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SPATIAL HETEROGENEITY OF STEPPE BIRD COMMUNITY IN THE AZOV-BLACK SEA ENCLAVE OF THE EUROPEAN DRY-STEPPE ZONE (SOUTHERN UKRAINE)

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Spatial Heterogeneity of Steppe Bird Community in the Azov-Black Sea Enclave of the European Dry-Steppe Zone (Southern Ukraine). Andryushchenko, Yu. O. — Over the period 2007–2019, the author's censuses of steppe birds in the Azov-Black Sea dry-steppe enclave determined five species as dominants and co-dominants by their abundance. Thus, *Melanocorypha calandra* dominates throughout the whole area, *Emberiza calandra* dominates in 4 subregions and co-dominates in 5 subregions, *Motacilla feldegg, Emberiza hortulana, Anthus campestris, Alauda arvensis* dominate in 1 subregion and do not dominate or co-dominate in 1–4 subregions. There is a general increasing trend in the total abundance of steppe birds and the number of their rare breeding species from north-west to south-east, whereas the number of their dominants and co-dominants grows in the opposite direction. According to the list, the correlation between the dominants/co-dominants and the number of rare breeding steppe species, it was revealed that the most valuable for the support of the steppe bird populations are subregions with the largest areas of virgin steppes (the Kerch Peninsula, Western and Central Crimea). The least important are the subregions with the highest degree of anthropogenic transformation (northern part of the Syvash region, western part of the Black Sea region) and the Lower Dnipro wetlands. Therefore, it is a high abundance of steppe birds and the maximum number of rare steppe species which should be a specific ornithological indicator of the status of zonal landscapes in the dry steppe zone (especially within protected natural areas of Ukraine) rather than general avian species diversity including introduced, invasive species, synanthropes, etc.
Key words: steppe bird community, abundance, spatial distribution, European dry-steppe zone, Ukraine.

Introduction

The dry steppes of Ukraine are the westernmost limit of the dry-steppe zone of Europe, separated from its continuous stretch by the steppe zone and the Sea of Azov (Kryvulchenko, 2005; Pashchenko, 1999; Perelman, 1975). The avifauna of this Azov-Black Sea enclave has been barely surveyed from the viewpoint of an integral natural area. Indigenous steppe bird the least studied, in particular (Andryushchenko & Diadicheva, 2020; Andryushchenko, 2021).

Given the geographical location (the area is partially enclosed by seas and mountains) and the landscape features (large stretches of marine and river wetlands, extensive unploughed steppes, landscape inversion, etc.), this enclave is divided into the subregions that differ significantly according to the availability and distribution of dominant landscapes (Andryushchenko & Vorovka, 2022) and, presumably, by the structure of their bird community. This article is the first attempt to investigate the spatial heterogeneity of the steppe bird community in the Azov-Black Sea enclave of the dry-steppe zone of Europe during the spring and summer seasons and to determine the importance of some of its subregions for the support of steppe avifauna.

Material and methods

Ornithologists of Southern Ukraine traditionally divide the studied area into several subregions (Chernichko et al., 1993), generally corresponding to standard physical-geographical zoning of the dry steppe zone within Ukraine (Popov et al., 1968; Podgorodetskii, 1988; Marinich et al., 1985) but having a slightly different configuration from the ornithological point of view (Andryushchenko & Vorovka, 2022): the northern part of the Black Sea region (Left-bank and Right-bank in relation to the Dnipro River, or further in the text RB Prychornomoria and LB Prychornomoria, respectively), the Lower Dnipro (Lower Dnipro), the northern part of Syvash region (N Prysyvashshia), Syvash, north-western part of the Azov Sea region (NW Pryazovia), Western Crimea, Central Crimea, the Kerch Peninsula (Kerch Peninsula), the foothills of the Crimean mountains (Foothills) (fig. 1). The only exception among these subregions is Syvash, the largest and almost isolated bay of the Sea of Azov, which, together with its adjacent depressions, salt marshes, lakes and land between them, makes up a single wetland (Chernichko et al., 1993). Compared with the adjacent areas, this witland is more valuable for the support of the avian populations (both water and terrestrial species) and thereby represents an integral subregion from an ornithological viewpoint.

Currently, the dry-steppe enclave is dominated by agrolandscapes — territorial natural-anthropogenic systems, which (in addition to arable lands) integral components are the integral components are transformed steppe vegetation, predominantly chestnut soils, mostly salty surface groundwater in the lowlands, and various anthropogenic objects — field protection forest belts, field roads, pastures, hayfields, and engineering systems (for drainage, irrigation, watering and mixed ones), etc. (Andryushchenko & Vorovka, 2022). The subregions of the Azov-Black Sea dry-steppe enclave differ in the availability and sizes of agrolandscapes as well as remaining natural landscape components — coasts of sea bays and limans, gullies, various small bodies of water (lakes, rivers, streams, dry rivers) with natural and artificial vegetation on their slopes and shores (table 1).

The article is based on the results of the studying of the spatial heterogeneity of the steppe bird community in the Azov-Black Sea enclave of the dry-steppe zone of Europe during the spring and summer seasons in 2007–2020. The area was surveyed from a moving car along shuttle (zigzags) transects within squares of 10x10 km (fig. 1) making frequent stops and observing the area with 10–12-x binoculars and a 30-x telescope.

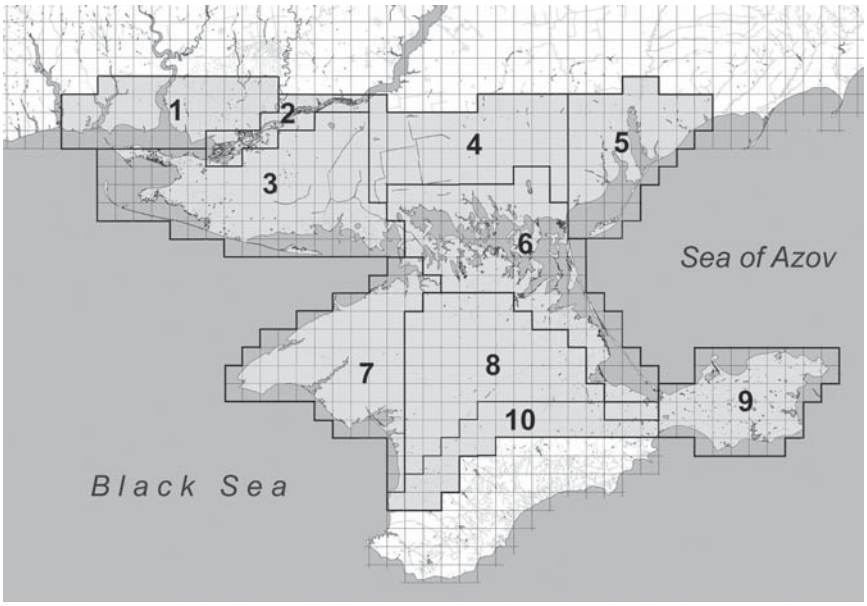

Fig. 1. Division of the Azov-Black Sea dry-steppe enclave into count squares of 10x10 km and subregions: 1 — RB Prychornomoria, 2 — Lower Dnipro, 3 — LB Prychornomoria, 4 — N Prysyvashshia, 5 — NW Pryazovia, 6 — Syvash, 7 — Western Crimea, 8 — Central Crimea, 9 —Kerch Peninsula, 10 — Foothills.

This technique allowed obtaining information on the abundance and distribution of birds rapidly, simultaneously covering different habitats and landscapes as well as individual subregions. In open landscapes, the birds are better recorded on automobile routes (Cheltsov-Bebutov, 1959) with a broken trajectory, due to higher representativeness of transects and comparability of results than in the control sites, thus making them the closest to random sample distribution (Ravkin, Livanov, 2009). The routes were selected freely, not in homogenous habitats (like forest tracts), or areas adjacent to them (the shores of large water bodies), which made it possible to equally count birds from different ecological groups. According to I. B. Volchanetskii (1940), N. A. Gladkov (1950), M. M. Drozdov (1963) and K. P. Filonov (1972), all birds were recorded, irrespectively to the character of their stay (breeding, post-breeding), migrating, nomadic, etc.), in all landscapes and habitats (agricultural fields, forest belts, pastures, hayfields, fallows, ravines, small water bodies, small planted forests, field roads, small villages, etc.). The total length of census routes constituted 6285.3 km.

The term "bird community" has several meanings, but this study uses its chorological meaning — a set of individuals of all species of birds registered in the studied geographical subdivision (natural boundary, landscape, zone, etc.) (Voronov, 1963). Dominant and co-dominant species were determined based on the abundance of steppe birds recorded on automobile routes (ind./km). Dominants were species which numbers exceeded 20 % of all the recorded birds in each subregion, and co-dominants — species which was 5–20 %. Subregions were compared according to the abundance, the number and list of dominant and co-dominant species, and by the number of rare steppe bird species (Red Book of Ukraine, 2009) using the Jaccard coefficient and cluster analysis in the "Past" program.

Taxonomy and scientific names of birds are given according to L. S. Stepanian (2003).

Results and discussion

Among 42 species of steppe birds which, according to M. A. Voinstvenskii (1960), belong to ornitho-faunal complexes of dry and wet steppes (i. e., inhabit open steppe landscapes), the dry-steppe enclave currently holds 23 representatives: two species of Falconiformes (*Circus pygargus* (L., 1758), *Buteo rufinus* (Cretzschmar, 1827)), two — Galliformes

Table 1. Characteristics of subregions of the Azov-Black Sea dry-steppe enclave that determine spatial heterogeneity of its bird community

N	Subregions	Features of relief, soils, hydrology or man-made objects characterizing zonal landscapes	
		natural	artificial
1*	RB Prychornomoria	Rivers, gullies, limans, rocky soils	A zone of permanent recreation, water reclamation systems **
2	Lower Dnipro	Watercourses, islands, coastal slopes and cliffs	A zone of permanent recreation
3	LB Prychornomoria	Sand areas, wet depressions (*sagi)* ***, coastal slopes, spits, islands	Planted forests, water reclamation systems, rice paddies
4	N Prysyvashshia	Flat-bottom depressions (*pods*) ****, dry watercourses (*sukhorichchia*) *****	Water reclamation systems
5	Syvash	Salt marshes, spits, peninsulas, islands	Ponds, dykes, artesian wells, water reclamation systems, rice paddies
6	NW Pryazovia	Rivers, gullies, limans	A zone of permanent recreation, water reclamation systems
7	Western Crimea	Dry gullies, coastal cliffs, rocky soils	Open-pit mines, water reclamation systems, a zone of permanent recreation
8	Central Crimea	Dry gullies, rocky soils, dry riverbeds, river valleys	Open-pit mines, water reclamation systems
9	Kerch Peninsula	Dry gullies, rocky soils, dry watercourses (*sukhorichchia*), lakes, coastal cliffs	Open-pit mines, water reclamation systems, a zone of permanent recreation
10	Foothills	River valleys, cliffs, rocky soils	Planted forests, open-pit mines

* Figures correspond to those in fig. 1; ** water reclamation systems — irrigation and drainage canals along with associated dykes, bridges, roads, pumping stations, power lines, forest belts, etc.; *** wet depressions (*sagi*) — enclosed depressions on sand areas with wet bottoms, sometimes with fresh or salt lakes surrounded by reed-marsh and tree-bush vegetation; **** flat-bottom depressions (*pods*) — enclosed depressions with a flat bottom, from several dozens of meters to 10 km in diameter, covering up to tens and thousands square meters; ***** dry watercourses (*sukhorichchia*) — valleys with temporary watercourses forming after a significant amount of precipitation or rapidly melting large amounts of snow.

(*Perdix perdix* (L., 1758), *Coturnix coturnix* (L., 1758)), four — Gruiformes (*Anthropoides virgo* (L., 1758), *Otis tarda* (L., 1758), *Tetrax tetrax* (L., 1758), *Burhinus oedicnemus* (L.,1758) (some experts (Lowe, 1931; Yudin, 1965; Kozlova, 1951), argumentatively regard this species as Gruiformes, not Charadriiformes), one — Strigiformes (*Asio flammeus* (L., 1758)) and fifteen species of Passeriformes, among which five larks (*Galerida cristata* (L., 1758), *Calandrella cinerea* (Gmelin, 1789), *Calandrella rufescens* (Vieillot, 1820), *Melanocorypha calandra* (L., 1766), *Alauda arvensis* (L., 1758)), one — pipit (*Anthus campestris* (L., 1758)), one — wagtails (*Motacilla feldegg* (Michachelles, 1830), which was earlier considered to be Motacilla flava (L., 1758) and, therefore, absent from the list of M. A. Voinstvenskii), two — chats (*Saxicola rubetra* (L., 1758), *Saxicola torquata* (L., 1766), two wheatears (*Oenanthe oenanthe* (L., 1758), *Oenanthe isabellina* (Temminck, 1829)), and three — buntings (*Emberiza calandra* (L., 1758), *Emberiza hortulana* (L., 1758), *Emberiza melanocephala* (Scopoli, 1769)).

Melanocorypha calandra, according to their abundance, dominates throughout the entire dry steppe enclave, whereas *Emberiza calandra* dominates in three subregions (Lower Dnipro, LB Prychornomoria, Foothills) and co-dominates in all other subregions, except for NW Pryazovia (table 2). In counts, these two species constitute 80.8 % of the abundance of all steppe birds. Moreover, in RB Prychornomoria dominates *Motacilla feldegg*, and in the north-western part of the Azov Sea region — *Emberiza hortulana*. *Motacilla feldegg* also co-dominates in LB Prychornomoria, NW Pryazovia and Syvash, while *Emberiza hortulana* — in RB Prychornomoria, N Prysyvashshia and in Foothills. In some subregions, co-dominants are also represented by *Anthus campestris* (RB Prychornomoria and the Lower Dnipro) and *Alauda arvensis* (in Foothills).

In the light of the above, the current structure of the steppe bird community in the dry-steppe enclave in terms of their abundance and dominance/co-dominance in different subregions is determined by the following species (in decreasing order): *Melanocorypha calandra, Emberiza calandra, Motacilla feldegg, Emberiza hortulana, Anthus campestisis, Alauda arvensis*, which in total make up 90.06 % of the number of all the recorded species in this avifaunal complex. However, the structure and ratio of dominant and co-dominant species are not constant because their abundance may change over time, rather significantly for some species — up to their almost complete extinction in some subregions. For instance, among the 5 species of larks, currently the most numerous is *Melanocorypha calandra* and in one subregion — *Alauda arvensis*. In contrast, during the 1960–1970s, the prevailing species were represented by *Calandrella cinerea* and *Calandrella rufescens;* in recent decades, however, they occur only in some subregions (Popenko, 1979; Andryushchenko & Diadicheva, 2020). Moreover, the numbers of *Melanocorypha calandra* and *Emberiza calandra* are also decreasing, apparently as a result of the excessive use of various pesticides, often of dubious origin.

Table 2. Ranking of the steppe species of birds according to their abundance and dominance/co-dominance in different subregions of the Azov-Black Sea dry-steppe enclave

Species	Abundance, ind./km	% ind.	Number of subregions where the species dominates or co-dominates		
			dominating	co-dominating	total
Melanocorypha calandra	4.298	66.65	10		10
Emberiza calandra	0.919	14.26	4	6	10
Motacilla feldegg	0.195	3.00	1	4	5
Emberiza hortulana	0.193	3.02	1	4	5
Anthus campestris	0.122	1.90		2	2
Alauda arvensis	0.080	1.24		1	1
Dominating–co-dominating	5.808	90.06			
Other steppe species	0.641	9.94			

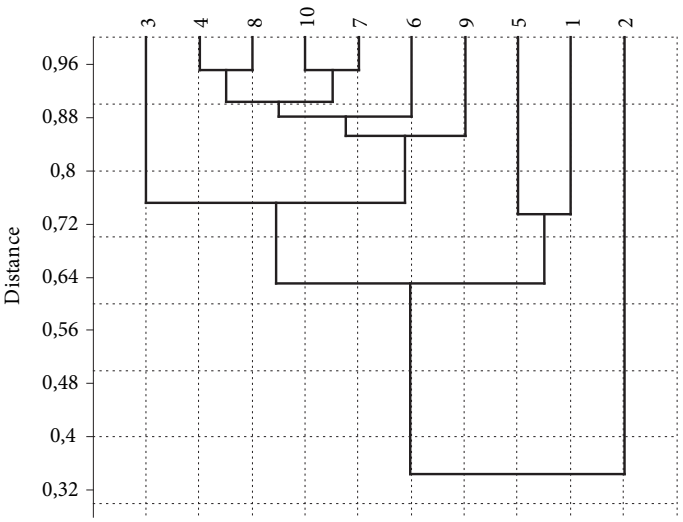

Fig. 2. Similarity of subregions of the dry-steppe enclave in the number of all steppe bird species: 1 — RB Prychornomoria, 2 — Lower Dnipro, 3 — LB Prychornomoria, 4 — N Prysyvashshia, 5 — NW Pryazovia, 6 — Syvash, 7 — Western Crimea, 8 — Central Crimea, 9 —Kerch Peninsula, 10 — Foothills.

Subregions with the largest areas of unploughed steppes, generally hold 1 dominating and 1 co-dominating species, and among them, a dominant *Melanocorypha calandra* is the most numerous: in Western Crimea — 8.815 ind./km, in Central Crimea — 4.234 ind./km and on the Kerch Peninsula — 6.325 ind./km. The largest number of dominants and co-dominants is observed in the subregions with the mildest climate: in RB Prychornomoria — 2 dominants and 3 co-dominants, in the Foothills — 2 dominants and 2 co-dominants. In the subregions with the highest degree of land cultivation and reclamation, the total abundance of dominants and co-dominants is the lowest (except for the Lower Dnipro): 3.220 ind./km in RB Prychornomoria, 2.923 ind./km in the northern part of Syvash region, and 2.983 ind./km in the north-western part of Azov Sea region. The most similar in terms of the number of all steppe species of birds are subregions that do not have large wetland areas (N Prysyvashshia, Western Crimea, Central Crimea, Foothills), and most of all — subregions with large wetlands (RB Prychornomoria, NW Pryazovia), especially the Lower Dnipro (fig. 2). The exception is the Sivash — a wetland area that has preserved significant amounts of steppe on islands, peninsulas and coastal shores.

In general, the steppe bird community of the Azov-Black Sea enclave have a quite vulnerable status as 9 out of 23 species, is listed in the Red Data Book of Ukraine (2009): *Circus pugargus, Buteo rufinus, Anthropoides virgo, Otis tarda, Tetrax tetrax, Burhinus oedicnemus, Asio flammeus, Calandrella rufescens, Emberiza melanocephala.* The representativeness of these rare species in the population of a specific subregion to some extent points to its value both in terms of supporting the community of steppe birds in particular and conserving the local avifauna as a whole. In general, in the dry steppe enclave, there is a general trend of increasing the total abundance of steppe birds and the number of rare steppe species from northwest to southeast. The maximum abundance of birds is in Western Crimea (11.218 ind./km), the highest number of rare species is on the Kerch Peninsula (n = 8). Obviously, this also corresponds to the degree of preservation of virgin steppes, which most extensive areas lay in the Crimea, in particular, its western and eastern parts. In terms of the number of rare steppe species, the greatest similarity is observed between N Prysyvashshia, Western Crimea, Central Crimea and Foothills, while RB Prychornomoria, NW Pryazovia and the Lower Dnipro are not identical (fig. 3).

Thus, *Melanocorypha calandra* is dominant in all subregions, there are some differences in the species structure and abundance of other five dominants and co-dominants, as

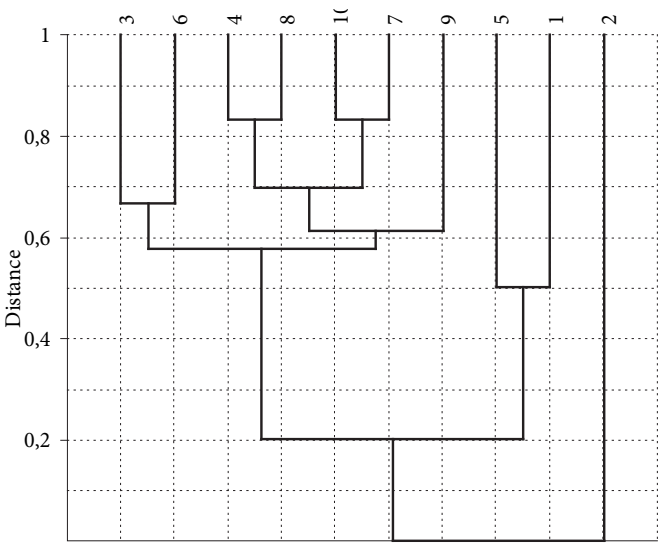

Fig. 3. Similarity of subregions of the dry-steppe enclave in the number of rare steppe bird species: 1 — RB Prychornomoria, 2 — Lower Dnipro, 3 — LB Prychornomoria, 4 — N Prysyvashshia, 5 — NW Pryazovia, 6 — Syvash, 7 — Western Crimea, 8 — Central Crimea, 9 —Kerch Peninsula, 10 — Foothills.

well as in the number of rare steppe species. Thus, with the exception of the Foothills, the highest similarity is observed among the Crimean subregions (Western Crimea, Central Crimea and the Kerch Peninsula) where *Melanocorypha calandra* is dominant, *Emberiza calandra* is co-dominant, and the number of rare steppe species is the highest among the enclave subregions (table 2). Syvash is also similar to these indicators, with the dominance of *Melanocorypha calandra, Emberiza calandra* and the co-dominance of *Motacilla feldegg*. Another similar subregion is LB Prychornomoria, where, in addition to the above-mentioned species, *Emberiza hortulana* also co-dominates. However, as for the rare species, Sivash has more in common with the Crimean subregions rather than LB Prychornomoria.

The next in the ranking, according to these indicators, are N Prysyvashshia and NW Pryazovia. The first is almost identical with the previous subregions in the number of dominant and co-dominant species, and the second has a higher number of rare species. The Foothills and the Lower Dnipro are a certain exception in this respect. Thus, the Foothills is the only subregion in which dominating *Melanocorypha calandra, Emberiza calandra* and co-dominanting *Emberiza hortulana* are also supplemented by a co-dominant *Alauda arvensis*; but instead, it has a higher number of rare species than the previous four subregions. The Lower Dnipro, with the dominance of *Melanocorypha calandra* and the co-dominance of *Emberiza calandra*, holds only one rare steppe species. So, according to the number of dominant–co-dominant and rare steppe species, the subregions of the Azov-Black Sea dry-steppe enclave are conditionally divided into 4 groups (fig. 4):

— "Western Crimea–Central Crimea–Kerch Peninsula" with the highest abundance of dominant and co-dominant species (4,898–9,513 ind./km), smallest their number (n = 2) and a significant number of rare species (n = 6–8);

— "Syvash — LB Prychornomoria — Foothills" with a moderate abundance of dominants and co-dominants (4,142–5,057 ind./km), small their number (n = 3–4) and the moderate number of rare species (n = 4–7);

— "N Prysyvashshia — NW Pryazovia — RB Prychornomoria" with the low abundance of dominants and co-dominants (3,102–3,464 ind./km), large their number (n = 4–5) and the low number of rare species (n = 4–5);

— "Lower Dnipro" with the lowest values of these indicators (0,646 ind./km, n = 3 and n = 1, respectively).

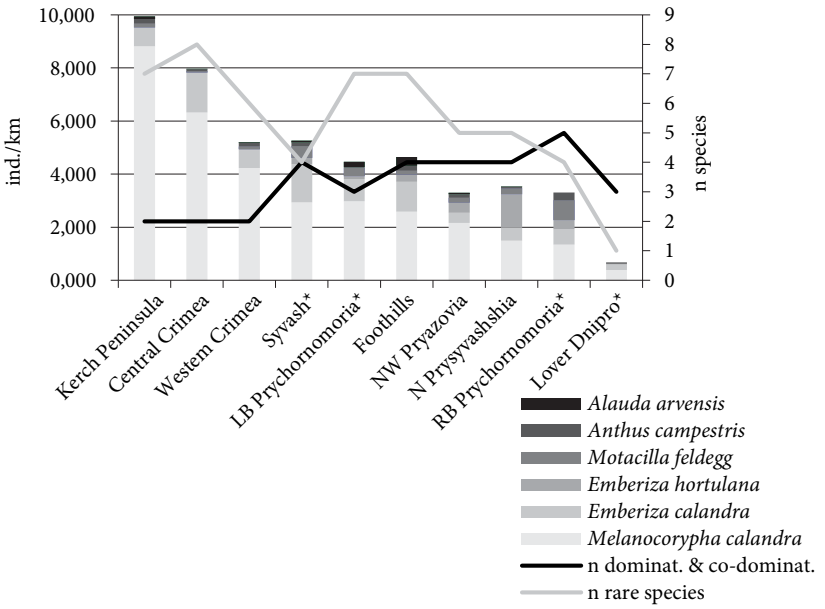

Fig. 4. Distribution of steppe dominants, co-dominants and rare steppe species (Black Book of Ukraine, 2009) by subregions of the dry-steppe enclave: * the largest areas in most count squares are covered by large bodies of water (seas and their bays, limans, the Dnipro floodplain).

The structure of the bird community somewhat reflects the landscape features of the subregions of the Azov-Black Sea dry-steppe enclave. Thus, the rocky steppes of the Crimea are the least transformed in the studied area. They have minimally suffered from destruction, afforestation, urbanization, flooding, desalination of reservoirs, etc. (anthropogenic load on them increased, but the landscape as a whole mostly remained steppe). The largest areas of such steppes with the least fragmented are concentrated in Western Crimea, in the south-western part of Central Crimea, in the Foothills and on the Kerch Peninsula. That is why the structure of the steppe bird community of these subregions are least suffered from deformation.

Steppes on the flat elevated areas (*plakor*s) of Central Crimea, N Prysyvashshia, RB Prychornomoria and LB Prychornomoria, NW Pryazovia are barely remained intact, and steppe bird species that could occupy agricultural fields are forced out by irrigation, rice cultivation, afforestation and horticulture, to the remaining steppe patches on the slopes of gullies and river valleys, on the islands of the limans and seas. The smallest steppes are in the Lower Dnipro region, where the area is predominantly covered by variety of water bodies and floodplain tree-shrub vegetation with the bank slopes almost entirely occupied by settlements, recreational facilities, planted forests, gardens and vineyards. Therefore, it is only natural that the Lower Dnipro has the lowest abundance and the lowest number of steppe birds, including rare species.

Conclusion

Such species as *Melanocorypha calandra, Emberiza calandra, Motacilla feldegg, Emberiza hortulana, Anthus campestris,* and *Alauda arvensis* dominate and co-dominate in the spring-summer season in the community of steppe birds of the Azov-Black Sea dry-steppe enclave. *Melanocorypha calandra* dominates throughout the entire study area, *Emberiza calandra* dominates in 4 subregions and co-dominates in 5 subregions, other mentioned species dominate in 1 subregion or do not dominate at all, and also co-dominate in 1–4 subregions. The subregions with the largest steppe areas (the Kerch Peninsula, Western and Central Crimea) are the most valuable for the support of the steppe community as they have the highest abundance and number of dominant and co-dominant species, and the highest

number of rare steppe species. The least valuable are the regions suffered from excessively man-made transformation (Syvash region, the RB Prychornomoria) and the Lower Dnipro.

Based on the above, it is a high abundance of steppe birds and the maximum number of rare steppe species which should be a specific ornithological indicator of the status of zonal landscapes in the dry steppe zone (especially within protected natural areas of Ukraine) rather than general avian species diversity including introduced, invasive species, synanthropes, etc. Additional indicators could be the representativeness and abundance of steppe species that do not currently nest but are accidental or not numerous migratory species within the Azov-Black Sea dry steppe enclave — *Circus macrourus* (Gmelin, 1771), *Aquila nipalensis* (Hodgson, 1833), *Oxyura leucocephala* (Scopoli, 1869), *Glareola nordmanni* (Nordmann, 1842), etc.

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