THE NORTHERNMOST RECORD OF THE WESTERN MEADOW LIZARD, *Darevskia pontica* (LANTZ ET CYRÉN, 1918)

S. N. Litvinchuk[1] and D. V. Skorinov[1]

Submitted May 31, 2017

A new record of *D. pontica* in the Kuban-Azov Lowland was described. This is the northernmost locality for the species. This population could be relic or recently introduced. To estimate the presumed relic origin of the population, we using GIS modeling estimated distributional range dynamics of the species since the Late Pleistocene. Currently and during the previous times, the locality had little suitable environmental conditions for a survival of the species. Therefore, we consider that the population more likely to be introduced.

Keywords: Sauria; Lacertidae; GIS modeling; the Pleistocene; the Kuban-Azov Lowland; the Caucasus; introduced populations.

INTRODUCTION

The western meadow lizard, *Darevskia pontica* (Lantz et Cyrén, 1918) is listed on Annex III of the Bern Convention and included to the IUCN Red List of Threatened Animals under the category "near threatened" (Agasyan et al., 2009). A distributional range of the lizard is still poorly studied. Formerly, it was assumed that the species have a large disjunct distribution, covering the Balkan and Caucasus regions. The recent molecular study revealed polyphyly of *D. pontica* (Freitas et al., 2016). It was found that the Balkan and Caucasian populations represent the separate clades. The time of divergence between them was estimated as the Late Pliocene (about 2.5 Ma). Since the type locality of the species is Gagry Town (the Western Caucasus), we consider that the name "*pontica*" belong to the Caucasus taxon. Hence, the species inhabit the Caucasus only.

Last time, the distribution of the species was carefully studied by various authors. Previously, it was supposed that the northern border of the range does not pass floodplain forests of the Kuban River valley (e.g., Tuniyev et al., 2011). However, Doronin (2013, 2014, 2015a, 2015b) found several new more northern localities. The author (Doronin, 2015b) made a model of present time distribution of the species using of the Maxent program, altitude and bioclimatic GIS layers, as well as 231 georeferenced localities. According to the model, areas which are to the north of 45.7° of northern latitude are poorly suitable for the species. Moreover, Doronin (2014, 2015a) considered that isolated populations of *D. pontica* in the Kuban-Azov Lowland are relic and mark the former distribution of forests in the region.

The aim of our paper was to describe a new record of *D. pontica* in the Kuban-Azov Lowland which is a northernmost locality for the species. Additionally, we attempt to estimate distributional range dynamics of the species since the Late Pleistocene using of GIS modeling to assess a presumed origin of the population.

MATERIAL AND METHODS

For the contemporary niche predictions, we used dataset included 231 localities of *D. pontica* taken from Doronin (2015b) and our new record (Fig. 1). Duplicated localities were removed by ENMTools 1.3 (Warren et al. 2010). Altitude and 19 bioclimatic layers were extracted from the WorldClim 1.4 database (http://www.worldclim.org). Additional layers were extracted from the GlobCover 2009 (due.esrin.esa.int/globcover), the Global Aridity and PET (http://www.cgiar-csi.org), the Global Habitat Heterogeneity (http://www.earthenv.org/texture.html), as well as from the Percent tree coverage (http://www.iscgm.org/gm/ptc.html) databases. Five landscape layers (aspect, exposition, slope, rough-

[1] Institute of Cytology, Russian Academy of Sciences, 4, Tikhoretsky pr., St. Petersburg, 194064, Russia;
e-mail: litvinchukspartak@yandex.ru

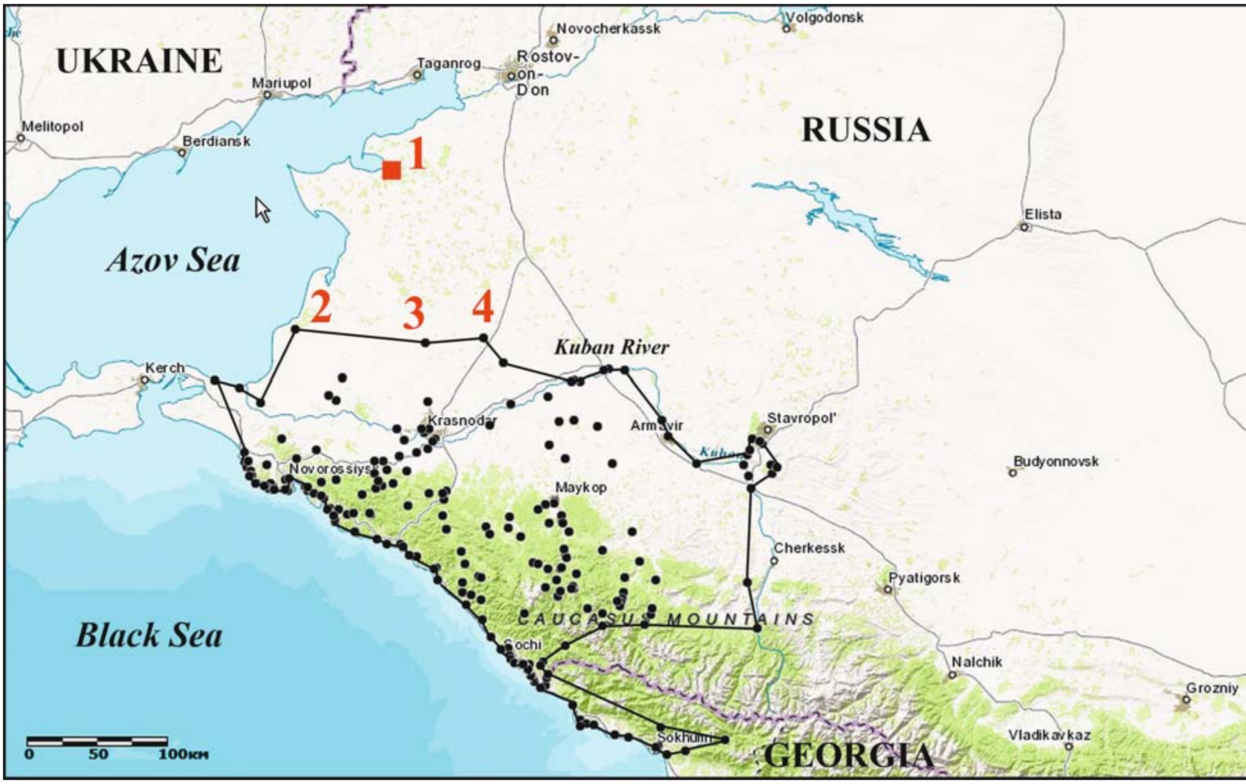

Fig. 1. Present time native range of *Darevskia pontica* with localities used for the Maxent analyses: 1, Staroshcherbinovskaya village (a new record); 2, Protoka River; 3, Timashevsk Town; 4, Komsomolskiy Settlement.

ness, and terrain roughness index) were constructed by us with use of the altitude layer and QGIS 2.18.1 program (http://www.qgis.org). The mask applied for the distribution modeling extends from 40° to 48° N and 35° W to 44° E.

To avoid highly correlated and redundant variables for the analysis of predicted potential geographic distribution, correlations between pairs of 19 bioclimatic variables were assessed using the Pearson correlation coefficient by ENMTools. Two variables sharing a correlation coefficient of 0.75 or higher were considered highly correlated. Previous knowledge on biology and requirements of the studied species is crucial for optimal modeling. Therefore, we selected variables based on known preferences of *D. pontica*. Unlike the most species of the genus, which occupy saxicolous habitats, *D. pontica* is a largely terrestrial species and inhabits meadows and forest environments. The species can be often found in clearings with lush vegetation and glades within open broad-leaf woodland (Agasyan et al., 2009). After correcting for correlation among data layers, eleven variables were retained: Bio2 (mean diurnal range; °C × 10), Bio3 (isothermality), Bio4 (temperature seasonality; standard deviation×100), Bio5 (maximum temperature of warmest month; °C × 10), Bio8 (mean temperature of wettest quarter; °C × 10), Bio9 (mean temperature of driest quarter; °C × 10), Bio11 (mean temperature of coldest quarter; °C × 10), Bio13 (precipitation of wettest month; mm), Bio15 (precipitation seasonality; CV), Bio17 (precipitation of driest quarter; mm), and Bio19 (precipitation of coldest quarter; mm). For the Mid Holocene (about 6000 years ago), the Last Glacial Maximum (about 22,000 years ago; the Community Climate System Model), and the Last inter-glacial (about 120,000 – 140,000 years ago), these eleven uncorrelated bioclimatic layers from the WorldClim database were extracted as well.

Models were generated by Maxent 3.3.3. For the analysis of the present time distribution of *D. pontica* we applied 21 layers (11 uncorrelated bioclimatic, altitude, aridity index, aspect, exposition, land cover type, habitat heterogeneity, slope, roughness, terrain roughness index, and tree coverage percent) with 30 sec resolution. Additionally, for estimation of past distributions of the species we performed models with use of eleven uncorrelated bioclimatic layers only with 30 sec (the present time, the

Fig. 2. Biotope of *Darevskia pontica* in Staroshcherbinovskaya village (Krasnodar kray, Russia).

Mid Holocene and the Last inter-glacial) and 2.5 angle min spatial resolutions (the present time and the Last Glacial Maximum).

We used 70% of the occurrence localities as training data, and the remaining 30% were reserved for testing the resulting models. Optimum model parameters were determined leading to the lowest omission rate and highest Area Under the Curve (AUC). Models with test AUC values above 0.90 were considered as very good (Swets, 1988). To properly parameterize the model, we evaluated the performance of various combinations of regularization multipliers (from 0.5 to 5, in increments of 0.5). The best-fit models were parameterized with a regularization multiplier of 0.5. We used a jackknife analysis for estimation of relative contributions of the variables to the Maxent model.

Fig. 3. Subadult male of *Darevskia pontica* which basked on acacia tree in natural conditions.

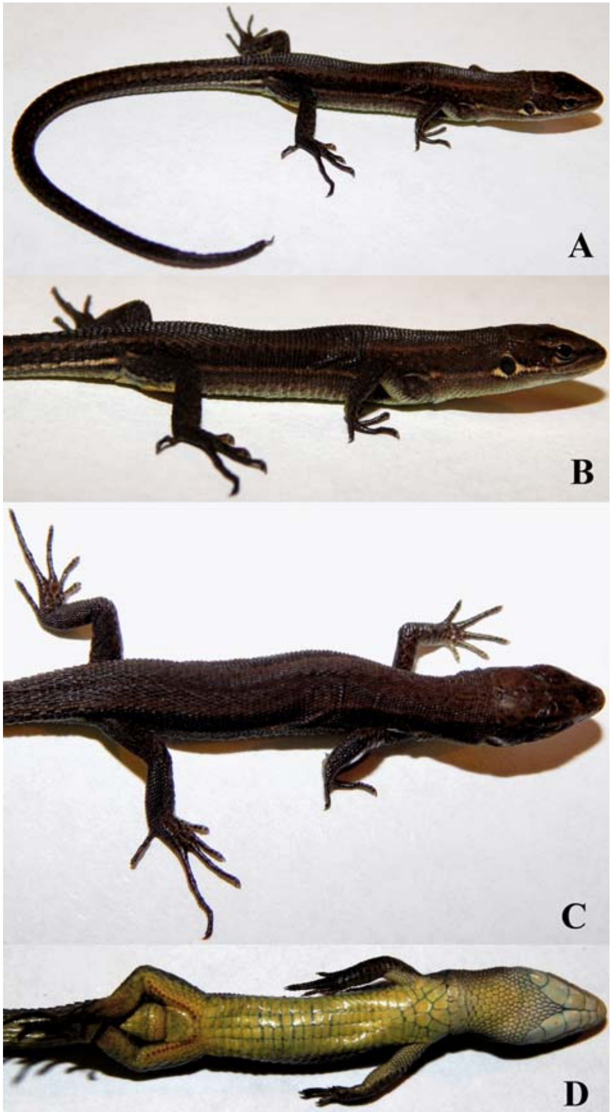

Fig. 4. Subadult male of *Darevskia pontica* from Staroshcherbinovskaya village: A, general view; B, lateral view; C, dorsal view; D, ventral view.

RESULTS AND DISCUSSION

In May 18, 2017, we found *D. pontica* in the northern border of Staroshcherbinovskaya village ("stanitsa"), Krasnodar Kray, Russia (Fig. 1). An adult and two subadult individuals were observed on a cavernous bark of acacia trees growing on the high bank of the Eya Liman along Rechnaya Street (46.642437°N 38.654124°E, 4 m a.s.l.; Fig. 2). These lizards basked on trees (Fig. 3). An additional fourth lizard (adult) was found here under a stump of acacia together with three adults of the European grass snake, *Natrix natrix* (Linnaeus, 1758). In the area, the marsh frog, *Pelophylax ridibundus* (Pallas, 1771) and the green toad, *Bufotes viridis* (Laurenti, 1768) were registered by us. According to local people data, the European pond turtle, *Emys orbicularis* (Linnaeus, 1758), the sand lizard, *Lacerta agilis* Linnaeus, 1758, and the dice snake, *Natrix tessellata* (Laurenti, 1768) inhabit the region as well.

In the locality, we collected a subadult male of *D. pontica* (Fig. 4) which is stored in herpetological collections of the Zoological Institute of Russian Academy of Sciences, St. Petersburg, Russia (ZISP 29694).

According to Doronin (2015b) data, the northernmost localities of the species are Protoka River (45.6754°N 37.8033°E), Timashevsk Town (45.5906°N 38.9599°E), and Komsomolskiy Settlement (45.6178°N 39.4741°E) in Krasnodar kray of Russia (Fig. 1). Our record of *D. pontica* from Staroshcherbinovskaya village is located at distance 119 – 130 km to the north from these localities. To the north of our record in Rostov oblast' of Russia, the species was not previously registered (Belik, 2011).

The species is very labile in choice of biotopes. Sometimes, it can occupy unsuitable (e.g., reeds) or anthropogenically transformed biotopes. Such strategy allows the species to conserve a long time isolated populations after deforestation, for example, in the Kuban River valley (Doronin, 2014; Kidov et al., 2015). Therefore, we guess that the species could previously live to the north of its present main range spreading along riverine meadows and floodplain forests.

Therefore, the population of *D. pontica* from Staroshcherbinovskaya village could be relic or recently introduced. To estimate the presumed relic origin of the population, we made several GIS models of distribution of the species since the Late Pleistocene. The present time model had a high mean test AUC value (0.937 ± 0.011) showed significance for the binomial omission test, indicating a good its performance. The predicted distribution of the species is shown in Fig. 5. The relative contributions to the model of mean temperature of coldest quarter (19%), precipitation of driest quarter (13%), and isothermality (10%) were high. Additionally, we performed two other present time models (30″ and 2.5′ spatial resolution) with use of eleven uncorrelated bioclimatic layers only. All of them had the high mean test AUCs as well (0.941 and 0.910, respectively). According to the present time models, the locality in Staroshcherbinovskaya vil-

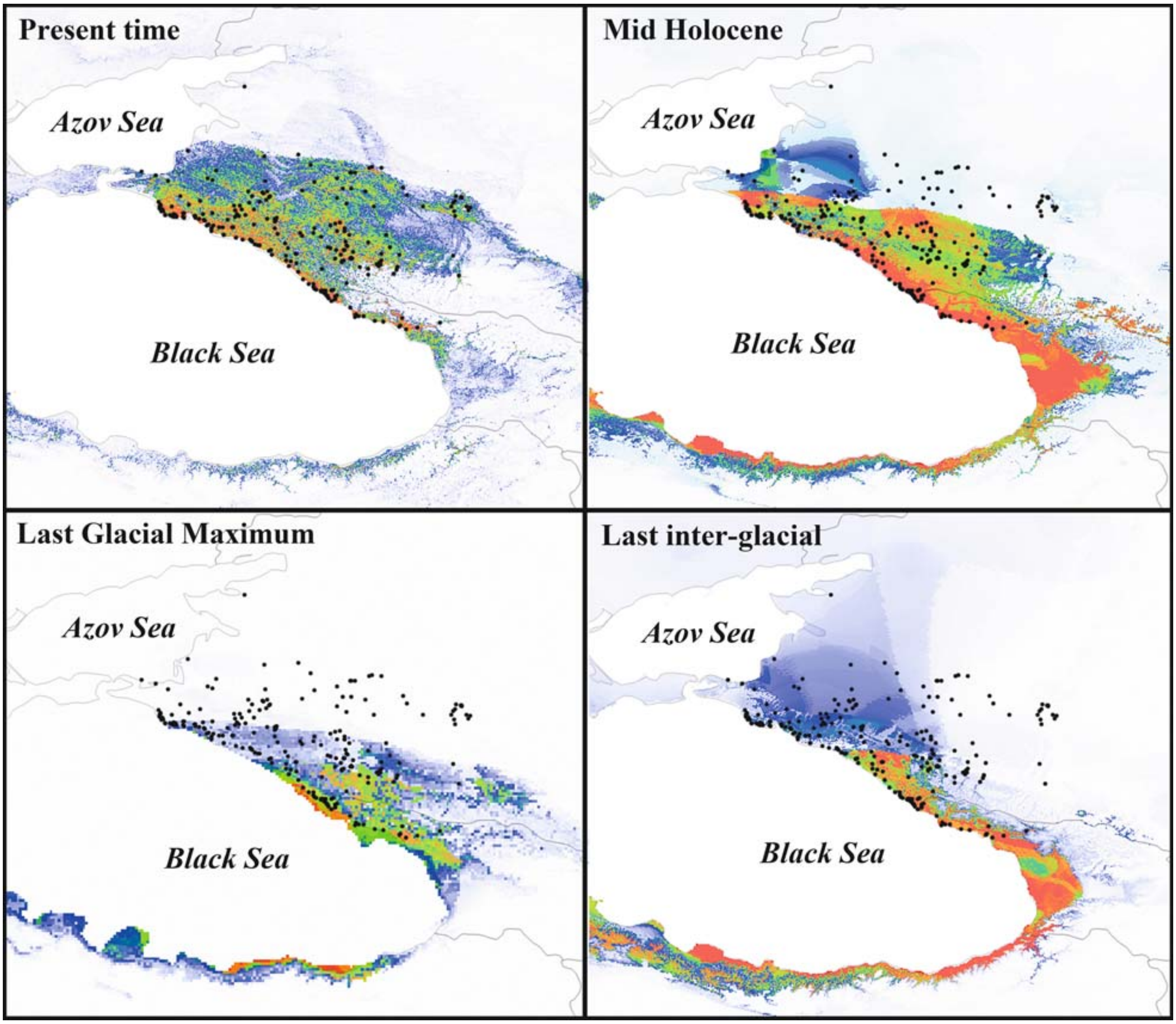

Fig. 5. The present time, the Mid Holocene, the Last Glacial Maximum, and the Last inter-glacial predicted potential geographic distributions for *Darevskia pontica* made using all known records (dark circles). All areas with red (probability of occurring of the species are 0.75 – 1.0), yellow (0.50 – 0.75), green (0.25 – 0.50), and blue (0.10 – 0.25) colors likely represent suitable environmental conditions.

lage has little suitable environmental conditions for survival of *D. pontica* (probability of occurring is 0.008).

Taking in consideration that bioclimatic layers had high relative contributions to the models, we made three additional models for the Mid Holocene, the Last Glacial Maximum, and the Last inter-glacial times (Fig. 5). Based on these models, the range limits of *D. pontica* strongly changed during these periods, especially in the northeastern part of the species range. However, vicinities of Staroshcherbinovskaya village was little suitable for the species at all periods studied (probabilities of occurring are 0.006 – 0.008). Taking into account that a survival of the species for a long period under such uncomfortable conditions is unlikely, we consider that this population seems to be recently introduced. Local peoples widely use tree seedlings and various woods (boards and firewood) originated from the Caucasian forests and can occasionally transport these lizards. It is important to note, that acacia trees which inhabits the local population of *D. pontica* are introduced as well.

Acknowledgments. We thank Igor V. Doronin (St. Petersburg, Russia) for helpful comments and literature.

REFERENCES

Agasyan A., Avci A., Tuniyev B., Crnobrnja-Isailović J., Lymberakis P., Andrén C., Cogalniceanu D., Wilkinson J., Ananjeva N., Üzüm N., Orlov N., Podloucky R., Tuniyev S., Kaya U., Böhme W., Ajtic R., Tok V., Ugurtas I. H., Sevinç M., Crochet P.-A., Nettmann H. K., and Krecsák L. (2009), "*Darevskia praticola*," The IUCN Red List of Threatened Species 2009: e.T157245A5058913. DOI: 10.2305/IUCN.UK.2009.RLTS.T157245A5058913.en.

Belik V. (2011), *Resources of Biodiversity of Steppe Don River Territory. Amphibia. Reptilia*, LAP Lambert Acad. Publishing [in Russian].

Doronin I. V. (2013), "New records of rock lizards of the genus *Darevskia* Arribas, 1997 (Sauria: Lacertidae) in the Caucasus," *Tr. Zool. Inst. RAN*, **317**(3), 282 – 291 [in Russian].

Doronin I. V. (2014), "*Darevskia pontica* (Pontic Lizard)," *Herpetol. Rev.*, **45**(2), 282.

Doronin I. V. (2015a), *Systematics, Phylogeny and Distribution of Rock Lizards of* Darevskia (praticola), Darevskia (caucasica) *and* Darevskia (saxicola) *Complexes. Author's Abstract of Candidate's Thesis*, Zoological Institute, Russian Academy of Sciences, St. Petersburg [in Russian].

Doronin I. V. (2015b), "Distribution data of rock lizards from the *Darevskia* (*praticola*) complex (Sauria: Lacertidae)," *Curr. Stud. Herpetol.*, **15**(1/2), 3 – 38 [in Russian].

Freitas S., Vavakou A., Arakelyan M., Drovetski S. V., Crnobrnja-Isailović J., Kidov A. A., Cogălniceanu D., Corti C., Lymberakis P., Harris D. J., and Carretero M. A. (2016), "Cryptic diversity and unexpected evolutionary patterns in the meadow lizard, *Darevskia praticola* (Eversmann, 1834)," *Syst. Biodiv.*, **14**(2), 184 – 197.

Kidov A. A., Kovrina E. G., Timoshina A. L., Matushkina K. A., Blinova S. A., and Afrin K. A. (2015): "Reproductive strategy of the Black Sea lizard (*Darevskia pontica* (Lantz et Cyren, 1919) in the northwestern Caucasus," *Izv. TSKhA*, **6**, 47 – 57 [in Russian].

Tuniyev S. B., Doronin I. I., Kidov A. A., and Tuniyev B. S. (2011), "Systematic and geographical variability of meadow lizard, *Darevskia praticola* (Reptilia: Sauria) in the Caucasus," *Russ. J. Herpetol.*, **18**(4), 295 – 316.

Swets K. (1988), "Measuring the accuracy of diagnostic systems," *Science*, **240**, 1285 – 1293.

Warren D. L., Glor R. E., and Turelli M. (2010), "ENMTools: a toolbox for comparative studies of environmental niche models," *Ecography*, **33**(3), 607 – 611.