7. Ермаков В.В. Биогеохимические провинции: концепция, классификация и экологическая оценка /Основные направления геохимии. – М.: Наука, 1995. – С.183-196.

8. Калинин А.П. Вклад И.К. Ахунбаева в изучение проблемы эндемического зоба // Известия АН Киргиз. ССР. Химико-технологические науки. – Фрунзе: Илим, 1988. – №3. – С.15-20.

9. Ковальский В.В. Геохимическая экология: Очерк. М.: Наука, 1974. – 300 с.

10. Кононов В.С. Динамика увеличения щитовидной железы и уролитиаза у детей в Джалал-Абадском очаге эндемического зоба // Современные аспекты адаптации организма к экстремальным условиям. – Бишкек, 1998. – С.147-155.

11. Концепция зеленой экономики в Кыргызской Республике «Кыргызстан - страна зеленой экономики» [Электронный ресурс]. – Бишкек, 2018. – Режим доступа: http://cbd.minjust.gov.kg/act/view/ru-ru/83126

12. Мурсалиев А.М., Токобаев М.М. Районирование Кыргызстана по содержанию микроэлементов в растениях и почвах // Известия АН КР, серия биология. – №2. – 1991. –.37-45.

13. Национальная стратегия развития Кыргызской Республики на 2018-2040 годы [Электронный ресурс]. – Бишкек, 2018. – Режим доступа: https://www.gov.kg/ru/programs/8

14. Стратегический мастер-план восстановления окружающей среды на площадках уранового наследия в Центральной Азии. Представлен на 65-й сессии Генеральной конференции МАГАТЭ (Вена, Австрия, 21 сентября 2021 г.).

15. Djenbaev B. M., Zholbolduev B.T., Zhumaliev. T.N., and Voitsekhovitch O.V. Radioecological Assessment of the Uranium Tailings in Tuyuk-Suu (Kyrgyzstan) // Journal of Geological Resource and Engineering. – Volume 3. – №2. – Mar-Apr.2015. – P.89-97.

16. Djenbaev B.M., Kaldybaev B.K., Zholboldiev B.T. – Book title: Radioactive Waste. – 2012: https://www.intechopen.com/chapters/36019

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GRAZING IS THE MAIN THREAT TO THE STABILITY OF POPULATIONS OF RANODON SIBIRICUS (AMPHIBIA, HYNOBIIDAE) IN THE CENTRAL PART OF THE SPECIES RANGE (KAZAKHSTAN)

T. N. Dujsebayeva, D. V. Malakhov

Institute of Zoology of the Republic of Kazakhstan, 93 al-Farabi Avenue, Almaty 050060, Kazakhstan

СКОТОВОДСТВО КАК ГЛАВНАЯ УГРОЗА СТАБИЛЬНОСТИ ПОПУЛЯЦИЙ RANODON SIBIRICUS (AMPHIBIA, HYNOBIIDAE) В ЦЕНТРАЛЬНОЙ ЧАСТИ АРЕАЛА ВИДА (КАЗАХСТАН)

Т.Н. Дуйсебаева, Д.В. Малахов

Институт зоологии Республики Казахстан, пр. аль-Фараби, 93, Алматы, 050060, Казахстан

МАЛ ЧАРБАЧЫЛЫК RANODON SIBIRICUS (AMPHIBIA, HYNOBIIDAE) ПОПУЛЯЦИЯЛАРЫНЫН ТУРУКТУУЛУГУНА НЕГИЗГИ КОРКУНУЧ КАТАРЫ (КАЗАКСТАН)

Т.Н. Дуйсебаева, Д.В.Малахов

Казакстан Республикасынын Зоология институту, Аль-Фараби пр., 93, Алматы, Казакстан, 050060

tatjana.dujsebayeva@zool.kz, dmitry.malakhov@zool.kz

Abstract: The article summarizes the results of monitoring of Semirechensk Salamander (Ranodon sibiricus) populations and their habitats in the central part of the species' range in Kazakhstan in 2021. Distant cattle breeding is considered the main reason for the serious degradation of salamander's habitats, and the death of amphibians and their clutches. Attention is emphasized on the urgency of creating a protected area to conserve the species in situ.

Keywords: Semirechensk Salamander, anthropogenic threats, grazing, habitat degradation

Аннотация: В статье подводятся итоги мониторинга состояния популяций семиреченского лягушкозуба, Ranodon sibiricus и мест его обитания в центральной части ареала вида на территории Казахстана в 2021 году. Отгонное скотоводство рассматривается как главная причина серьёзной деградации мест обитания лягушкозуба, гибели амфибий и их кладок. Акцентируется внимание на срочности создания заповедной территории для сохранения вида in situ.

Ключевые слова: семиреченский лягушкозуб, антропогенные угрозы, скотоводство, деградация мест обитания

Аннотация: Макалада 2021-жылы Казакстанда семиреченск бакатишинин, Ranodon sibiricus популяциясынын жана анын түрдүк ареалынын борбордук бөлүгүндө жашаган чөйрөлөрүнүн абалына мониторингдин жыйынтыгы чыгарылган. Алыскы жайыттарда мал багуучулук бакатиштеринин жашоо чөйрөсүнүн олуттуу бузулушунун, жерде-сууда жашоочулардын жана алардын жумурткаларынын өлүмүнүн негизги себеби катары каралат. In situ түрүн сактоо үчүн корук түзүүнүн актуалдуулугуна көңүл бурулат.

Негизги сөздөр: Семиреченск бакатиши, антропогендик коркунучтар, мал чарбачылыгы, жашоо чөйрөсүнүн бузулушу.

The Semirechensk Salamander (Ranodon sibiricus Kessler, 1866) is rare endemic anuran amphibian. It lives only in the Dzhungarian Alatau Mountains in southeastern Kazakhstan and is extremely limited in neighboring northwestern Xinjiang (China). The conservation status of the species is IUCN (Red List) Status Endangered (EN); National Status VU (Kazakhstan), EN (China); Red Data Books of the former USSR and Kazakhstan [14].

Several populations represent the species with minimal intraspecific genetic differentiation [4, 16]. It occurs in the main sub-latitudinal river basins of the Dzungarian Alatau, separated by high mountain ranges [10]. Amphibian habitats have historically been continuously reduced due to climate aridization and anthropogenic impact [15]. Over the last decade, the mountain regions of Central Asia in general and the Dzungarian Alatau, in particular, continue to go on the way of climate instability [12], livestock increases and the invasive mammal Neovison vison has emerged for R. sibiricus a new danger [5]. The scale of illegal removal of the Semirechensk salamanders from nature for medicinal and commercial purposes, established as far as in the last century [3, 17], is currently not estimated. Until now, this species lacks strict protection in situ.

Although the Koksu and Chizhe rivers' basins, which form the centre of the species range, were visited by scientists as early as the middle of the last century [1, 3, 13], systematic and full-scale studies have not been carried out here. Modern threats and risk factors for the species were previously assessed mainly on the example of populations from the southern part of the range in Kazakhstan (the valley of the Borokhudzir river) and from China [6–8, 20, 21]. Works on the study of the distribution and ecology of R. sibiricus in the central part of the range with the identification of factors limiting its well-being and the assessment of current risks were started by us in 2009 as a part of the project of the Institute of Zoology of the Republic of Kazakhstan and continued in 2012, 2014, 2015 and 2021 under the roof of the Kazakhstan Association for the Conservation of Biodiversity (ACBK). In this article, we briefly highlight the results of the latest monitoring of the status of R. sibiricus populations, carried out in 2021 as part of the CEPF project "Advancing Cooperative Biodiversity Conservation in Kazakhstan's Dzungaria Ecological Corridor". (Conservation Grants Number: CEPF-110779).

MATERIAL AND METHODS

Monitoring activity design in 2021 and used terminology were based on the same methods and principles that we applied for the long-term study of the salamander [8, 10].

Study area and period. According to available data, mid-June to mid-September is the most suitable time for amphibian activity [7, 8]. On 10–25 June and 10–25 September 2021, the direct field observations on R. sibiricus were conducted in the central part of Dzungarian Alatau Mountains

within the altitude range from 1600 to 2900 m above sea level. The field survey includes the territory of the Koksu and Chizhe rivers basins. In July, the data on vegetation and water conditions in the model habitats of R. sibiricus were additionally collected.

Methods. We have inspected 33 water streams and 60 sites within them, including those visited previously: in late May 2009, July and September 2012, July 2014 and 2015 [9]. Of 60 localities, 12 were inspected twice during the 2021 season – in June and September. We have undertaken the road routes with short-term (a few hours to one-two days) stays in some localities to look for salamanders, to fix the ground-truth points on its distribution, to assess its abundance, to describe the habitat parameters, to collect the data on some aspects of its ecology (breeding, development, age composition, etc.) and to check the anthropogenic impact. The data have been entered into the database. Accounting work during the day and night was conducted in all streams where we found the salamanders. We have conducted 45 counts of the amphibians in June и 26 – in September (in some localities during the day and night). The counts included the adults, immature individuals, metamorphosed specimens, as well as larvae after the first wintering (1+) (see in detail [8]). The data with maximal occurrence (maximal abundant) of salamanders independently upon the time (day/night) of account and season were used for comparative analysis.

Analysis of human impact (distant-pasture cattle and deforestation) was based on field data (58 sites). We paid special attention to the degree of disturbance of the water streams and their banks: the destruction of the banks and niche shelters, the state of the riparian vegetation, the stream siltation, and overgrowth with aquatic plants. Based on previous experience, we classified the different stages of habitat degradation into three main classes (Table 1).

Table 1. Simplified three-level classification of the state of Ranodon sibiricus habitats being under anthropogenic impact

Class of destruction	Description
I – Weak	The coastline is not disturbed: the niches are preserved, no traces of hooves. The riverbed is clean, without soil deposits and livestock waste products, coastal and aquatic vegetation, if any, is represented by species of mountain streams with the domination of *Veronica beccabunga*. Original plant species composition is preserved.
II – Moderate	In the points of livestock watering, the banks are collapsed with traces of hooves. Some sections of the channels are with soil sediment and/or siltation; the flow rate is decreased. Coastal vegetation is moderately etched: the grass stand is preserved, but its height is reduced, the number of natural species of the original community is reduced due to an increase in the percentage of species not eaten by livestock. Slopes in the watercourse valley with livestock trails interspersed with untouched vegetation; the visible erosive collapse of the slopes.
III – High	The banks are destroyed along the entire surveyed channel of the streams: the niches are collapsed, there are numerous traces of hooves, and the stones along the bank and in the streams are turned up. The channel is full of sediments from the collapse of the banks, heavily silted, and overgrown with sedges (*Carex* sp.) and mud. Water flow is noticeably reduced, or water is almost stagnant. Coastal vegetation is severely etched: the height of the vegetation cover is insignificant; the non-eaten plant species absolutely dominate. The slopes near the streams are dotted with livestock trails, and its vegetation is heavily etched. The percentage of erosion phenomena is high.

Above-ground biomass (AGB) influences environmental processes, such as the hydrological cycle, soil erosion and degradation, especially in semi-arid areas [11]. Remotely sensed satellite data are well-known and effective in vegetation monitoring. Due to the high reflection of chlorophyll in the infrared spectrum, NIR reflectance spectroscopy has proved to be very effective for analyzing grassland biophysical parameters like above-ground biomass (AGB), the proportion of dead material, health and moisture conditions of plants, etc. The red-edge spectral region (680–740 nm), the peak of maximum reflectance region (900 nm) and the moisture-sensitive feature around 970 nm have been widely investigated in the literature [18]. Another advantage of red-edge bands is the enhanced distinction between grasslands and shrub encroachment in mountain ecosystems [2]. We used the standard ENVI 5.3 (for Landsat data) radiometric calibration and atmospheric correction routine. Sentinel-2 imagery was processed with SNAP Desktop 9.0.

RESULTS AND DISCUSSION

As far as we know, many factors are limiting the well-being of the salamander populations: natural – climate change, weather conditions, spring floods and mudflows, etc.; anthropogenic – cattle grazing and removal from nature for scientific and commercial purposes [8, 15]. Despite the relatively positive results obtained during the survey of the Koksu river basin and adjacent areas of the upper basins of the Oisaz and Shymbulak rivers (where salamanders were found in many watercourses, and their number was not critically low), we noted significant changes in its habitats and observed the deaths of the animals themselves and their clutches arose from anthropogenic influence.

Among the risks for salamander populations in the central part of the range, we distinguished the following: 1) direct death of amphibians and their clutches in places of livestock migration and watering, 2) low level of water flow, 3) high degree of siltation of many channels and their overgrowth with aquatic plants, 4) degradation of coastal vegetation, 5) destruction of riverbanks and niches which serve as daytime and winter shelters for salamanders; 6) slope erosion, 7) dispersal of American Mink. Excessive and uncontrolled grazing we consider the main risk factor.

The influence of grazing was expressed in the death of the animals, their clutches and larvae, and in the significant degradation of habitats. One of the particular dangers to this animal is the season of the spring migration of livestock to summer pastures which occurs in late May – the first half of June. It also is the most active season for salamander egg-laying. The death of amphibians and their clutches under the hooves of livestock was discussed earlier in the example of the state of populations of the species in the southern part of the range [8]. This risk factor was no less serious for the Koksu river and adjacent basins of the Oisaz and Shymbulak rivers. In June, we found only single facts of the death of adult and subadult specimens of R. sibiricus, and of the 48 clutches, 8% were torn off. However, our study fell on the first phase of raising livestock to pastures, when the main herds and flocks were moving up the valley. The grazing period in the Koksu river valley starts around the beginning of June when first herds appear in the lower flow of the Koksu river and start moving up to the mountains. June is a month of maximum precipitation, and it is still cold. July, a less wet but well-heated month, should provide the maximum vegetation biomass, gradually decreasing from the beginning of August to mid-September, when the first snowfalls are possible. Most herds are leaving the Koksu river valley from mid to end of August. Following this logic, the difference in NDVI calculated for mid-July and the beginning of grazing season should indicate a significant increase of NDVI values for intact areas and, at least, minor changes for moderately grazed pastures. Figure 1 illustrates the actual NDVI dynamics from the last week of May 2022 till mid-July 2022 for the Karabulak cluster. Estimation of grazing load to the pasture area provides an optimal cattle amount. It is equal to 6900–7000 sheep and goats. This estimation may vary slightly between dry and wet or warm and cold years. The cattle amount that was officially permitted to graze within the Karabulak cluster was 7200 in the year of 2020 and 7634 in the year of 2021. Unfortunately, it is impossible to calculate the actual cattle amount within the Forestry, but even official permissions gave up to 10% excess of grazing cattle. Such an excess, if continues, will lead to further pasture degradation. In the Borokhudzir river valley, where the grazing is uncontrolled, the excess of livestock leads to severe deterioration of natural ecosystems, including numerous evidences of soil erosion, mechanical destruction of shelters for endangered newts, and biochemical water pollution due to livestock excretions, making the water of springs unsuitable for autochthonous species.

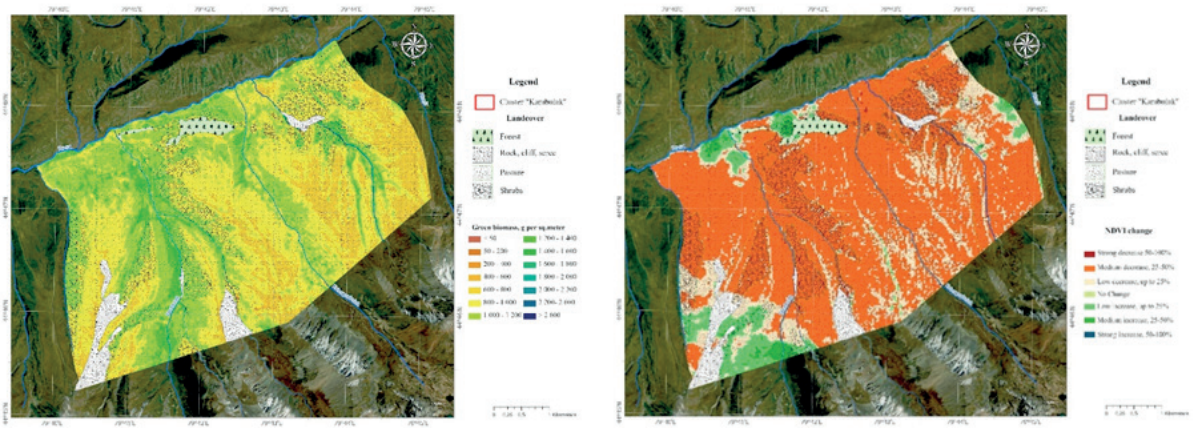

Fig. 1. Above Ground Biomass in the model site in the upper part of the Koksu river basin: A – above Ground Biomass, July 2023. The highest AGB values referred to the plainest areas along streams. The higher altitude up by the slope, the less soil wetness may be expected, and the AGB decreases following the decrease of soil wetness; B – NDVI difference between 21 July 2022 and 20 May 2022. The natural growth of NDVI is shown for very small areas, mostly forests and remote areas that are hard to herd access. Most of the grazing areas demonstrated the fall of NDVI due to overgrazing.

Of 60 sites inhabited by salamanders, in 58 (!) we recorded the changes, which, according to the degree of impact, were characterized as moderate (class 2: 57% of streams) or strong (class 3: 40% of streams) (Fig. 2A). The degradation and destruction of the habitats of R. sibiricus could be schematically represented as a series of several events (see also Table 1):

1) The collapse of the banks under the hooves of livestock – the destruction of coastal niches, shuffling stones along the riverbed and on the coast – leads to the disappearance of daytime and wintering shelters, the disappearance of areas for laying eggs and the development of 0+ larvae. The destruction of the sources of streams and saz springs seems to be very dangerous, which can cause a serious change in the regime of watercourses, and in some cases – their complete disappearance (Fig. 2B).

2) A filling of the channel with products of bank collapse – stones and soil resulting in a change in the speed of the water flow, including its slowdown.

3) A slowdown of the flow rate, stagnation of water against the background of the channel packing with coastal soil that leads to the growth of plankton and algae (Fig. 2C), intensification of eutrophication processes and a decrease in the oxygen content in water. The final phase is an overgrowth of the channel by sedge (Carex sp.).

4) The processes of eutrophication are intensified and accelerated when the channel is polluted with livestock products (manure), which is expressed, in particular, in the appearance of characteristic foam and/or traces of fat accumulations on the surface of watercourses.

5) The degradation of natural coastal plant communities, mainly a decrease in the height and biomass of the grass stand, provokes greater heating of the soil, increases the evaporation of moisture from the surface of the soil and the watercourse itself, and leads to the drying up of coastal areas in general. This process is intensified in dry years.

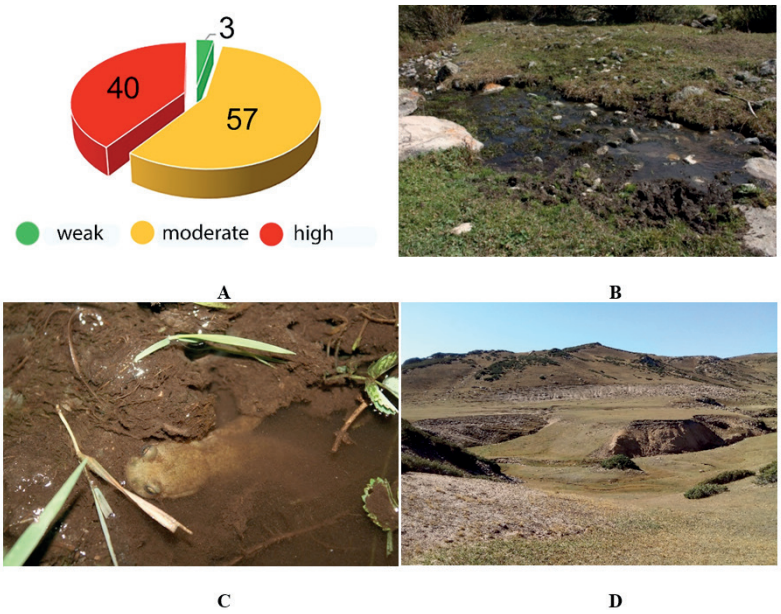

Fig. 2. The changes in the habitats of Ranodon sibiricus under the influence of grazing and other anthropogenic factors: A – distribution of the habitats in the project area by degradation classes; B – broken sources of the stream in the valley of the river Ermensai (Koksu basin); C – the salamander in the stagnant silty water of the degraded stream; D – the erosion of mountain slopes in the Koksu river valley, especially noticeable in autumn. Photo by T. Dujsebayeva.

6) A particular danger to the general microclimate of the salamander habitat is posed by erosion processes, actively proceeding along the slopes with intensive grazing (Fig. 2D). These processes have both natural and anthropogenic causes (knocking out the vegetation cover with exposure of the ground). The most serious negative effect of such processes is the increase (as in the case of the shores, but on a larger scale) of the warming up of the slopes and, accordingly, the intensification of moisture evaporation, leading to aridization of the microclimate of the R. sibiricus habitats.

In general, all the above processes and phenomena observed in areas of intensive grazing are interrelated and reinforce each other, leading to a deterioration in the ecological conditions of the species' habitat.

CONCLUSION

According to our data, the streams of the project area of the central part of R. sibiricus range were in a threatened state. On the surveyed territory, we practically did not find the streams untouched by livestock, and the percentage of streams with a high degree of degradation was 40%. By mid-June, after only one and half weeks after the rise of the first consignments of cattle to the valley of Koksu and Chizhe rivers, many streams were noticeably disturbed. By September, due to a natural decrease in water flow and a drier summer season than in previous years, the streams in grazing areas were deplorable. Against the background of further warming of the regional climate and the subsequent intensification of glacier melting [19], the intensification of livestock grazing is becoming a severe threat to the stability of R. sibiricus.

Earlier, based on some arguments, it was assumed that because of its relatively stable statement, the central part of R. sibiricus range could be considered as a potential reserve area for the species [8]. Today we see that the negative consequences of anthropogenic impact on the habitats of the salamander are becoming more pronounced here and may lead to the species extinction even in the near future. The creation of a protected area for R. sibiricus is becoming not just a necessity but an urgent measure to preserve populations of the species in situ. Since this part of the species range is closest to the Chinese populations of R. sibiricus, it would be desirable to combine the efforts of the two countries and try to solve the problem of conserving the endangered species at the transboundary level.

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REFERENCES

1. Bannikov A.G. On the biology of Ranodon sibiricus // [Reports of Academy of Sciences of USSR]. – 1949. – Vol. 65. – No. 2. – P. 237-240 [in Russian].

2. Bayle A., Carlson B.Z., Thierion V., Isenmann M., Choler P. Improved mapping of mountain shrublands using the Sentinel-2 red-edge band. Remote Sensing. – 2019. – Vol. 11. – No. 2807. https://doi.org/10.3390/rs11232807

3. Brushko Z.K., Kubykin R. A., Narbayeva S.P. 1988. Recent distribution of Siberian Salamander Ranodon sibiricus (Amphibia, Hynobiidae) in Dzhungarian Alatau // Zoologichesky Zhurnal. – 1988. – Vol. 63. – No. 1. – P. 1753-1755 [in Russian].

4. Chen S.–Y., Zhang Y.–J., Wang X.–L., Sun J.–Y., Xue Y., Zhang P., Zhou H., and Qu L.-H. 2012. Extremely low genetic diversity indicating the endangered status of Ranodon sibiricus (Amphibia: Caudata) and implications for phylogeography // PLoS ONE. – 2012. – Vol. 7. – No. 3. e33378. https://doi.org/10.1371journal.pone.0033378

5. Cheremnov D.V., Dujsebayeva N.N., Cheremnov V.E., Dossbolov U.K. First results of comparative monitoring of the American Mink (Neovison vison) and the Semirechensk Salamander (Ranodon sibiricus) in the Junggarian Alatau (Kazakhstan) // Selevinia. – 2015. – No. 23. – P. 159-165 [in Russian with English resume].

6. Dolmen D., Arnekleiv J.V., Kubykin R.A. and Mikutavichus D. Habitats and threats to the red list species Ranodon sibiricus (Hynobiidae). Abstracts of the Second World Meeting of Herpetology. – 1993. – (29th December 1993 – 6th January 1994, Adelaide, Australia). – P. 74.

7. Dolmen D., Kubykin R. A., and Jo V. Arneklein. Diel activity of Ranodon sibiricus (Amphibia: Hynobiidae) in relationship to environment and treats // Asiatic Herpetological Research. – 1999. – No. 8. – P. 29-37.

8. Dujsebayeva T.N. Results of monitoring of Ranodon sibiricus Kessler, 1866 (Amphibia: Caudata: Hynobiidae) populations in the southern part of the area // Trudy Zoologicheskogo Inst. RAS. – 2013a. – Vol. 317. – No. 2. – P. 151-175 [in Russian].

9. Dujsebayeva T.N. Final report of the grant project "Ranodon sibiricus Kessler, 1866: Monitoring study at the early XXI century with goal to establish and substantiate protected territory", supported by the STIFTUNG ARTENSCHUTZ's "Amphibian Funds" in cooperation with the Verband Deutscher Zoodirektorene. V. (VDZ) and co–funding zoological gardens. 2013b.

10. Dujsebayeva T.N., Malakhov D.V. 2017. The model of Ranodon sibiricus ecological niche: GIS and Remotely Sensing Approach // Russian Journal of Herpetology. – Vol. 24. – No. 3. – P. 171-192. https://doi.org/10.30906/1026-2296-2019-24-3-171-192

11. Eisfelder C., Kuenzer C., Dech S. Derivation of biomass information for semi–arid areas using remote–sensing data. International Journal of Remote Sensing. – 2012. – Vol. 33. – No. 9. – P. 2937-2984.

12. IPCC, 2014: Climate Change: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.). – Geneva, Switzerland: IPCC. – 2014. – 151 p.

13. Kubikyn R.A. 1986. On the ecology of the Semirechensk Salamander // Rare Animals of Kazakhstan. – Almaty: Nauka. – P. 187-191 [in Russian].

14. Kuzmin S.L., Xiuling W., Ishchenko V.G., Tuniyev B.S. 2004. Ranodon sibiricus. The IUCN Red List of Threatened Species 2004:e.T19304A8851144. https://dx.doi.org/10.2305/IUCN.UK.2004.RLTS.T19304A8851144.en Downloaded on 05 July 2021

15. Kuzmin S.L., Kubykin R.A., Thiesmeier B., Greven H. The distribution of the Semirechensk Salamander (Ranodon sibiricus): a historical perspective // Advances in Amphibian Research in the Former Soviet Union. – Sofia – Moscow: Pensoft, 1998. – P. 1-20.

16. Nishikawa K., Dujsebayeva T., Matsui M., Yoshikawa N., Tominaga A. Historical demography of an endangered salamander, Ranodon sibiricus (Amphibia, Urodela, Hynobiidae), a reassessment // Zoological Science. – 2017. – Vol. 34. – P. 18-25. https://doi.org/10.2108/zs160099

17. Shnitnikov V.N. Some data on Semirechensk Newt (Ranidens sibiricus Kessl.) // Ezhegodnik Zoologicheskogo Muzeya Akademii Nauk. – 1913. – Vol. 18. – No. 53. – P. 53-61 [in Russian].

18. Vescovo L., Wohlfahrt G., Balzarolo M., Pilloni S., Sottocornola M., Rodeghiero M., Gianelle D. 2012. New spectral vegetation indices based on the near–infrared shoulder wavelengths for remote detection of grassland phytomass // International Journal of Remote Sensing. – Vol. 33. – No. 7. – P. 2178-2195.

19. Vilesov E.N., Morozova V.I., Seversky I.V. Glaciation of Jungar (Zhetysu) Alatau: Past, Present, Future. – Kazakh State Univ. Press, 2013. – Almaty [in Russian].

20. Yang G.Y., Zhang L. Research on Ranodon sibiricus Kessler living conditions and imminent danger degree and protection // Environmental Protection of Xinjiang. – 2006. Vol. 28. P. 19-21.

21. Yang G.Y., Wang X.L. Reason analysis on decreasing number of Ranodon sibiricus and conservative strategies // Journal of Xinjiang Normal University (Natural Sciences Edition). – 2009. – Vol. 28. – P. 15-18.