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Small Mammals in a Complex Assessment of Subarctic Ecosystems, Kamchatka Peninsula Case

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Abstract. The article provides assessment results of certain subarctic regions of the Kamchatka Peninsula (Parapolsky Dol, Bering forest tundra landscape complex) based on small mammals indicator characteristics. The integral fluctuating asymmetry index of binary nonmetric skull characteristics shows that the dominant species *Clethrionomys rutilus* population development in the flood-plains of the Ichiginnyvayam River, the Tylakrylvayam, on the shore of Lake Talovskoye is stable, and the environment quality is conditionally normal. Due to harsh weather conditions, the studied small mammal communities are characterised by low diversity indices and low sustainability. The studied communities diversity and evenness struture is similar to the same of unidsturbed ecosystems of Central and Southern Kamchatka, and Siberia.
Keywords: small mammals, developmental stability, «environmental health», community structure, species diversity, community sustainability.
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Introduction

Global average annual surface temperature and global precipitation are considered key weather indicators of climate change [1], and small mammals are used as an indicator animal group sensitive to direct and indirect – through vegetation cover change – influence of weather changes. This is the most numerous group of vertebrates in the Arctic and Subarctic terrestrial ecosystems consisting of small rodents and insectivores.

An important role of small mammals in studying how global and regional climatic changes influence biota, is reported in a number of peer-reviewed articles [2-15], and is corroborated by data on species composition, number of species, and space and biotopic distribution of this group of animals in the Eurasian Chronicle of Nature – Large Scale Analysis of Changing Ecosystems, a project of Helsinki University, registered in GBIF (https://www.gbif.org/publisher/d2b114bc-0fef-4d47-9af3-78392f8f7144) [16-17].

Long-term data from a number of Russian state nature reserves and research stations of the Russian Academy of Sciences show statistically significant influence of meteorological variables on population dynamics of certain species and on small mammals communities structure. For example, E. Ivanter and E. Moiseeva analysed changes in the Northern red-backed vole *Clethrionomys rutilus* Pallas, 1779 number in Karelia over 56 years (1958-2013). They found out that it has been at the lowest level over the recent decades [18]. The data confirm the idea that the South of Finland and South-West of Karelia are not a part of *Cl. rutilus* continuous range [18-19].

A.V. Bobretsov used data from Pechora-Ilych Nature Reserve and studied influence of 24 weather and phenological parameters on the number of bank voles (*Cl. rutilus, Clethrionomys glareolus* Schreber, 1780). He concludes that meteorological factors influence abundance of different red-backed voles' species diversely and mainly in mid-season (spring, fall). The 1989-2013 data reveal opposite trends in numbers of *Cl. rutilus* and *Cl.glareolus*. Against the background of considerable climatic changes, the former dominant species *Cl. rutilus* gave way to *Cl.glareolus*, a species better adapted to the new microlandscape and microclimate [2-3].

Yu.N. Litvinov studied changes of the dominance structure in the Western Siberia small mammals communities over the last decades [20]. He analysed data of 13-year (1978-1990) Baraba forest steppe observation, 15-year (1992-2006) Novosibirsk Academic Town forest park zone observation, and 21-year (1984-2004) Teletsk Region taiga observation, and showed long-term Shennon diversity index (H) change, that may be accounted for rather by community

dominance structure changes, than by long-term dynamics of community species number.

But it is worth pointing out that these regularities could be only tracked on long-term time-series data gathered at one and the same territory. But there is a question: what are the appropriate methods to assess the influence of global and regional climate change on the biota over a short term period?

Literature analysis shows that when we start investigating climate change influence on landscapes and biota at a certain new site, apart from the basic parameters of dynamic processes of ecological modelling and prediction, such as species composition, number, space and biotope distribution, and population structure of small mammals, the following parameters may be informative for integral assessment of environment quality: stability of certain species population development (population canalization), as well as integral indices of micromammal communities.

To study population canalization, scientists use phenetic methods based off discrete, alternative oligogenic morphological characteristics – phenes [21-26]. In small mammals, nonmetric scull characteristics (like extra foramina, or missing bone fragments, etc.) are considered to be phenes. According to methodological approach developed by the Koltzov Institute of Developmental Biology of Russian Academy of Sciences (Moscow, Russia) [27-33], the best population stability measure is an integral sample index of fluctuating asymmetry of binary morphological features. This index captures the level of accidental insignificant swerves in development, and is at minimum in case of optimum conditions, and is growing in stress. This measure is at the base of assessment scale of degree of environment deviation from the norm.

To assess small mammal's community health, it is possible to use methods of synecology. They help analyzing communities according to a standard pattern on the basis of the following criteria: species richness, distribution of community species number complying with a certain diversity model, comparison of dominance structure and sustainability of various communities as manifested in the indices [34-41].

All these define the purpose of this study, which is to assess condition of certain Kamchatka Peninsula ecosystems in the changing climate using integral population development stability index and a complex of integral indices characterising small mammals' comunities condition.

Materials and Methods

The material for this scientific investigation is small mammal censuses conducted from August 25 to September 15, 2017 on the Parapolsky Dol territory, one of the three sites of the Koryak Nature Reserve, Russia (60.975–61.775 N; 164.000–166.125 E). It is one of the largest protected wetland areas in the world.

The field study took place at the shore of Lake Talovskoye, in the the floodplains of the Tylakrylvayam and Ichiginnyvayam rivers (Fig. 1).

Figure 1. The map of the research areas: 1 – Lake Talovskoye shore; 2 – Ichigin-nyvayam River floodplain; 3 – Tylakrylvayam River floodplain

The animals were caught with snap traps arranged in trapping lines of 25-100 traps 16-23 ft (5-7 m) apart, with 164 ft (50 m) pitfall traps and 164-ft (50 m) fences with 5 cylinder traps 32 ft (10 m) away from each other [42-43]. All traps were baited with pieces of bread soaked in crude sunflower oil. Within each site, the traps were mounted in all types of habitats. Each habitat was described in terms of plant association dominants of each layer [44]: 1) Lake Talovskoye shore: *Pinus pumila* + *Betula middendorffii* (Pp+Bm); *Betula exilis* – *Ledum decumbens* + *Vaccinium uliginosum* – *Aulacomnium palustre* + *Dicranum majus* (Be-Ld+Vu-Ap+Dm); *Eriophorum polystachyon* + *Carex bigelowii* (Ep+Cb); *Pinus pumila purum* (Ppp); 2) Tylakrylvayam River floodplain: *Pinus pumila* + *Betula middendorffii* (Pp+Bm), *Salix pulchra* – *Eriophorum polystachyon* + *Carex bigelowii* (Sp-Ep+Cb); *Ledum decumbens* + *Vaccinium uliginosum* – Cladonia sp. + Cladina sp. (Ld+Vu-C+C); *Ledum decumbens* + *Vaccinium uliginosum* – Sphagnum sp.(Ld+Vu-S); *Eriophorum polystachyon* + *Carex bigelowii* (Ep+Cb); *Carex chordorhiza* + *Carex gynocrates* – *Sphagnum sp.* (Cc+Cg-S); 3) Ichiginnyvayam River floodplain *Chosenia arbutifolia* + *Populus suaveolens* – *Salix schwerinii* + *Salix udensis* (Cha+Ps-Ss+Su); *Ledum decumbens* + *Vaccinium uliginosum* – *Cladonia* sp. + *Cladina* sp. (Ld+Vu-C+C); *Ledum decumbens*

+ *Vaccinium uliginosum* – *Sphagnum sp.* (Ld+Vu-S); *Betula middendorffii* – *Sphagnum sp.* (Bm-S).

The methods used for trapping the animals are common in studies of mammals and are approved by the members of *Chronicle of Nature*, an international scientific cooperation network.

Over the total of 2735 trap days and 144 cylinder days, 120 animals were captured. On Lake Talovskoye shore, 51 animals were captured over 1235 trap days. In the Tylakrylvayam River flood-plain, 9 animals were captured over 750 trap days and 79 cylinder days. In the Ichiginnyvayam River flood-plain, 60 animals were captured over 550 trap days and 125 cylinder days. Standard methods for fauna and population and ecology research were used in laboratory study [43; 45-47]. In order to assess the environment quality (so-called environment health) we registered phenes of nonmetric scull features of the dominant species of small mammals, *Clethrionomys rutilus* Pallas, 1779. We used a diagram and a catalogue developed by A.G. Vasilyev et al. (2000, 2005, 2009) in the Institute of Plant and Animal Ecology, Ural Branch of Russian Academy of Scieneces (Ekaterinburg, Russia) (Fig .1) [23-24; 26]. The picture shows 35 phenes. The total of 66 sculls of *Cl. rutilus* were examined, including 46 of individuals captured at the Ichiginnyvayam River flood-plain, 17 – at the shore of Lake Talovskoye, and 3 – at the Tylakrylvayam River flood-plain. The arithmetic mean of the share of asymmetric features per individual was calculated, serving as the integral index of fluctuating asymmetry for the samples from different areas under investigation.

As per the approach of Yu. N. Litvinov [39], multidimensional star icon plots representing Shennon's (H) and Simpson's (D) diversity indices, and Shannon's (J) and Simpson's (E) evenness indices [39; 48] were used to qualitatively assess the information structure of the small mammals communities and their habitats. It is common knowledge that Simpson's diversity index (D) adds weight to species with higher abundance, while Shannon's diversity index (H) adds weight to low-numbered species [34-37]. The results of the study were analysed with the help of standard biometric methods. Statistic comparison is based off Student t-test [49].

Results and Discussion

According to the values of integral indices of fluctuating asymmetry (<0.35), all *Cl.rutilus* populations under study are stable, their habitat health is within normal (Table 1) [28].

In the surveyed habitats of Parapolsky Dol, we captured several small mammal species common for Northern Kamchatka, from Insectivora – *Sorex isodon* Turov, 1924, *Sorex caecutiens* Laxmann, 1788, from Rodentia – *Clethrionomys rutilus* Pallas, 1779, *Clethrionomys rufocanus* Sundevall, 1846, and the stenotopic species from Lagomorpha – *Ochotona hyperborean* Pallas, 1811, restricted to large boulders area.

In all research areas, snap-trap surveys have revealed that *Cl. rutilus* dominates in most biotopes, *S. caecutiens* and *Cl. rufocanus* co-dominate (Fig.2). According to cylinder surveys, the absolute dominant in the open habitats is *S. caecutiens*. This kind of dominance structure is characteristic of North-Eastern Eurasia. The highest abundance indices of all small mammal species, except for one stenotopic species *O. hyperborean,* were registered in the most drained habitats of Ichiginnyvayam River flood-plain (Bm-S); its lowest value was registered in the wettest habitats of low Tylakrylvayam River flood-plain (Ld+Vu-C+C; Ld+Vu-S) (Fig.2).

Table 1. Integral indices of fluctuating asymmetry of nonmetric skull features in Cl.rutilus samples from protected areas of Kamchatka Peninsula

Study Area	Number of Skulls	Integral index of fluctuating asymmetry
Ichigin-nyvayam River floodplain	n = 46	0.18±0.01
Tylakrylvayam River floodplain	n = 3	0.14±0.05
Lake Talovskoye shore	n = 17	0.16±0.02
Geysernaya River valley	n = 29	0.23±0.02
Uzon volcano caldera	n = 18	0.26±0.03
Lake Kuryl shore	n = 26	0.19±0.02

Note: The differences between the samples are statistically insignificant $p \geqslant 0.05$.

No animals were captured in the wetland on the shore of Lake Talovskoye (Ep+Cb) and the floodplain of the Tylakrylvayam River (Ep+Cb; Cc+Cg-S). At the edge of Sp-Ep+Cb plant association in the floodplain of the Ichiginnyvayam River we captured one young male of *S. caecutiens* in a pitfall trap, it can be considered a migrant. These facts evidence that area wetness is an important natural factor determining the spatial distribution and abundance of small mammals.

The small number of identified species and the numerical dominance of one or two species are conditioned by the habitats' low resource capacity due to a number of natural and climatic features (negative average annual temperature, high precipitation ratio, short summer) making the study area's climate very harsh. Therefore, all small mammal communities under investigation are characterized by low diversity, medium and high evenness indices.

Relatively higher diversity and sustainability indices are characteristic of the communities in certain habitats and, in general, of the small mammal community on Lake Talovskoye shore (Fig. 3, 4). This lets us consider the latter area to be key for biodiversity research and conservation as a part of complex ecological minitoring.

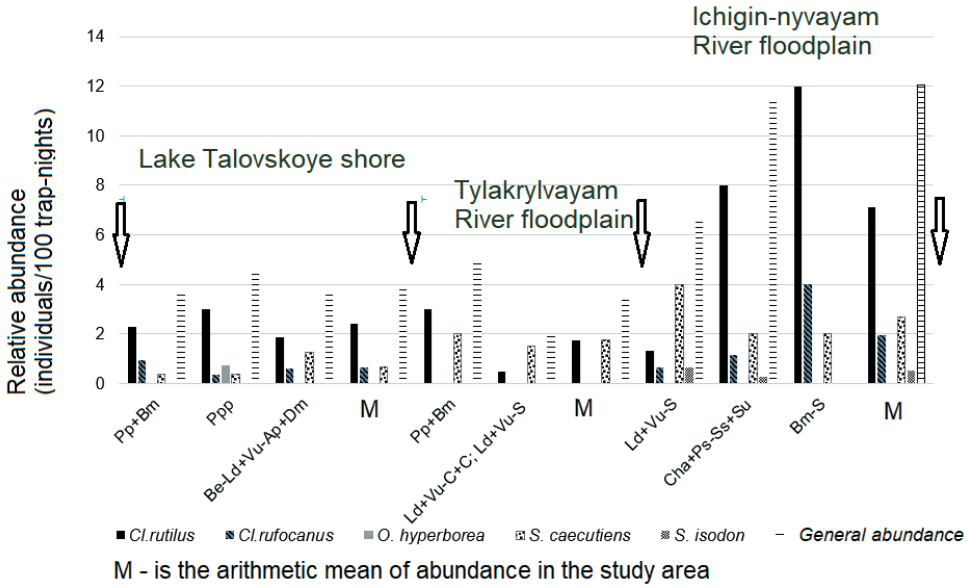

Figure 2. Relative abundance of small mammal species
on the surveyed sites in Parapolsky Dol

The star plots showing mean values of small mammal communities diversity and evenness indices for each investigatied area revealed identic structures of Lake Talovskoye shore and Ichiginnyvayam River flood-plain communities. In these star plots, Shannon's diversity indices are higher than Simpson's diversity indices indicating higher ratio of 'rare' species; and evenness indices are not very high. The small mammal community with low number of species from Tylakrylvayam River flood-plain differs from the other two by lower indices of species diversity, but at the same time by a considerably higher evenness (Fig.3).

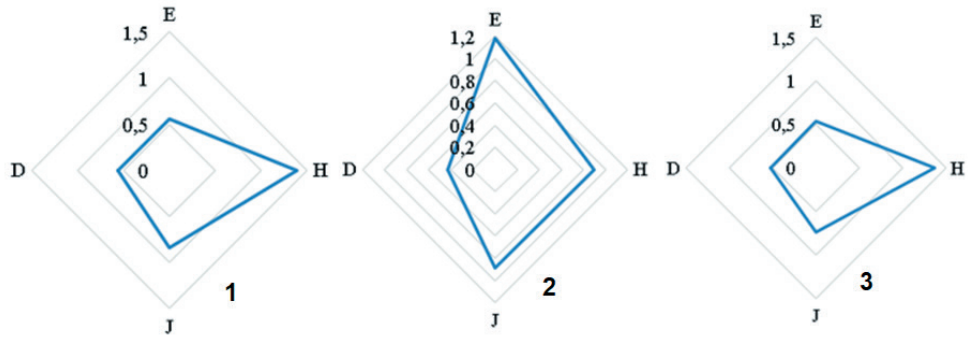

Figure 3. Icon Plots of Averaged Information Indices of Small Mammals Communities' Diversity: 1 — Talovskoye Lake Shores; 2 — Tylakrylvayam River Flood-Plains; 3 — Ichiginnyvayam River Flood-Plains

Mean values of Simpson's evenness index (E) show a statistically significant difference between the small mammal communities coming from different investigation areas: $E_{Talovskoye} = 0.56\pm0.04$; $E_{Tylakrylvayam} = 1.18\pm0.15$; $E_{Ichiginnyvayam.} = 0.54\pm0.07$ (Statistical comparison: Talovskoye-Tylakrylvayam — $t=5.11$, $p<0.05$; Tylakrylvayam-Ichiginnyvayam — $t=4.57$, $p<0.05$).

The shape of star plots representing small mammal communities inhabiting Lake Talovskoye shore and the Ichiginnyvayam River floodplain is comparable with that of open habitats of the Geysernaya River floodplain, the Uzon volcano caldera [50], as well as with undisturbed open habitats of Siberia, Taymyr Peninsula, and the Altai Mountains [39-40]. The reason behind that is that in these communities, small mammals' population of open habitats accounts for a bigger share in species diversity. These habitats include: lichen- and sphagnum-and-dwarf-shrub tundra (Be-Ld+Vu-Ap+Dm) and large boulders area (Ppp) on Lake Talovskoye shore; sphagnum-and-dwarf-shrub dwarf birch thicket (Bm-S), and lichen- and sphagnum-and-dwarf-shrub tundra on the Ichiginnyvayam River floodplain (Ld+Vu-C+C; Ld+Vu-S) (Fig.4).

The shape of star plots representing small mammals communities from the Tylakrylvayam River floodplain is different from those of Lake Talovskoye and the Ichginnyvayam River flood plain. It is elongated vertically, and is comparable to radar charts' shape of stone birch forests communities of the Geysernaya River floodplain, the Uzon volcano caldera, Kurile Lake shore, undisturbed forest communities of Siberia and the Altai Mountains [39-40]. The reason behind that is that in these communities, small mammals' population of floodplain cedar-and-birch ribbon forests accounts for the biggest share in their species diversity, and these communities are characterized by a higher evenness value (Fig.4).

All the star plots shapes are asymmetric, this is an indicator of a low sustainability of the studied small mammal communities [39-40].

The analysis of star plots distribution in the plane of Simpson's diversity (D) and evenness (E) indices shows that due to low diversity index all communities from the studied biotopes have similar profiles along the D axis, but form three distinct clusters along the E axis (Fig.5).

The majority of communities inhabiting different biotopes and study areas are a compact group with Simpson's evenness index lower than its mean value in the whole sample. Another cluster is a small mammal coummunity of cedar-and-birch ribbon forest (Pm+Bm) in the Tylakrylvayam River floodplain with a low diversity index, but a significantly higher evenness, the latter is generally characteristic of forest habitats [39; 50]. The third cluster includes a two-species micromammal community of *M. rutilus, S. caecutiens* inhabiting lichen- and shpagnum-and-low-bush tundra (Ld+Vu-C+C; Ld+Vu-S) in the the Tylakrylvayam River flood-plain. This cluster features minimal Simpson's diversity index, but at the same time maximal evenness (Fig.5).

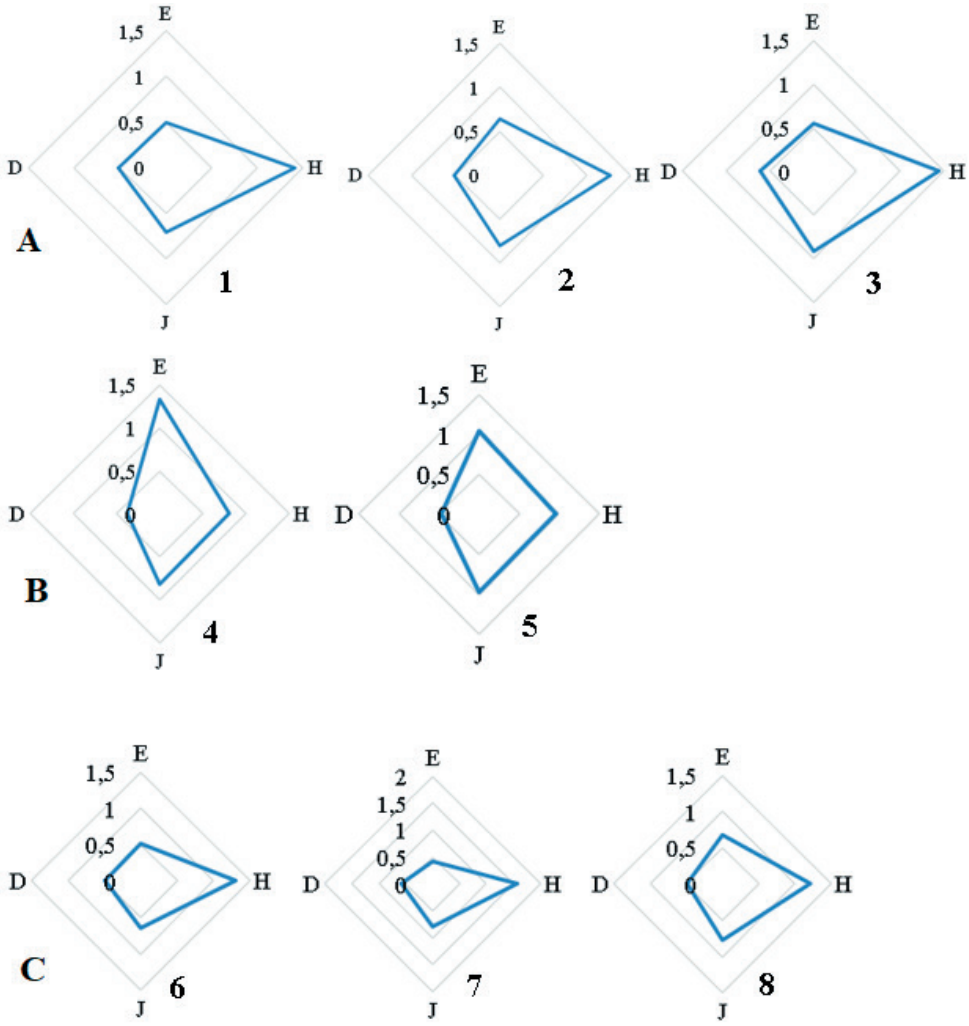

Figure 4. Star Plots Rrepresenting Diversity Information Indices of Small Mammal Communities Inhabiting Certain Biotopes of Parapolsky Dol:
A — Lake Talovskoye Shore (1 – area of large boulders (Ppp); 2 – cedar-and-birch forest (Pp+Bm); 3 – lichen- and sphagnum-and-low-bush tundra (Be-Ld+Vu-Ap+Dm)); B — Tylakrylvayam River Flood-Plain (4 – sphagnum-lichen tundra (Ld+Vu-C+C; Ld+Vu-S); 5 – cedar-and-birch forest (Pp+Bm)); C — Ichiginnyvayam River Flood-Plain (6 – lichen- and sphagnum-and-low-bush tundra (Ld+Vu-C+C; Ld+Vu-S); 7 – chosenia-poplar-willow forest (Cha+Ps-Ss+Su); 8 – sphagnum-and-low-bush dwarf bich thicket on river bench (Bm-S))

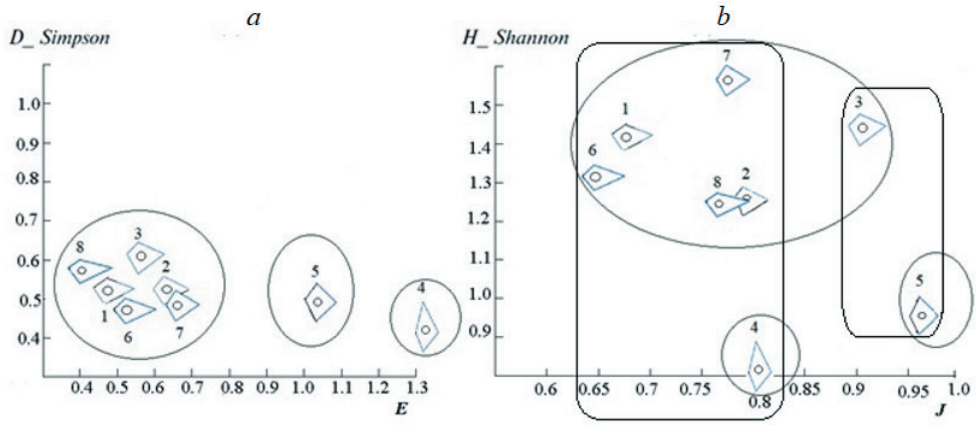

Fig. 5. Icon Plots Distribution along Axes D, E (a) and H, J (b): Lake Talovskoye Shore (1 – area of large boulders (Ppp); 2 – cedar-and-birch forest (Pp+Bm); 3 – lichen- and sphagnum-and-low-bush tundra (Be-Ld+Vu-Ap+Dm); Tylakrylvayam River Flood-Plain (4 – sphagnum-lichen tundra (Ld+Vu-C+C; Ld+Vu-S); 5 – cedar-and-birch forest (Pp+Bm); Ichiginnyvayam River Flood-Plain (6 – lichen- and sphagnum-and-low-bush tundra (Ld+Vu-C+C; Ld+Vu-S); 7 – chosenia-poplar-willow forest (Cha+Ps-Ss+Su); 8 – sphagnum-and-low-bush dwarf bich thicket on river bench (Bm-S); for figure б clusters along the H axis are enclosed in ovals; clusters along the J axis are enclosed in rectangles

In the space of Shannon's diversity (H) and evenness (J) indices, the communities under investigation cluster along both axes (Fig.5). Along the H axis there are three groups: 1) a small mammal community inhabiting lichen- and shpagnum-and-low-bush tundra (Ld+Vu-C+C; Ld+Vu-S) of TylakrylvayamRiver flood-plain; 2) a small mammal community inhabiting cedar-and-birch ribbon forest (Pm+Bm) in the Tylakrylvayam River flood-plain; 3) a group of other communities inhabiting different biotopes and areas under investigation (Fig.5). Along the J axis there are two distinct clusters distinguished. The first set groups around the median values of evenness indices comprising most studied communities. The other cluster is characterized by high evenness index values and includes communities inhabiting lichen- and sphagnum-and-low-bush tundra (Be-Ld+Vu-Ap+Dm) areas at the Talovskoye Lake shore and a community inhabiting cider-and-birch ribbon forest in the Tylakrylvayam River flood-plain.

It is obvious that the Tylakrylvayam River flood-plain communities cluster separately in both coordinate systems used. Excessive wetness is a general geoecological characteristic of the area under scrutiny. Despite the fact that the lichen- and sphagnum-and-low-bush tundra area (Be-Ld+Vu-Ap+Dm) is the wettest biotope at the Talovskoye Lake shore and is a sink habitat for the local small mammals, and the cedar-and-birch ribbon forest (Pp+Bm) is the most

drained biotope and is a source habitat in the Tylakrylvayam River flood-plain, these two communities have similar evenness structure (along the J axis) and similar level of habitats' wetness. The structural difference of the cedar-and-birch ribbon forest (Pp+Bm) in the Tylakrylvayam River flood-plain is its narrow width and adjacent overmoistened biotopes (Ld+Vu-C+C; Ep+Cb) on both sides of it.

On the whole, our research is indicative of the following.

The fauna, species diversity and evenness structure of micromammals communities of Parapolsky Dol habitats located in the Kamchatka Peninsula forest tundra zone are the same as those typical for undisturbed subarctic ecosystems of Siberia, Taymyr Peninsula, the Altai Mountains, and North-East Eurasia.

All the studied micromammal communities have a low number of species, and are characterised by low values of general abundance, certain species abundance, low species diversity indices, and low sustainability. These facts can be accounted for by harsh weather conditions of the area under study, and as a consequence by low resource capacity of the habitats.

The micromammal communities under investigation have median and high evenness indices due to low number of species and their low abundance. The differences in the abundance of the most and least numerous species within one area is within 1.5 to 8 fold.

The habitat wetness level is an important natural factor influencing the spacial distribution and abundance of small mammals within the studied territory of Parapolsky Dol.

The integral index of fluctuating asymmetry of binary nonmetric skull characteristics of the dominant *Cl.rutilus* shows that development of all population groups may be considered stable, and the environment quality to fall within the conventional normal range.

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Levykh A.Yu. – conducting field, cameral research, statistical processing of data; writing the text of the article.
Belousov I.S. – accounting fen non-metric features of the skull.
Ganjerli N.V. – translation of article

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