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Boloria eunomia (Esper, 1799) (Lepidoptera: Nymphalidae) revised in the Caucasus: taxonomy, life history, rediscovery and conservation in Armenia

Новые данные о *Boloria eunomia* (Esper, 1799) (Lepidoptera: Nymphalidae) на Кавказе: таксономия, биология, новое нахождение и охрана вида в Армении

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Ключевые слова: Lepidoptera, *Boloria eunomia*, Кавказ, таксономия, экология, новое нахождение, Армения, фауна.

Abstract. The population of *Boloria eunomia tenera* Morgun, 2011 is reliably found for the first time since the 1920–1930s. Short survey of the research history of this species in Armenia is given. The taxonomy of the species is discussed. New data on ecology and distribution of *B. eunomia* in Transcaucasia upon the population rediscovered in Armenia are presented. The Caucasian *Boloria eunomia* (Esper, 1799) populations peculiarities and the suggestions on conservation of the species in Armenia are given.

Резюме. Впервые с 1920–1930-х годов достоверно обнаружена популяция *Boloria eunomia tenera* Morgun, 2011. Приводится краткий обзор исследования вида в Армении, обсуждается его таксономия. Сообщаются новые данные о распространении и экологии вида в Закавказье, полученные при исследовании его в Армении. Обсуждаются особенности биологии *Boloria eunomia* (Esper, 1799) на Кавказе, даются рекомендации по охране вида.

Introduction

Boloria eunomia (Esper, 1799) (= *aphirape* Hübner, 1799) belongs to the family Nymphalidae Swainson, 1827, subfamily Argynninae Duponchel, [1835] and is characterized by a broad circumboreal distribution in the Holarctic. This species has almost continuous distribution in tundra and forest-tundra in Eurasia (Scandinavia, the north of the European and Asiatic parts of Russia) and North America (from Labrador and Alaska to Wisconsin in the south, and also in the Rocky Mountains to Central Colorado [Gorbunov, 2001; Pyle, 2006; Tuzov, Bozano, 2006; Lvovsky, Morgun, 2007; Nève et al., 2008]. From the Caucasus region it has been recently known only by museum material (a single specimen from the Great Caucasus in the Institute of Zoology of the National Academy of Sciences of Ukraine (Kiev) and a series from Armenia in the same collection and in the collection of the Zoological Museum of the Moscow State University (Moscow, Russia). The late XIX century references to the species occurrence in Talysh (Azerbaijan) and Akhaltsikhe (Georgia) have not been confirmed by the actual material and seem to be in doubt [Lederer, 1870; Bohatsch, 1886; Tschikolovets, Nekrutenko, 2012]. The closest reliable finding of the species belongs to Erzurum Province in Eastern Anatolia (Turkey).

In 2011 I described subspecies *B. e. exspectata* Morgun, 2011 and *B. e. tenera* Morgun, 2011 from the Caucasus region. In 2010 and 2011 I collected a series of this species in the Great Caucasus in Teberda vicinities. The *exspectata* holotype and parartypes were collected in the same locality, in the upper flow of Nazylykol River. The type material of *tenera* was stated upon museum samples collected in the Tsakhkadzor vicinities in Armenia [Morgun, 2011].

Material studied and results

Boloria eunomia tenera was previously known only by museum specimens from the Tsakhkadzor vicinities (Kotayk Region of Armenia) in the south-eastern part of the Tsakhkuni Mountains. In L.A. Sheljuzko's collection there is a male and a female from the same locality labeled "Armenia, Darachichag (dub. Erivani), 22.VI.1934, Tkachukov B.". In recent years the literature sources devoted to the butterfly fauna of Armenia did not include concrete references to new reliable observations and provided the abstract information [Dantchenko et al., 2011].

In 2017 the species was rediscovered in Armenia a little more than 80 years since the last verified findings. One female was found not far from the type locality of the *tenera* subspecies on 6 July 2017 (Figs 1, 2). In 2018 a special investigation of this place was undertaken. As a result, 17 males were registered from 13 to 16 June. *Boloria*

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eunomia tenera occurs above the village Tsakhkadzor within an area of not more than 100 m² (Figs 3–18). The population inhabits a damp grass subalpine meadow with the aspect of Polygonum bistorta L. at an altitude of about 2250 m a.s.l. (Figs 19–21). We found that the population is not dense enough, and the imagines activity is significantly determined by the direction of the wind and the weather conditions in general. The limits of its occurrence are clearly defined by the snakeweed association, on which butterflies feed; the species is extremely stenotopic. The survey of the slope above and below the biotope height, as well as of meadows, including similar phytocenosis at the same height and slope exposure, within a radius of approximately 10 km, did not give any results. It can be assumed that this relict population is unique to this species in the studied locality and in the region as a whole. Moreover, now it is one of the southernmost confirmed locations of the species in the West Palaearctic [Kudrna, 2002; Tolman, 2008]. The closest population possibly belonging to the same subspecies *tenera* is reliably known from Şenyurt in the Erzurum Province (Turkey), where it was found in 2017 at 2400 m a.s.l. and was also associated with the snakeweed meadows (data of Nurdan Çakır and Munir Hançer, personal communication).

The type series of *B. e. tenera* was collected by V. Gamburaev in the third decade of June. The specimens of 1930s were collected by B. Tkachukov in the third decade of July. The species was spotted at a damp gramineous and varied grass meadow at 1800–1900 m a.s.l.

The imagines of *exspectata* from the North Caucasus fly in the second half of July in the broad river valley, among the damp sites of alpine meadows formed by grass, sedges and cotton grass associations with Alchemilla caucasica Bus., A. vulgaris L., Geranium gymnocaulon DC. and distinct aspect of the larval host plant – snakeweed Polygonum bistorta L. The imagines fly above the swampy sites, feed and overnight on the flowers of snakeweed. In 2011 the population was quite abundant: on average, about 50 individuals were observed on 2 km of the linear route passing through the biotope of the species. Adults are observed annually, and that fact excludes typical for some alpine species bicyclic development.

Discussion

A study of the specimens from two known population showed stable features of their external and internal morphology that differ individuals of both mountain Caucasian and Transcaucasian populations from each other and from lowland North European ones. In addition to the complex of morphological differences of Caucasian and Transcaucasian populations individuals, the obvious ecological features associated with the peculiarities of the species distribution in the highlands were identified. Thus, the North Caucasian population of *B. eunomia* inhabits the highest altitudes (2300–2500 m a.s.l.) comparing it to other European populations.

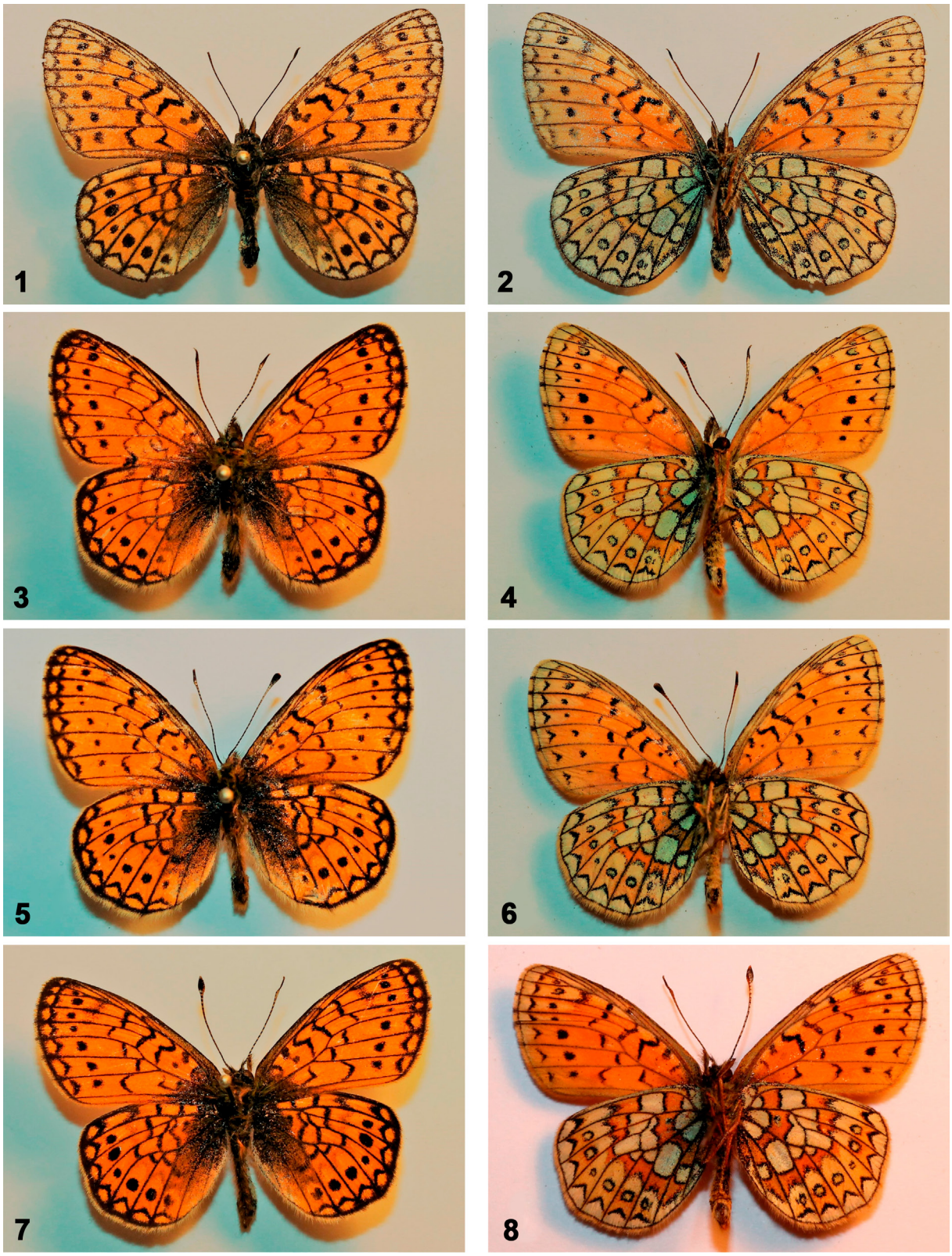
However, in 2018 R.V. Yakovlev and his co-authors revealed little congruence between previous interpretations of different subspecies of *B. eunomia* based mainly on geographical distribution or relatively minor morphological characters with molecular data, including *B. e. exspectata* from the North Caucasus. Based on the analysis of DNA barcodes they mentioned that molecular data provide evidence to support a monotypic species hypothesis rather than the recognition of several subspecific forms, with the exception of *B. e. riamia* Korshunov et Ivonin, 1998 from Siberia in Russia [Yakovlev et al., 2018]. But these authors didn't analyze *B. e. tenera* due to the absence of the available fresh material of this subspecies. Thus, its status remains to be a subspecific rank.

In the type diagnosis of this subspecies it was shown that the *B. e. tenera* males have a very thin pattern, partially reduced in the discal and postdiscal areas, compared to males of other subspecies. The females are more saturated orange, with bright wings upperside background and slightly developed dark pattern than females of other subspecies, characterized by well-developed dark suffusion. The *B. e. tenera* individuals have a soft pattern on the wings underside, more dull than individuals of other subspecies of *B. eunomia*. The spots are of yellow and orange shades, and gray in the postdiscal row on the hind wing (grey-blue, yellowish or white in adults of other subspecies). Dark elements on the underside of the forewing are partially reduced. The noticeable stable difference in the genitalia of *B. e. tenera* male is the configuration and proportions of the costal process of the valva. It has a narrow base and "stem", then – sharply isolated, massive, in the form of a rounded foot, which has numerous ventral-oriented teeth on the outer edge. The *B. e. eunomia* individuals of lowland populations have a narrow process costal margin throughout its length, with a prominent sharply forward bottom corner, forked or triangular with a notch at the bottom. The males of the North Caucasian population have a costal process with a wide base, in shape-trapezoidal, without prominent corners and projections, but with a smooth notch in the center of the outer edge. The caudal process of valva in *B. e. tenera* is hidden under the rest in the lateral projection, has a sharp, forked top, rather than lobate, blunt, as in males of other subspecies. The apical edge of valva in *B. e. tenera* lies almost on one line with the lower edge of the costal process, unlike specimens of European populations.

Thus, unique configuration and proportions of costal processes of valva was found in the male genitalia of *B. e. exspectata* and *B. e. tenera*: massive, wide, indistinctly prominent relative to the apical edge of the valva in both subspecies, trapezoidal with rounded corners in *B. e. exspectata* and oval, foot-shaped in *B. e. tenera*. In this diagnostic and taxonomic context it was shown that this described subspecies differ by a complex of the distinctive morphological and ecological peculiarities.

Significant environmental differences are determined by the relict nature of distribution and habitation of North Caucasian population in the alpine zone and *B. e. tenera* in the subalpine zone of high mountains, both of which different from the biotopes of the species in the lowland part of its European range on the set of abiotic factors.

In the North Caucasus, the species is known by one common macropopulation in the upper reaches of the Nazylykol River that is a tributary of the Dzhemagat River,

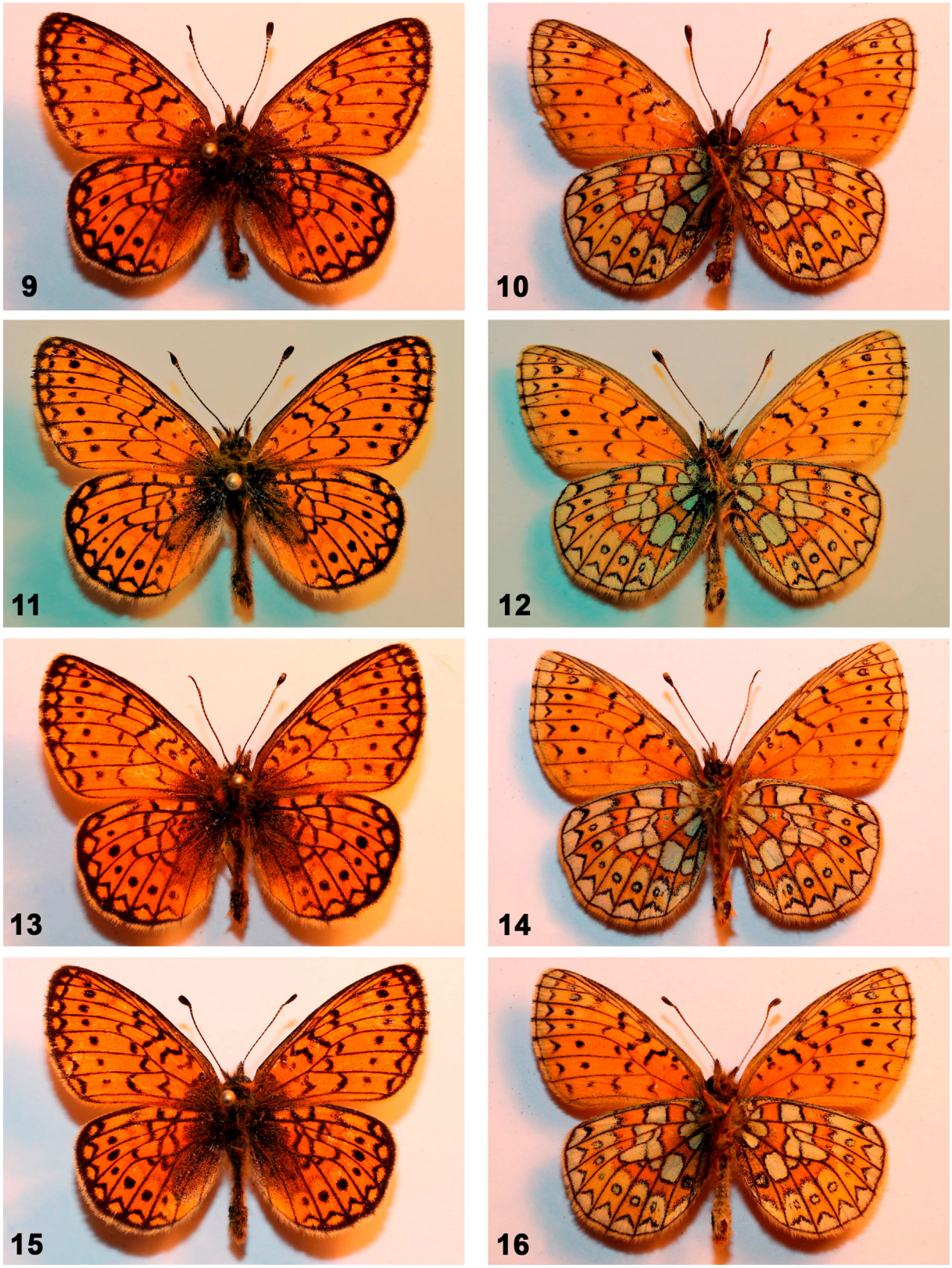


Figs 1–8. *Boloria eunomia tenera* (Armenia, Kotayk Region, Tsakhkadzor, 2250 m).

1–2 – female (6.07.2017, E.A. Mikhaylova leg., coll. D.V. Morgun); 3–8 – males (13–16.06.2018, E.A. Mikhaylova leg., ex coll. D.V. Morgun); 1, 3, 5, 7 – wings upperside; 2, 4, 6, 8 – wings underside.

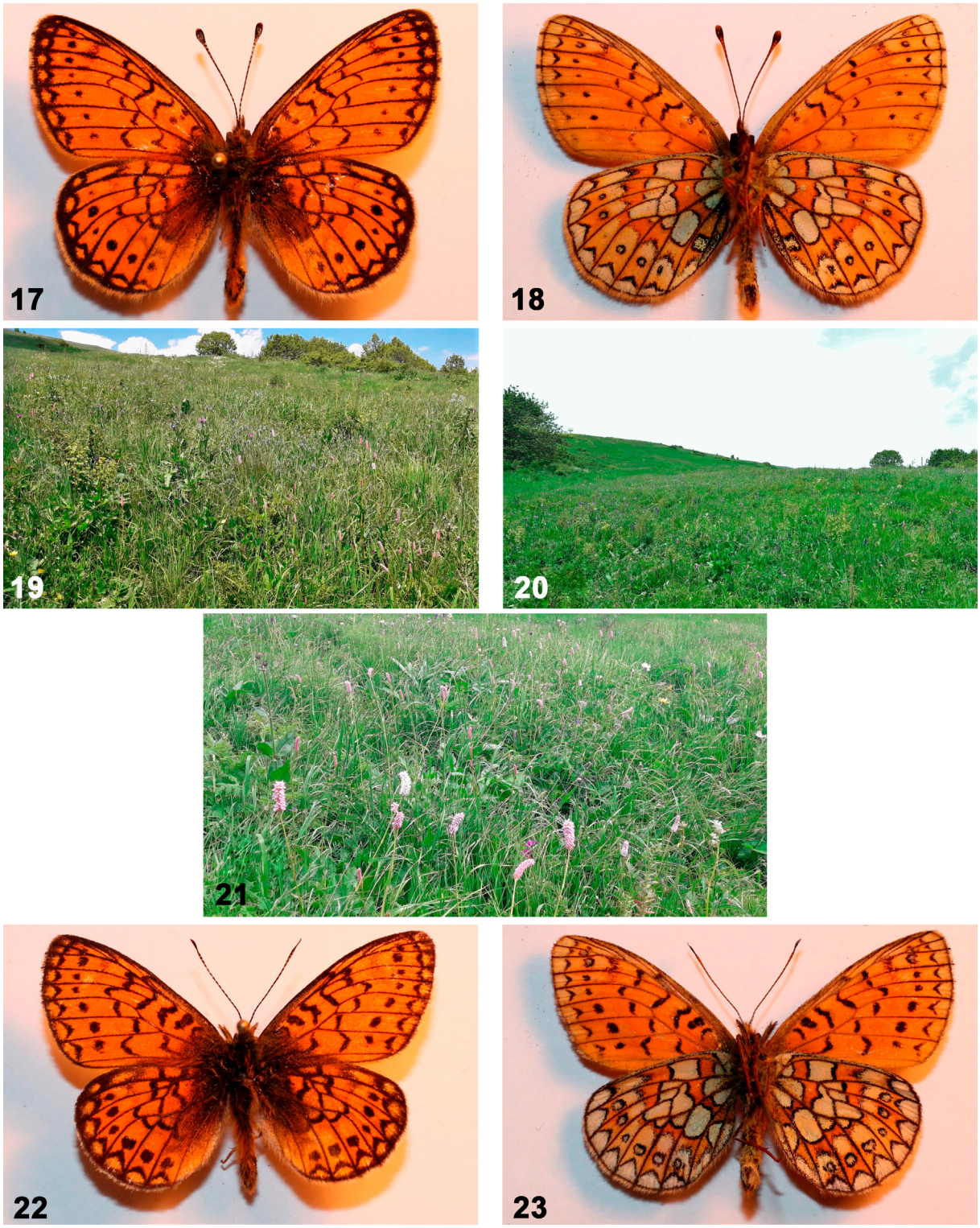
Рис. 1–8. *Boloria eunomia tenera* (Армения, Котайкская область, Цахкадзор, 2250 м).

1–2 – самка (6.07.2017, leg. E.A. Михайлова, из коллекции Д.В. Моргуна); 3–8 – самцы (13–16.06.2018, leg. E.A. Михайлова, из коллекции Д.В. Моргуна); 1, 3, 5, 7 – верхняя сторона крыльев; 2, 4, 6, 8 – нижняя сторона крыльев.



Figs 9–16. *Boloria eunomia tenera*, males (Armenia, Kotayk Region, Tsakhkadzor, 2250 m, 13–16.06.2018, E.A. Mikhaylova leg., coll. D.V. Morgun).
9, 11, 13, 15 – wings upperside; 10, 12, 14, 16 – wings underside.

Рис. 9–16. *Boloria eunomia tenera*, самцы (Армения, Котайкская область, Цахкадзор, 2250 м, 13–16.06.2018, leg. Е.А. Михайлова, из коллекции Д.В. Моргуна).
9, 11, 13, 15 – верхняя сторона крыльев; 10, 12, 14, 16 – нижняя сторона крыльев.

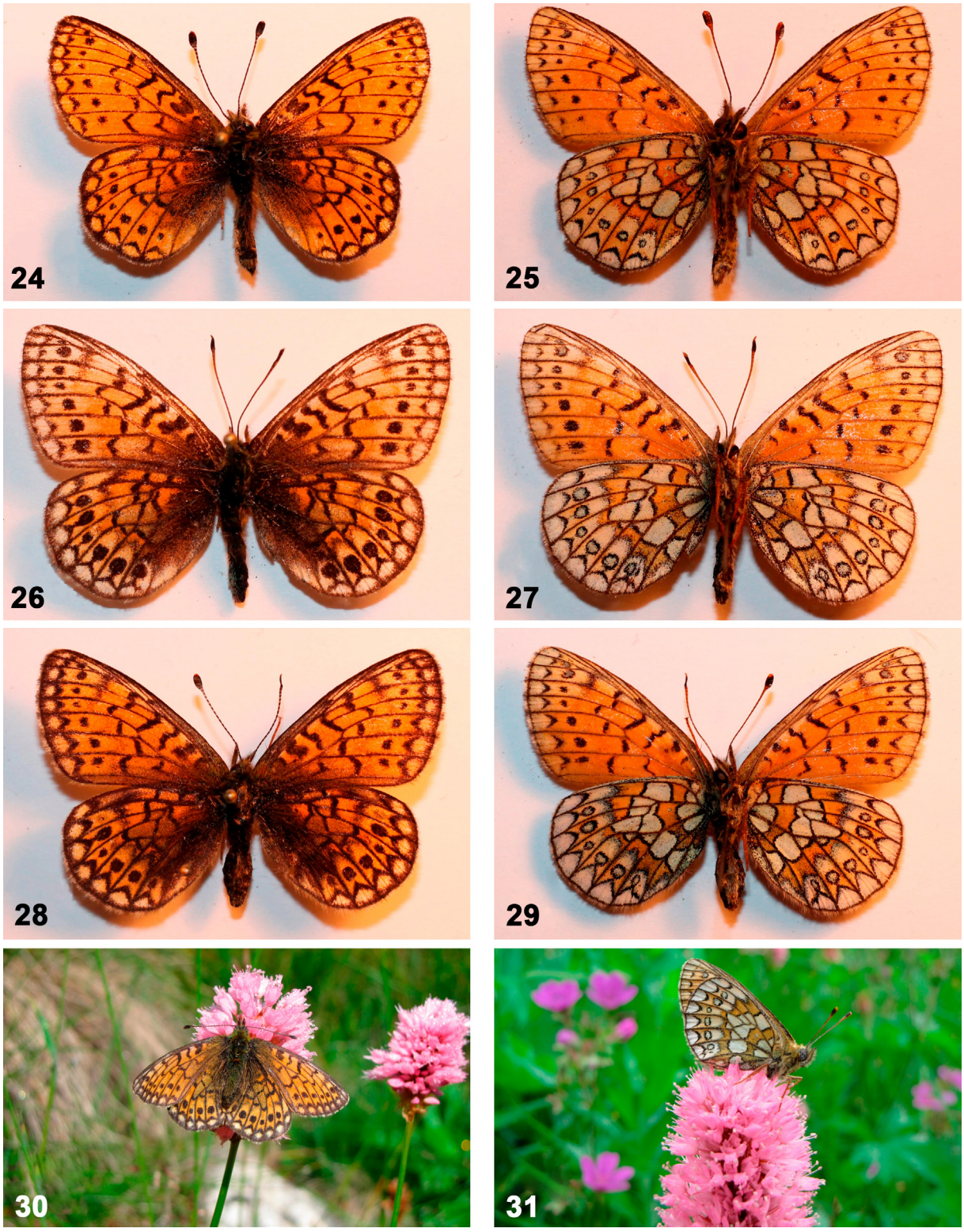


Figs 17–23. *Boloria eunomia*.

17–18 – *B. e. tenera*, male (Armenia, Kotayk Region, near Tsakhkadzor, 2250 m, 13–16.06.2018, E.A. Mikhaylova leg., coll. D.V. Morgun): 17 – wings upperside, 18 – wings underside; 19–20 – varied grass subalpine meadows, biotope of *B. e. tenera*; 21 – snakeweed Polygonum bistorta L., adult and larval host plant of *B. e. tenera*; 22–23 – *B. eunomia*, male (Russia, Karachay-Cherkess Republic, Teberda Biosphere Reserve, Nazylykol River, 2450 m, 21.07.2011, D.V. Morgun leg., coll. D.V. Morgun): 22 – wings upperside, 23 – wings underside.

Рис. 17–23. *Boloria eunomia*.

17–18 – *B. e. tenera*, самец (Армения, Котайкская область, Цахкадзор, 2250 м, 13–16.06.2018, leg. Е.А. Михайлова, из коллекции Д.В. Моргуна): 17 – верхняя сторона крыльев, 18 – нижняя сторона крыльев; 19–20 – разнотравные субальпийские луга, биотоп *B. e. tenera*; 21 – горец змеиный Polygonum bistorta L., кормовое растение имаго и гусениц *B. e. tenera*; 22–23 – *B. eunomia*, самец (Россия, Карачаево-Черкесская Республика, Тебердинский биосферный заповедник, Назылыкол, 2450 м, 21.07.2011, leg. Д.В. Моргун, из коллекции Д.В. Моргуна): 22 – верхняя сторона крыльев; 23 – нижняя сторона крыльев.



Figs 24–31. *Boloria eunomia* from the North Caucasus (Russia, Karachay-Cherkess Republic, Teberda Biosphere Reserve, Nazylykol River, 2450 m).
24–29 – females (21–22.07.2011, D.V. Morgun leg., coll. D.V. Morgun): 24, 26, 28 – wings upperside, 25, 27, 29 – wings underside; 30–31 – imagoes in nature (21.07.2011, D.V. Morgun leg., coll. D.V. Morgun).

Рис. 24–31. *Boloria eunomia* с Северного Кавказа (Россия, Карачаево-Черкесская Республика, Тебердинский биосферный заповедник, Назылыкол, 2450 м).
24–29 – самки (21–22.07.2011, Д.В. Моргун leg., из коллекции Д.В. Моргуна): 24, 26, 28 – верхняя сторона крыльев, 25, 27, 29 – нижняя сторона крыльев; 30–31 – имаго в природе (21.07.2011, Моргун Д.В. leg., из коллекции Д.В. Моргуна).

at an altitude of 2250 to 2500 m a.s.l., on the territory of the Teberda Biosphere Reserve (Karachay-Cherkess Republic, near Teberda) (Figs 22–31). Until recent times it was known from the Caucasus by a single specimen from the Teberda vicinities that was stored in L.A. Sheljuzhko's collection in the Zoological Museum of the Kiev University. This specimen, labeled "Teberda (Cauc. s.) ms. Dzhiltraus 7.VII.1935 Th. Weidinger leg. Coll. L. Sheljuzhko", was included in Sheljuzhko's collection in the second part of the 1930s when he bought the F.F. Weidinger's private collection.

The rediscovered population of *tenera* is characterized by a smaller number and density than the North Caucasian one (that occurs in a protected natural area) and faces a risk of elimination due to the intensive recreational development of the territory. Tsakhkadzor is one of the largest tourist areas of Armenia; it is a center of sports events and a popular resort for several decades. There is a ski trail and a cable car on the slope of the mountain inhabited by the population of the species. The traffic of hiking trails in the area is high too. Moreover one of the routes passes in close proximity to the biotope inhabited by the population. This determines significant risks to the sustainability of the species population. Besides, grazing near this biotope and above the slope which becomes more intense in the middle of summer is observed. Together with the recreation on this site, it creates extremely unfavorable conditions that can cause the elimination of the species in this area. Taking into consideration high environmental requirements, low population size and density of the species, these limiting factors tend to posess risk to the species in a short term perspective. One of the effective mechanisms could be legislative protection of the species, for instance its inclusion in the red list of animal species of Armenia with the assessment of regional status as Endangered by IUCN/SSC Regional Applications Working Group. However, the species does not appear in the global red list and at the global level can be assessed as LC – causing the least concern. Another measure is a creation of a local protected area in the refugium, where this relict species could be preserved. It should be noted, that the subspecies is a regional endemic and has not been found anywhere else in the Transcaucasia in recent decades. According to the current IUCN criteria for the red lists, further studies, as well as immediate environmental measures, are needed to specify its status and to save it in Armenian nature.

Thus, the new material of *B. eunomia tenera* from Transcaucasia confirms the presence of stable internal and external morphological features for subspecific differentiation that correlate with clear ecological differences of populations. Taking into account the identified risks of population elimination in the recreationally significant region of Armenia, the population of the species needs protection and constant monitoring and is subject to inclusion into the regional red list.

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