Russian J. Theriol. 22 (2): 142–149

A 12-year population study of the reed vole (*Alexandromys fortis*) (Rodentia: Cricetidae) in Khonin Nuga, West Khentey, Mongolia

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ABSTRACT: The reed vole *Alexandromys fortis* is a small herbivorous species primarily inhabiting open meadows in northern and central Eurasia. While the reed vole population in Mongolia is classified as least concern, there are limited information available about this species. To address this knowledge gap, a survey was conducted in the Khonin Nuga region of West Khentey, along the Yeroo River in Northern Mongolia, to assess the physical characteristics and population structure of reed voles. Over the course of a 12-year study, the reed vole population exhibited significant oscillations. Notably, the species demonstrated strong sexual dimorphism, with males consistently displaying larger size than females among all individuals measured. Furthermore, an imbalanced sex ratio was observed, with a greater number of males present both in the captured individuals (male-to-female ratio of 1.19:1) and the adult samples (male-to-female ratio of 1.45:1).

How to cite this article: Tserendavaa P., Eredenechimeg E., Hackländer K., Samiya R., Sheftel B.I., Undrakhbayar E., Nomin A., Muehlenberg M. 2023. A 12-year population study of the reed vole (*Alexandromys fortis*) (Rodentia: Cricetidae) in Khonin Nuga, West Khentey Mongolia // Russian J. Theriol. Vol.22. No.2. P.142–149. doi: 10.15298/rusjtheriol.22.2.07

KEY WORDS: *Alexandromys fortis*, Rodentia, population structure, population dynamics, sex dimorphism.

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Двенадцатилетние исследования популяции большой полевки (*Alexandromys fortis*) (Rodentia: Cricetidae) в Хонин-Нуге, Западный Хэнтэй, Монголия

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РЕЗЮМЕ. Большая, или дальневосточная полёвка, *Alexandromys fortis* — мелкий травоядный вид, обитающий в основном на открытых лугах северной и центральной Евразии. Популяция этого вида в Монголии слабо изучена. В ходе двенадцатилетнего исследования, которое проводилось в Хонин-Нуге, Западный Хэнтэй, вдоль реки Еро-гол в Северной Монголии, численность большой полевки претерпевала значительные колебания. Для популяции характерен выраженный половой диморфизм, самцы достоверно крупнее самок среди всех измеренных особей. Соотношение полов неравномерное: самцов больше как во всей выборке (1.19:1), так и среди взрослых особей (1.45:1).

КЛЮЧЕВЫЕ СЛОВА: *Alexandromys fortis*, Rodentia, популяционная структура, популяционная динамика, половой диморфизм.

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Introduction

The genus *Microtus* Schrank, 1798 which is known for its species richness, comprises over 60 extant species found across the Palearctic and Holarctic regions (Jean *et al.*, 1999). Classification of the genus into subgenera and species groups had been a complex and contentious matter (Ellerman & Morrison-Scott, 1966; Meyer *et al.*, 1996), leading to multiple revisions in the past.

Latest study of Lissovsky *et al.* (2018) that examines the genetic distances and relationships among specific vole species, contributing to the understanding of their taxonomic status and biodiversity of East Asian voles of the *Alexandromys* Ognev, 1914 genus (Rodentia, Arvicolinae) definitively determined that the genus separates into 12 distinct and valid species. Significant findings such as nomenclature issues, taxonomy, phylogenetic relationships issues were established through the application of multilocus analysis.

In the Mongolian Red List of Mammals, 61 extant species of subterranean rodents are listed, seven belong to the genus *Alexandromys*, around 57% are categorized as "Data deficient" (Clark & Munkhbat, 2006). The reed vole *Alexandromys fortis* (Buchner, 1889) specifically, is a small herbivorous microtine rodent species that primarily inhabits open meadow habitats in the Khonin Nuga area of the West Khentey region, along the Yeroo River in Northern Mongolia. Despite the widespread abundance of reed voles, research on their biology and ecology in Mongolia is rather unstudied (Hauck & Samiya, 2006).

According to a study conducted on a Chinese population of *A. fortis*, it was observed that these animals do not exhibit sedentary behavior. During the period from early autumn to spring, the population was found to reside on the beach of a lake. However, in summer, when the beach became flooded, the population migrated to the nearby farmland (Wang *et al.*, 2004). This seasonal movement from the lake to the farmland was attributed to the flooding of the beach and the subsequent availability of alternative habitat. The study further revealed that the population of *A. fortis* exhibited significant fluctuations during the wet season, primarily influenced by the migration triggered by summer precipitation, which drove the animals from the lake to the adjacent rice fields. These oscillations in population size were likely the result of a combination of extrinsic factors, such as seasonal changes in habitat availability, as well as density-dependent intrinsic factors (Wang *et al.*, 2010). The findings of those study suggest that both external environmental factors and internal population dynamics, influenced by population density, play crucial roles in shaping the population dynamics of *A. fortis* in China

The main objective of this study was to examine the external morphology, sex ratio, sexual dimorphism, and population structure of *A. fortis* in the Khonin Nuga Valley of the West Khentey region. Additionally, the study aimed to investigate the population dynamics, daily captures, and the relationship between body mass, body length, and tail length. The researchers hypothesized that reed voles would exhibit distinct local and temporal variations in their morphological characteristics due to diverse patterns of climatic changes and population cycles.

Material and methods

Research area — The study area is situated within the West Khentey Mountain Range, located south of Lake Baikal and near the border between Mongolia and Russia (Walter, 1974). Encompassing an area of 400 km², the study area spans between 49.0166 and 49.1666°N latitude and 107.1833 and 107.5166°E longitude, with approximately 85% of the total area covered by forests. The study site represents a transitional zone between the southern extension of the Siberian taiga and forest steppe. On the northern slopes, natural forests growing on permafrost soil can be found, while the southern slopes receive higher solar radiation and naturally support steppe vegetation due to relatively dry conditions. This transition zone showcases a convergence of boreal conifer forests and the floristic elements of the Central Asiatic steppe (Dulamsuren *et al.*, 2005; Hauck *et al.*, 2006). Within the study area, meadow steppes dominate the drier southern slopes at lower elevations (up to 1100 m), alternating with forests of varying composition on slopes less exposed to the sun at higher elevations. The valleys are characterized by moisture — tolerant forests, shrublands, and wet grasslands (Dulamsuren *et al.*, 2004). The forests within the study area can be classified into four distinct types, differing in their ecological characteristics and adaptations to fire (Babintseva & Titova, 1996; Larsson *et al.*, 2001; Wirth, 2005).

In the study area, five primary habitats were identified and characterized. The streamside habitats were characterized by a combination of larch-birch forest on the first river terrace and adjacent willow-poplar bushes. The upper layer of the streamside forest consisted of single 30–40-meter *Larix sibirica* trees, while the second layer was formed by *Betula platifylla* birch trees. The bush layer encompassed bird cherry trees (*Padus asiatica*) and prickly wild roses (*Rosa acicularis*). Within the grass cover, *Calamagrostis purpurea, Equisetum pretense*, and *Filipendula palmata* were dominant. The willow-poplar bushes were composed of *Salix schwerinii*, *S. rorida*, *Populus laurifolia*, along with *Calamagrostis purpurea*. *Trifolium lupinaster* and *Ranunculus japonicas* were the prevailing species in the grass cover of this habitat. Two ditches were constructed within this habitat.

Betula fuska bushes typically occupied 2–3 terraces and exhibited dense vegetation covering from 70% to 90% of the production area. Groves of *Betula platifylla* were found in clearer patches of the area, accompanied by *Carex macroura*, *Geranium vlassovianum*, and *Geranium pretense*. *Trisetum sibiricus* dominated the grass cover within the bushes, while *Aster tataricus*, *Stipa sibirica*, and *Carex pediformes* were present under the *Betula platifylla* canopy. This habitat complex also featured two ditches.

The forests on the slopes, comprising the third habitat type, were characterized by a combination of birch (*Betula platifylla*) and larch (*Larix sibirica*) trees, with occasional patches of aspen (*Populus tremula*). The bush coverage in this habitat was relatively sparse, mainly consisting of *Rhododendron dauricum*. Evidence of old fireplaces (15–20 years old) could be observed, resulting in a littered forest floor. Dominant species in the grass cover included *Calamagrostis obtusata*, *Equisetum pretense*, *Iris ruthenica*, and *Carex schmidtii*. This habitat complex also featured the establishment of three ditches.

Valley motley grass meadows were located on one and two river terraces, covering extensive areas. The dominant species in these meadows varied, with different species of wormwood (*Artemisia vulgaris*, *A. tanacetifolia*, *A. sericia*) observed in drier areas, and *Hemerocallis minor*, *Iris sangunea*, and *Achilea asiatica* more common in wetter areas. Two ditches were present in this habitat complex.

The steppe mountain meadows occupied slopes with a southern exposure. Dominant species in this habitat included *Artemisia frigida*, *A. commutate*, and *Poa stepposa*. A single ditch was located within this habitat.

Animal trapping — All materials were collected and processed with the use of standardized methods. Single annual captures of animals were conducted by the standard method of ditch trapping (20 m in length with two cones) at the same time of each year from 8 to 18 August, during the peak of abundance of small mammals in boreal forests (Schwartz *et al.*, 1992). August marks the end of the reproductive season and is also the best month to compare population sizes of successive years. Traps were checked once a day, between 07:00 and 09:00 hours. To avoid repeated captures, all animals were sacrificed and analyzed in the field laboratory.

In the laboratory, we identified the age classes and sex of the specimens by breeding status (based on external and internal condition of reproductive organs, scrotum, and testicle size, for female's uterus, apparent mammary, open vagina, vaginal plug features or evident pregnancy).

Morphometrics — For each culled individual the following morphological data were recorded: body length (BL), from the ventral edge of the nose to the anus; tail length (TL), from the anus to the tip of the tail, excluding fur; and body weight (BW, measured with a scale of 1 g precision). The two external variables (BL and TL) were measured with a ruler of 0.5-millimeter accuracy.

Data analysis — All measurements were taken by the same researcher. To minimize errors stemming from body measurements, separate assessments were conducted for each age class and sex, and their respective mean values were utilized. This approach ensured a more accurate representation of the population's characteristics while mitigating potential inaccuracies caused by variations within different groups. Descriptive statistics (mean, range, standard deviation, error) of these three variables for *A. fortis* studied are presented in Table 1. Reed voles were classified as juvenile (immature animals, born in the year of investigation), subadult (sexually maturated individuals born in the same year) or adult (sexually matured and wintered animals) on the basis breeding status and body mass. To test the hypothesis, we conducted a test using the two-sample *t*-test. The index of relative number, namely the number of individuals calculated for 100 conventional cones per day (c/d), as well as the index of dominance, which is a percentage of the species in the catch (Beklemishev, 1961), were used for the quantitative characteristics of species in the community. The total number of c/d is 2400. The data on population dynamics of *A. fortis* was analyzed. The studied material includes 206 individuals. We assessed the relationship between measurements (BL, TL, and BW) of *A. fortis* using nonparametric Spearman rank correlation (STATISTICA StatSoft, Inc. 2011) for standardized body measurement testing. Daily capture on Reed voles were analyzed using a One-way analysis of variance (ANOVA/MANOVA; STATISTICA StatSoft, Inc. 2011)

Results

A total of 206 *A. fortis* individuals, comprising 94 females and 112 males, were captured and subjected to measurements. The external morphological parameters of the reed voles, categorized by age classes and sexes, are presented in Table 1. Sexual dimorphism was observed in *A. fortis*, with males exhibiting significantly larger measurements than females across all variables, as indicated by the results of the two-sample *t*-test (Table 1).

It should be noted that the dataset does not include the two heaviest pregnant females (108 and 113 g) captured in August 2011. On average, males and females displayed higher mean body mass across all age categories, except for juveniles, where the body measurements were relatively higher (Tab. 1).

The population dynamic of *A. fortis* revealed significant fluctuations, with distinct peak years observed in 2011, while periods of disappearance occurred between 2002–2005 and 2007–2009. The highest recorded population size was in 2011, reaching 57.5 individuals per 100 c/d (Fig. 1). In contrast, the lowest recorded value was in 2001, with only 1.3 individuals per 100 c/d, representing a drastic 44-fold change in this index over the 12-year observation period.

Figure 3 displays the Mean daily capture of *A. fortis* for each year. The highest mean daily capture was recorded in 2011, reaching 11.5 individuals per day, while the lowest capture was 0.1 individuals per day in 2001. Interestingly, in 2011, there was a slight predominance of females, accounting for 51.0 percent of the total number of individuals and 52 percent of the adult population (Table 2). The population structure in 2011 exhibited a different pattern, with the presence of individuals across all ages and sexes. Notably, there was a significant peak in juvenile numbers (n=78) during that year. Table 2 provides the absolute number of individuals categorized by sex, age, class, and year.

Table 1. Mean values and standard deviation for body measurements. Mass is in g, and lengths are in mm, n = number of measured voles.

Juvenile	Males (n = 60) M ± SD	Females (n = 57) M ± SD	t-values	p
Body length (mm)	113.7 ± 12.4	111.2 ± 9.7	1.2506	> 0.05
Tail length (mm)	40.9 ± 5.1	39.4 ± 4.1	1.7882	> 0.05
Body weight (g)	37.2 ± 8.1	33.7 ± 5.8	2.7209	> 0.05
Sub- adult	Males (n = 20) M ± SD	Females (n = 15) M ± SD	t-values	p
Body length (mm)	121.7 ± 9.7	119.5 ± 9.2	0.6687	> 0.05
Tail length (mm)	42.2 ± 3.5	41.9 ± 2.9	0.2857	> 0.05
Body weight (g)	43.4 ± 6.2	41.5 ± 6.9	0.8805	> 0.05
Adult	Males (n = 32) M ± SD	Females (n = 22) M ± SD	t-values	p
Body length (mm)	149.4 ± 7.3	135.4 ± 8.0	6.5421	< 0.05
Tail length (mm)	50.6 ± 4.6	47.9 ± 4.8	2.1194	> 0.05
Body weight (g)	78.5 ± 10.1	60.4 ± 8.5	6.9723	< 0.05

Table 2. Total number of individuals captured from 2000 to 2011 and sex ratio of the captured individuals of *Alexandromys fortis* at Khonin Nuga, West Khentey, Mongolia. M — males, F — females.

Years	Juvenile		Sub-adult		Adult		Sex ratio	Total sample M (%)	Sex ratio	Total adults M (%)
	M	F	M	F	M	F				
2000	15	18	10	6	8	4	1.18/1	54.09	2/1	66.67
2001			1		3	1	4/1	80.00	3/1	75.00
2006	4	2	3	1	6	2	2.6/1	72.22	3/1	75.00
2010	1		2	1	2	1	2.5/1	71.42	2/1	66.66
2011	40	37	4	7	13	14	1/1.01	49.56	1/1.07	48.14
Total	60	57	20	15	32	22	1.19/1	54.36	1.45/1	59.25

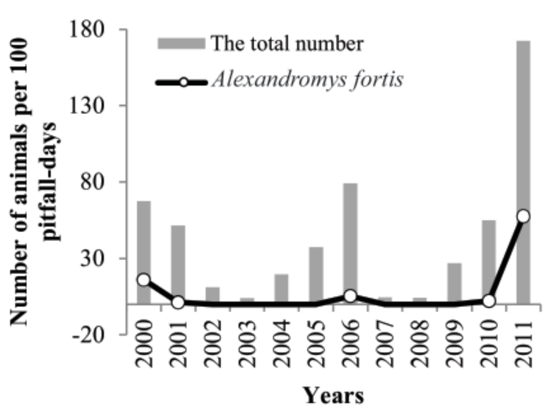

Fig. 1. Long–term dynamics of the total number of community and number of *Alexandromys fortis* in Khonin Nuga, West Khentey, Mongolia.

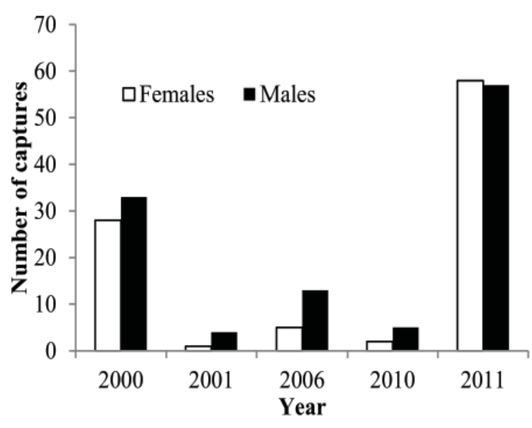

Fig. 2. Number of male and female *Alexandromys fortis* captured by year.

Table 3. Sex ratio of individuals of *Alexandromys fortis* captured in Khonin Nuga, West Khentey, Mongolia.

	Total sample		Adults	
Years	Sex ratio	Males (%)	Sex ratio	Males (%)
2000	1.18/1	54.09	2/1	66.67
2001	4/1	80.00	3/1	75.00
2006	2.6/1	72.22	3/1	75.00
2010	2.5/1	71.42	2/1	66.66
2011	1/1.01	49.56	1/1.07	48.14
Total	1.19/1	54.36	1.45/1	59.25

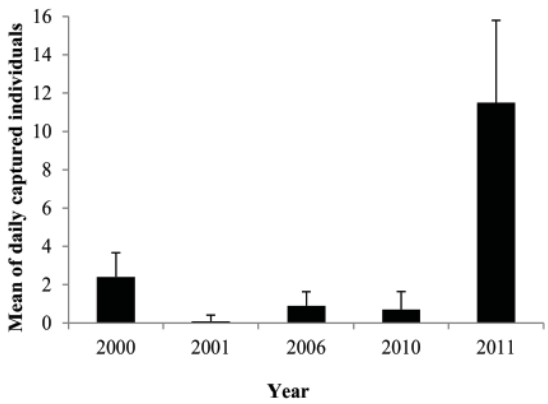

Fig. 3. Of daily captures in pitfall traps of *Alexandromys* in August 2000–2011 at the Khonin Nuga, West Khentey, Mongolia. ANOVA, (F(10.99) = 59.56; $p < 0.0001$).

Observations indicated that the majority of juvenile individuals were recorded in August each year, suggesting that they were produced during the preceding breeding months. In 2011, there was a notably high proportion of breeding young animals (Table 2). The sex ratio analysis, depicted in Figure 2, revealed an imbalanced distribution between males and females from 2000 to 2010. Males were more frequent, with a ratio of 1.19:1 (total) and 1.45:1.

Furthermore, the visual examination of Figure 4 confirmed that the distribution and overlap of body length among different age categories were broader compared to body mass. Therefore, age determination of the animals primarily relied on body mass, with body length serving as an additional measure.

Strong correlations were observed between body mass (BW), body length (BL), and tail length (TL) in male *A. fortis*, while females exhibited moderate correlations, both of which were statistically significant (Fig. 5).

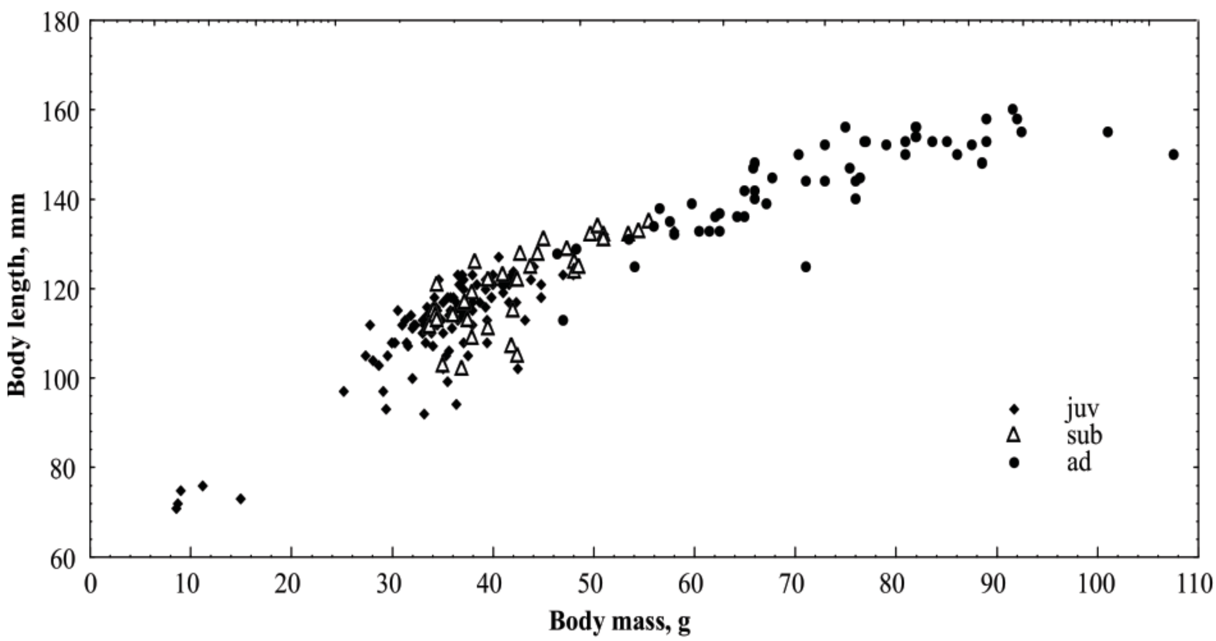

Fig. 4. Relation of body mass and body length to animal age in the reed vole (juv — juveniles, sub — subadults, and ad — adults).

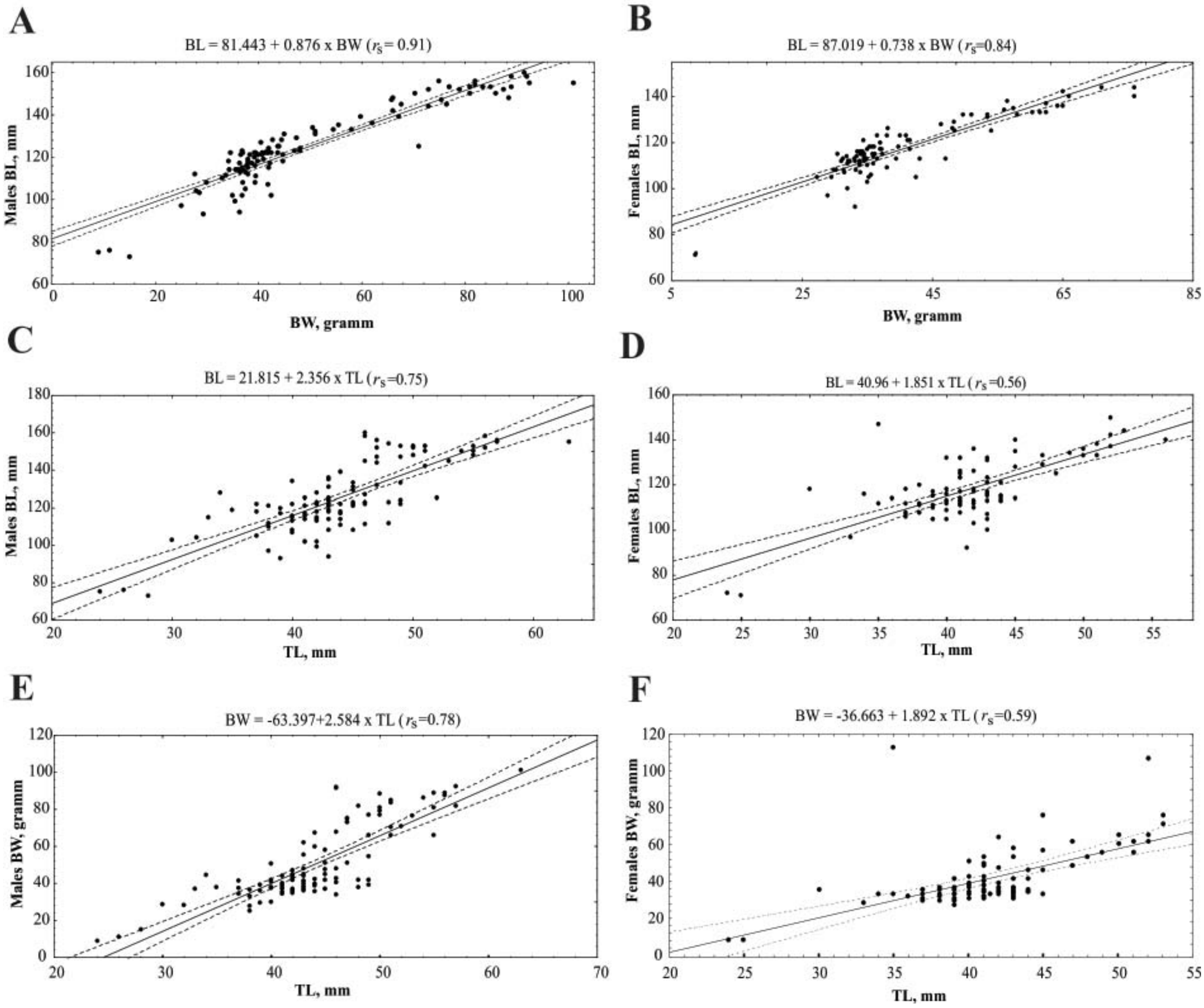

Fig. 5. Bivariate scatterplots of the morphological parameters: A, B — BL and BW; C, D — BL and TL; E, F — BW and TL of male and female *Alexandromys*. Regression line and 95% confidence limits are given.

The population under study displayed significant correlations among BW, BL, and TL (all $p < 0.001$). Notably, the strongest correlations were observed between BW and BL for both sexes (Spearman rank correlation: r_s=0.91, $p < 0.001$ for males and r_s=0.84, $p < 0.0001$ for females), as depicted in figures A to F.

Alexandromys fortis inhabit mostly meadow habitats of the Amur basin, and the river Yeroo, which belongs to lake Baikal basin, in the most western part of it's range (Moroldoev, 2017; Kadetova, 2019). Figure 6 presents the species were distributed in a similar way (FP, BB, MF) and the capture rates of *A. fortis* was the highest at the herb meadow plots.

Discussion

The reed vole (*A. fortis*) is recognized as one of the largest species within the *Alexandromys* genus, with males reaching weights of 101 g and 93 g, making them the heaviest individuals in the species. In our study, the grand mean body weights for adult males and females were 78 g and 60 g, respectively. Notably, two exceptionally heavy pregnant females weighing 108 g and 113 g were captured in August 2011 these two individuals are outliers but not included the average rating scales. Various extrinsic factors, such as food availability and quality, have been proposed to explain the variations in body mass observed in microtine rodents (Agrell *et al.*, 1992). Higher body mass is typically attained when environmental conditions favor plant growth, subsequently enhancing animal growth and survival (Lidicker & Ostfeld, 1991). For instance, in *Alexandromys oeconomus* (Pallas, 1776), the winter body mass (BM) exhibits a robust correlation with food availability during the dry season in Mediterranean and subtropical climates (Batzli & Pitelka, 1971; Cohen-Shlagman *et al.*, 1984). However, we were unable to ascertain a similar asso-

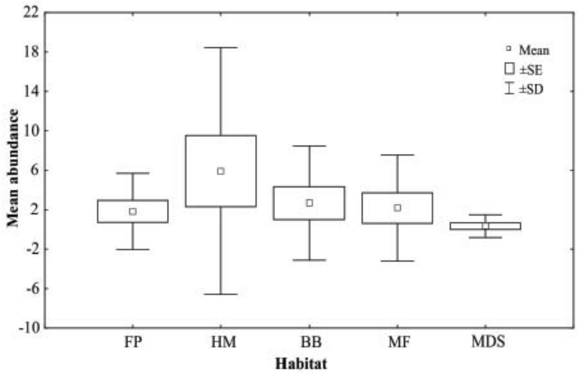

Fig. 6. Boxplots mean abundance by habitat of *Alexandromys* from Khonin Nuga, West Khentey, 2000–2011. FP — flood plain, HM — herb meadow, BB — *Betula* bushes, MF — mixed forest, MDS — mountain dry steppe.

ciation between BM variation and food availability in our vole population. Our study concludes and aligns with the previous study (Lissovsky & Obolenskaya, 2011) on *Alexandromys* that sexual dimorphism of *A. fortis*'s that adult males consistently exhibited larger body sizes compared to females.

The proportion of wintered animals within the reed vole population was notably low (Table 2). This can be attributed to the timing of our observations in August, which coincided with the end of the reproductive season. We conducted a comprehensive analysis over a twelve-year period to elucidate the population dynamics of small mammals in Khonin Nuga Valley of West Khentey. The study focused on establishing correlations between the abundance of these species and key winter weather variables, including mean monthly temperature, minimum temperature, mean monthly sedimentation, and monthly snow level. The species distribution ranges are explainable by the distribution of environmental factors (Lissovsky, 2015).

The population of *Alexandromys fortis* experienced a significant decline in 2001. Ecological analysis of this species indicated a preference for open habitats (refer to Fig. 6). Therefore, the pronounced decrease in population could be attributed to the unusually cold winters of 2000–2001 and 2006–2007, *as A. fortis* that we have observed inhabiting open fields are particularly vulnerable under such climatic conditions and face an increased risk of predation. Furthermore, variations in population dynamics may be linked to differences in the sex ratio. Specifically, in the years 2000, 2001, 2006, and 2010, an excess of males was observed in August. However, the situation in 2011 differed significantly, with a relatively balanced sex ratio in the overall sample, but a male-to-female ratio of approximately 1:1.07 among adults. Previous studies (Stein, 1953; Adamczewska-Andrejewska, 1981); Nabaglo, 1981) have highlighted a correlation between the number of females in a population and the overall abundance of individuals. Hence, we posit that the alteration in population structure played a crucial role in the observed peak density in August 2011.

The Khingansky State Nature Reserve (Amur region) which is located on the Khingan-Arkhara lowlands and south-western spurs of the Buryat mountain range, a study was conducted on the structure of small mammal population (Kadetova, 2019; Dorzhiev, 2019). Long-term observations were made it possible to accounts for fluctuations in species abundance over time as well as changes in dominating species in relation to the population of distinct biotopes. *Apodemus agrarius* (Pallas, 1771), *Alexandromys maximowiczii* (Schrenk, 1859), and *A. fortis* dominated in open habitats such as herb meadows which are along gradient of moisture.

ACKNOWLEDGMENTS. We thank E. Undrakhbayar, G. Batgerel, B. Tamir, B. Bayarjargal and O. Amarsaikhan for their assistance with fieldwork. We appreciate the logistical help given by A. Enkhmaa, field manager at Khonin Nuga Research Station. E. Erdenechimeg, Ch. Gantigmaa, T. Dayanjalba and Sh. Kherlen helping with data evaluation.

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