bar{X}$ ±SD	Range	*t*	P	d.f.
Isolation Index	3.25 ±1.4	1.53-7.67	5.95 ±2.37	2.58-11.17	3.51	<0.01	53
Connectivity Index	7.57 ±4.75	3.06-32.1	17.17 ±7.12	5.16-26.14	4.07	<0.01	53
Altitude	360.8 ±98.28	177-2200	370.4 ±136.9	217-615	0.21	>0.05	53

We think that the distance between EGS colonies in Bulgaria is very similar to the migration distance of other *Spemophilus* species. In the inactive colonies the average isolation index is 5.95±2.37, which could be considered as edge values in respect to the migration limits for species. The longest straight-line distance between East Rila mountain (№53 Belmeken and №52 Kutrovo) colonies and lowland colonies is above 19.00 km, with difference in altitudes of 1.7 km and forest barrier.

One of main highways – E 80 „Thrakia" passes across Pazardzhik district and there is not any animal migration equipment. This could become a serious problem not only for EGS migration, but for other species too.

Questionnaires. We have analyzed 62 interviews with local people with open field occupation. We inquired people of high expertise, who were working in the investigated region and had observations on habitat and EGS population changes: livestock experts, veterinary surgeons, agronomists, mayors of settlements, field biologists, shepherd, farmers, etc., independently of their age and gender. Most of the people (68.7%) declared that EGS doesn't cause any problems; 13.4% considered these animals responsible for damages in sown fields (in the villages Zvanichevo, Mokrishte, Ognianovo and Isperihovo), and 17.9% had no opinion. Relatively large part of the questioned people (48%) thought that there are less EGS that in the past, 34% of them didn't find any change in the population and 18% considered it more abundant. The local people in those regions, where the EGS disappeared, pointed several reasons: usage of chemical agents in agriculture (24%), decay of extensive livestock breeding (22%), intensive agriculture (20%), and 34% had no opinion.

As a whole, we didn't find any enduring negative attitude towards ground squirrels. The most people reckoned the EGS numbers notably decreased and charge with that equally the increased usage of chemical agents, pasture decay and intensive agriculture.

Threats. During the investigation 10 colonies have been found to become extinct because of chemical agents used (1 colony), ploughed up habitat (2 colonies), pasture decrease (3 colonies). For the rest 5 colonies no clear reasons were found. We suggested they

disappeared not because of direct impact (which in most cases is difficult to be established), but because of interruption of the natural dispersal corridors between the colonies in the regions with highest Isolation index.

The fact, that the colonies destroyed by the floods of 2005 are restoring now, confirms this suggestion. They, however, are situated on direct dispersal corridors of the species are recolonized after the habitat restoration. Our observations confirm the conclusions of Hoffman et al. (2003) about the extinction of this species in Austria. They explain this process by anthropogenic habitat alternations: sealing of soil and/or dispersal corridors, water regulation, landscape management (pasture and/or mowing) and intensive agriculture.

CONCLUSIONS

1. The European ground squirrel (*Spermophilus citellus*) distribution in Pazardzhik district is patchy. We found 55 colonies; ten of them were inactive (in comparison with previous data or questionnaires). The most part (67.3%) of colonies occurred in lowlands up to 300 m.

2. Probably the habitats around rivers Maritza, Topolnitza and Luda Yana represented dispersal corridors for the species.

3. The average distance between active colonies was 3.25±1.4km and 5.95±2.37km for inactive European ground squirrel colonies.

4. The isolation (t=3.51, $p<0.05$, d.f.=53) and connectivity (t=4.07, $p<0.05$, d.f.=53) indices were significantly different between active and inactive colonies.

5. The main cause for colonies extinction probably was the destruction of the natural dispersal corridors between colonies with high Isolation index. Probably this factor had a stronger influence on the colonies with small area and population density.

ACKNOWLEDGMENTS

I am very grateful to Miroslava Kosheva for essential help in field work. I would like to thank to: RIEW (MEW) – Pazardzhik district with expert Kiril Metodiev; Ivailo Nikolov and Svetoslav Velkov (BALKANI Wildlife Society); General Direction of NP “Rila”

and especially Park section "Belovo" with leader Elitza Vuchkova. The present study was supported by *Rufford Small Grants for Nature Conservation* and *Small Nature Management Projects (Matra/KNIP) Royal Netherlands Embassy*; and partly supported by grant *MU-B-1604/06 of* NATIONAL SCIENCE FOUND, Ministry of Education and Science of Bulgaria, and WORLD FEDERATION OF SCIENTISTS.

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