

Northern limits of distribution and migration strategy
of the dragonfly *Sympetrum fonscolombii* (Selys, 1840)
(Odonata, Libellulidae) in Russia

Северные пределы распространения и миграционная стратегия
стрекозы *Sympetrum fonscolombii* (Selys, 1840)
(Odonata, Libellulidae) в России

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Abstract. The northern limits of distribution and development in the territory of the Russian Federation are outlined for the migratory dragonfly *Sympetrum fonscolombii*. In the European part, the species is distributed north up to 56° N, but in the Ural and Western Siberia, its range is limited to 55° N by the forest-steppe zone. The easternmost point of the range is in South Primorye (42°47' N). Dragonflies of the first generation (immigrants) were recorded from April 19 to July 25. The development of the summer generation is known in two places — in Chelyabinsk (53°39' N) and Novosibirsk (54°33' N) oblasts. It is assumed that immigrants arrive to the Ural and Western Siberia in the spring-summer period from the regions of South-West Asia located south of 36° N.

Резюме. Для стрекозы-мигранта *Sympetrum fonscolombii* указываются северные пределы распространения и развития на территории Российской Федерации. В европейской части вид распространён на север до 56° N. На Урале и в Западной Сибири ареал этого вида ограничивается лесостепной зоной на север до 55° N. Самая восточная точка ареала находится в Южном Приморье (42°47' N). Стрекозы первого поколения (иммигранты) отмечены в период с 19 апреля по 25 июля. Развитие летних поколений известно в двух местах — в Челябинской (53°39' N) и Новосибирской (54°33' N) областях. Предполагается, что на Урал и в Западную Сибирь стрекозы-иммигранты прилетают в весенне-летний период из регионов Юго-Западной Азии, расположенных южнее 36° N.

Introduction

Obligatory migrations are characteristic of the dragonfly *Sympetrum fonscolombii* (Selys, 1840). The range of this species covers the Afro-Eurasian region, but its distribution is extremely uneven. This species is most numerous in Mediterranean, South-West and Central Asia [Kalkman, Bogdanovic, 2015; Borisov et al., 2020].

Since 1990s, in Western and Central Europe, which is well studied in odonatology, regular migrations of *S. fonscolombii* from the south and development of its summer generations of these dragonflies in temperate latitudes have been registered. In addition, in the last decade, the species has been actively moving northward, reaching Sweden and Finland, which is associated with general climatic warming [Kalkman, Bogdanovic, 2015].

In Middle Asia *S. fonscolombii* is a mass species, north to about 45° N. Regular seasonal latitudinal migrations of these dragonflies were revealed there. In spring, sexually mature dragonflies arrive from the south for reproduction. In autumn, the descendants of immigrants make return migrations southward [Borisov, 2011, 2015]. The migration area covers the regions of South-West Asia, Middle Asia and Kazakhstan [Borisov et al., 2020]. In Russia, *S. fonscolombii* is

common in the southern regions of the European part north to about 45° N. In recent years, its penetration to the north has been traced. It was found in the Moscow and Vladimir oblasts [Onishko, 2014, 2019] and in Chuvashia [Borisova, 2016]. In Siberia, *S. fonscolombii* was previously known only from a single finding at the beginning of the XX century in Omsk [Lavrov, 1927]. Currently, this species is found in the Southern Ural and southern Western Siberia [Popova, Eremina, 2016], in Tuva [Kosterin, Zaika, 2003, 2018] and in the Russian Far East [Onishko, 2019].

In relation to the supposed moving of this species to the north, it seems to be relevant to find out the northern limits of its distribution and the features of migration strategy in the Russian Federation.

Material and methods

To clarify the northern limits of the distribution of *S. fonscolombii* in Russia, the literature data were summarized and analyzed. Also, a new northernmost finds of this species are indicated. Where possible, it is illustrated with photos, by which the physiological age and status of dragonflies (immigrants or aboriginal individuals of the summer generation) can be approximately identified. Old individuals of *S. fonscolombii*, existing for a long time in imaginal phase, are different in colors from «post-teneral» individuals [Borisov et al., 2020], as explained below. Where possible, the physiological state of dragonflies is indicated below according to Ph. Corbet [1999]:

«teneral» — insects with the chitinous cover, that has not yet been fully hardened after emergence, and poorly developed coloration (this condition typically lasts for at least 24 hours after emergence) and «post-teneral» — insects with the chitinous cover already hardened but still with fresh sparkly wings and yellow coloration (without red) on the body, reflecting the relatively recent emergence.

The northern localities of *S. fonscolombii* in Russia are shown on the map of Fig. 1. SimpleMappr, an online tool to produce publication-quality point maps, was used for making a schematic map [Shorthouse, 2010].

Results and discussion

THE LIST OF LOCALITIES:

Loc. 1. [Shapoval, Buczycki, 2012]: Kaliningrad Oblast, Courish Spit, Biological Station Fringilla, 55°05' N, 20°44' E, 20.VIII.2007, 1♀; 30.IX.2007, 1♂; 24.VII.2010, 1♂.

(*Same as loc. 1*). [Shapoval, Shapoval, 2017]: 2015 (unspecified date), 6 individuals.

Loc. 2. [Onishko, 2019]: Moscovskaya Oblast, Volokolamskiy District, the vicinity of zoo nursery of Moscow Zoo, 55°57'22" N, 36°15'11" E, 260 m a.s.l., 25.VII.2015, 1♂.

Loc. 3. [Onishko, 2019]: Moscow, Mnevnikovskaya floodplain, 55°46'02" N, 37°24'45" E, 124 m a.s.l., 20.VI.2017, 1♀.

Loc. 4. Moscovskaya Oblast, Molzhaninovskiy District, quarries located 5 km north-west of the city of

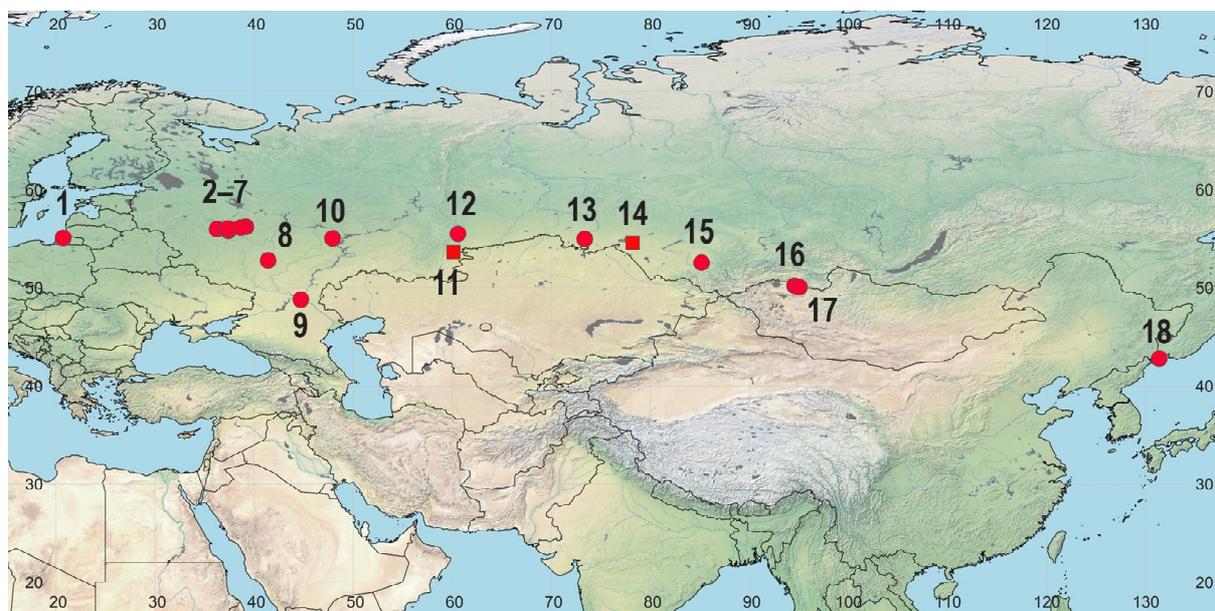


Fig. 1. Northern localities of *Sympetrum fonscolombii* in the territory of Russian Federation. The locality numbers correspond to those in the list of localities. The squares indicate the places, where the development of summer generations is determined.

Рис. 1. Северные местонахождения *Sympetrum fonscolombii* на территории Российской Федерации. Номера соответствуют таковым в списке местонахождений. Квадратами обозначены места, где установлено развитие летних поколений.

Khimki, 55°56'10" N, 37°21'43" E, 177 m a.s.l., 29.V.2019, 2♂♂, V.V. Onishko.

Remark. Only males were regularly observed from May 27 to June 10. Body coloration of all individuals was rich red (Fig. 2a).

Loc. 5. Moscovskaya Oblast, Solnechnogorsk, Tsyganskiy pond, 56°00'58" N, 37°24'40" E, 206 m a.s.l., 20.VII.2017, visual 1♀, V.V. Onishko.

Loc. 6. [Onishko, 2014]: Vladimirskaya Oblast, Kolchuginskiy District, Kozlyatyevoye village, 56°11'53" N, 39°10'52" E, 190 m a.s.l., 25.VI–15.VII.2010, 6♂♂, 6♀♀.

Loc. 7. Vladimirskaya Oblast, Kirzhachskiy District, Alenino village, peat lake, 56°06'14" N, 38°39'18" E, 131 m a.s.l., 04.VI.2019, 3♂♂, V.V. Onishko.

Remark. All males were old with a red body coloration.

Loc. 8. Tambovskaya Oblast, Tambov, Ryleeva street, the Krasnenskiy quarry, 52°46'12" N, 41°25'29" E, 132 m a.s.l., 04.VI.2019, the photo of male, A. Lezhnev.

Remark. The male has a rich red body coloration.

Loc. 9. Volgogradskaya Oblast, Volzhskiy, 48°48'00" N, 44°43'10" E, 0 m a.s.l., 16.V.2019, 3♂♂, V.V. Onishko.

Remark. All males have a rich red body coloration.

Loc. 10. [Borisova, 2016]: Chuvashia, Prisurskiy Nature Reserve, Yalchinskiy district, Eshmikeevo village (55°01'50" N, 47°55'10" E, 120 m a.s.l.), 26.VI.2015, 1♂.

Remark. Old male has rich red body coloration and noticeably worn out wings (Fig. 2b).

(Same as loc. 10). 30.V.2019, the photo of male, N.V. Borisov.

Remark. The photo shows an old male with a rich red body coloration.

Loc. 11. [Popova, Eremina, 2016]: Chelyabinskaya Oblast, Chesmenskiy District, the vicinity of Novotemirskiy village, 53°39'12" N, 60°07'24" E, 364 m a.s.l., 18.VIII.2010, 6♂♂ post-teneral, 4♀♀ post-teneral; 31.VIII.2010, 9♂♂ post-teneral, 7♀♀ post-teneral; 9.IX.2010, 2♂♂ post-teneral, 3♀♀ post-teneral.

Remark. All individuals are post-teneral with the prevailing yellow body coloration (Fig. 2d).

Loc. 12. [Popova, Eremina, 2016]: Chelyabinskaya Oblast, Argayashskiy District, the vicinity of Gubernskoye village, 55°30'11" N, 60°34'38" E, 274 m a.s.l., 9.VI.2010, 1♀.

Remark. Old female was caught during oviposition (Fig. 2c).

Loc. 13. [Lavrov, 1927]: Omsk (ca. 54°58' N, 73°22' E).

Loc. 14. [Popova, Eremina, 2016]: Novosibirskaya Oblast, Zdvinskiy District, Shirokaya Kurya village, 54°33'23" N, 78°12'19" E, 107 m a.s.l., 12.IX.2013, 1♂ post-teneral.

Remark. It is post-teneral male with yellow body coloration (Fig. 2e).

Loc. 15. Altaiskii Krai, Biysk, Lake Kovalevskoe, 52°32'10" N, 85°09'43" E, 180 m a.s.l., 12.VI.2019, the photo of male, A. Noskova.

Remark. The photo shows an old male with a prevailing red body coloration.

Loc. 16. [Kosterin, Zaika, 2018]: Ubsu-Nur depression, small freshwater lake at southern bank of large bitter-salt Lake Shara-Nur, 50°12'36" N, 94°33'0" E, 904 m a.s.l., 07.VII.2016, 1♂.

Loc. 17. [Kosterin, Zaika, 2003, 2018]: Ubsu-Nur depression, Lake Tore Khol' (50°03'18" N, 95°01'09" E, 1152 m a.s.l.), 15.VII.2000, two bright red males presumably of the considered species were observed.

Loc. 18. [Onishko, 2019]: Khasanskiy District, the vicinity of Ryazanovka village, 42°47'48" N, 131°21'05" E, 10–30 m a.s.l., 29.VII.2015, 4♂♂, 5♀♀.

Remark. From August 25 to September 9, 2015, well-colored individuals were noted repeatedly: bright red males (Fig. 2f) and olive-yellow females (Fig. 2g). They were flying along forest roads on the hills in the Baklan Bay on the Pacific coast. Signs of reproductive behavior of these dragonflies were not observed. In 2018, more than 20 dragonflies of this species were recorded in the same area in August–September. In addition, some males were found in ponds and they were observed on patrol flights.

THE NORTHERN LIMITS OF DISTRIBUTION OF *S. FONSCOLOMBII*

The northern limit of the range of *S. fonscolombii* slightly inclines to the south from the west to the east (Fig. 1). In Northern Europe, this species reaches Sweden and Finland (north to 60° N) in summer [Kalkman, Bogdanovic, 2015]. In the European part of the Russian Federation (Moscow and Vladimir oblasts, loc. 2–7), *S. fonscolombii* is known to the north only up to 56° N, even further east — this species is recorded at 55° N in Chuvashia (loc. 10). In the Ural and Western Siberia, the distribution of *S. fonscolombii* is limited to the forest-steppe zone in the north, approximately up to 55° N (loc. 11–14). Further east, this species is known in Tuva, approximately at 50° N (loc. 16–17).

In East Siberia, *S. fonscolombii* is not found, and the easternmost point of the range of this species in Russia lies in the south of Primorye — at 42°48' N (loc. 18). The absence of this species at the southern edge of Eastern Siberia (for almost 3 thousand km) can be explained in general by its rarity in the eastern part of Asia. The species occurs on this continent locally from ca 80° E [Kalkman, Bogdanovic, 2015; Borisov et al., 2020]. For instance, in Mongolia this species is known only in one place — Lake Ubsu-Nur [Belyshev, Doshidordzi, 1958]. This locality is close to the finding of the species in Tuva (loc. 16–17). There are only few its known findings in the vast territory of mainland China. In its extreme south the species is known in Yunnan Province [Chen, Yu, 2013]. In Central China, it is found in the upper reaches of the Yellow River [Bartenev, 1915]. In the north of this country, it is found in the provinces of Inner Mongolia [Dumont,



Fig. 2. Photo of *Sympetrum fonscolombii*: a — loc. 4, male (V.V. Onishko); b — loc. 10, male (N.V. Borisova); c — loc. 12, female (E.A. Chibilev); d — loc. 11, male (E.A. Chibilev); e — loc. 14, male (O.N. Popova); f — loc. 18, male (V.V. Onishko); g — loc. 18, female (V.V. Onishko).

Рис. 2. Фото *Sympetrum fonscolombii*: а — лос. 4, самец (В.В. Онишко); б — лос. 10, самец (Н.В. Борисова); с — лос. 12, самка (Е.А. Чибилёв); д — лос. 11, самец (Е.А. Чибилёв); е — лос. 14, самец (О.Н. Попова); ф — лос. 18, самец (В.В. Онишко); г — лос. 18, самка (В.В. Онишко).

2003] and Shanxi [Asahina, 1949] and on Liaotung Peninsula [Kohama, 1978].

More frequent findings of *S. fonscolombii* are known on islands near the eastern coast of Asia — from Hong

Kong [Reels, 2019] and Taiwan [Yeh et al., 2006] in the south to Honshu Island in Japan [Ryo, 2004; Naraoka, 2005] in the north. Probably, the species penetrates the Russian Far East from there.

THE FIRST GENERATION OF *S. FONSCOLOMBII*
AT THE NORTHERN LIMITS OF THE RANGE

The first generation of *S. fonscolombii* in Russia, as well as in Western and Central Europe, is represented by immigrants from the south. At the northern limits of the range in the Moscow Oblast, the earliest arrival of these dragonflies was recorded on May 27 (loc. 4) and further south, in the Volgograd Oblast — on May 16 (loc. 9). In the Southern Ural in Chelyabinsk (55°09' N, 61°18' E), bright red dragonflies of the genus *Sympetrum* were observed on April 19 and 26 and May 15, 2010 [Popova, Eremina, 2016]. With high probability, it can be assumed that these were immigrants, because at this time of year there can't be any imagines of other species of this genus. They begin to emerge there only in June.

Early spring migration of *S. fonscolombii* is also recorded in Western and Central Europe. These dragonflies arrive in Northern France and Germany in the second decade of May [Kalkman, Bogdanovic, 2015]. In Denmark, this species was recorded on May 2 [Dijkstra, van der Weide, 1997]. In Poland (Ostrowitko, 52° 46' N, 19° 08' E), *S. fonscolombii* immigrants were recorded on May 7 [Rychia et al., 2019].

Thus, in Russia, *S. fonscolombii* immigrants were recorded at the northern limits of the range from April 19 (supposedly) to July 25. For comparison, in the Netherlands they were recorded from May 2 to July 26, and some individuals were noted even on August 26 [Dijkstra, van der Weide, 1997].

THE SECOND GENERATION OF *S. FONSCOLOMBII*
AT THE NORTHERN LIMITS OF THE RANGE

Development of the second (aboriginal) generation of *S. fonscolombii* at the northern limits of the range in Russia has been recorded so far only in two places — in the Southern Ural (loc. 11) (Fig. 2d) and in the south of Western Siberia (loc. 14) (Fig. 2e) at latitude of 53°39'–54°33' N. Post-teneral individuals were noted here from August 18 to September 12. It should be expected that this species also breeds in the central regions of the European part of Russia at 55–56° N (loc. 2–7), where currently the findings of migratory dragonflies are not rare in the summer.

On Courish Spit in the Kaliningrad Oblast, *S. fonscolombii* got into the ornithological trap (loc. 1) from July 24 to September 30. In addition, the physiological age of these dragonflies (coloration and condition of chitinous cover) is not specified [Shapoval, Buczycki, 2012]. It can be assumed that dragonflies of the second generation were trapped in August and September.

The status (immigrants or residents) of *S. fonscolombii* from South Primorye (loc. 18), which were observed there in late August and early September [Onishko, 2019], remains unclear. Judging by the well-developed coloration (Fig. 2g, f), those dragonflies were in the imaginal phase for a long time. Mainly, they were

found at a distance from ponds and reproductive behavior was not observed among them. At the same time, some males were also recorded at ponds, where they were patrolling individual areas. It is one of the signs of reproductive behavior. In general, it can be assumed that all individuals of *S. fonscolombii* at that time of the year and at those latitudes were wandering or south-migrating individuals that emerged in the south of Primorye or even further north. A similar pattern was observed by us during the autumn migrations of *S. fonscolombii* at the Chokpak Pass in South Kazakhstan. Here, in October, at the peak of autumn migrations, already well-colored individuals, which had been existing for a long time in the imaginal phase, prevailed among these dragonflies [Borisov, 2011; Borisov et al., 2020].

There are no data on the duration of the preimaginal development of *S. fonscolombii* in Russia. In Europe, the duration of development of summer generations is from 54 days [Hunger, Schiel, 1999] to 75 days [Lempert, 1997]; while in Middle Asia the development takes about 2 months [Borisov, 2011].

Detailed data on the seasonal residence and development of *S. fonscolombii* were obtained in Germany. There, the northernmost places of breeding of these dragonflies in Western Europe were identified as Helgoland Island in the North Sea (54° 10' N, 7° 54' E) [Lempert, 1998] and Kreis Steinburg in the southwest of Schleswig-Holstein (53° 54' N, 9° 32' E) [Lempert, 1997], that is, at approximately the same latitudes as in the Southern Ural and southern Western Siberia. In general, in Germany, individuals of the second generation of *S. fonscolombii* were recorded from July 31 to November 10. In addition, the latest autumn emergence was noted on November 9 at Weißer Stein in the Nordrhein-Westfalen land [Lempert, 1997]. It should be stressed that the latter place is located at a rather high latitude — 50°25' N, 6°22' E. Late emergence of *S. fonscolombii* was also recorded on October 24 in the city of Bruchsal (48°54' N, 8°36' E) in Baden-Württemberg, and in a very peculiar habitat — in the public fountain [Martens, Zineckert, 2012].

THE NORTHERN LIMITS OF OVERWINTERING
OF *S. FONSCOLOMBII*

In the Russian part of the range, populations of *S. fonscolombii* are represented by immigrants from the south and their descendants — individuals of the summer generation. Wintering of these dragonflies in temperate latitudes is impossible, apparently due to the temperature factor.

In the Palaearctic, the range of *S. fonscolombii* can be conditionally divided into two parts — the southern part, where the species breeds all year round, and the northern part, where these dragonflies breed only in the warm season. In Europe, the northernmost points of the range where the breeding of the «winter» generation of *S. fonscolombii* is known are in the Iberian Peninsula in

Spain (39°36' N). In early April, a mass oviposition of migratory dragonflies, which had arrived from the south, was recorded, and at the same time the larvae which had developed here in winter emerged [Weihrauch, Weihrauch, 2003]. On the island of Malta (35°50' N, 14°25' E), the winter development of *S. fonscolombii* is also possible. In laboratory conditions, the period of preimaginal development of these dragonflies was determined as 217 days [Gardner, 1951]. In the western part of Asia, the northernmost place of the winter breeding of this species is in the southeast of Turkey (36°17' N). At the very end of March, migratory dragonflies from the south were recorded there, while emergence of overwintered local larvae was observed from April 5 [Dijkstra, Kalkmann, 2001]. A similar pattern was reported from the island of Cyprus, at 35°17' N. In the first half of April, immigrants arrive here at the same time when emergence of aboriginal dragonflies took place [De Knijf, Demolder, 2013].

There are no data on the overwintering of *S. fonscolombii* larvae in Middle Asia. The earliest finds of teneral individuals on May 16 in southwestern Tajikistan (Parkhar, 37°30' N, 69°24' E) and on May 18 in northern Turkmenistan (Lake Aibugir, 42°37' N, 58°11' E) can be interpreted either as emergence from the larvae that overwintered there or as the first appearance of the descendants of early spring immigrants [Borisov, 2012; Borisov et al., 2020].

MIGRATION STRATEGY

In the Russian part of the range, *S. fonscolombii* lives only in the warm season. In spring (in warm years, probably, starting from mid-April), dragonflies migrate from the overwintering part of the range to their northern limits for reproduction. Immigration continues until around the end of July and possibly even in August. Emergence of the second (summer) generation takes place in August-September. The fate of the individuals emerged in the northern part of the range is unknown, they could somehow migrate back to the south or just die. Regular autumn southward migrations of *Sympetrum fonscolombii* observed on a long-term study in Chokpak Pass in South Kazakhstan [Borisov, 2011, 2012, 2015; Borisov et al., 2020] suggest a possibility of existence of similar migrations also in Europe.

Where do these dragonflies come from to the territory of Russia? The study of migrations of *S. fonscolombii* using the isotopic method showed that in the western part of Asia the migration circuit of this species is very extensive. These dragonflies allegedly arrive to the Southern Ural and the south of Western Siberia from the regions of South-West Asia located south of 36° N, overcoming a distance of more than 4,000 km [Borisov et al., 2020]. The migration links of *S. fonscolombii* from the European part of Russia remain unclear. We can only assume that they come here from Northeast Africa and the countries of the Eastern Mediterranean in Southwest Asia. The migrations of *S. fonscolombii* in the Russian Far East also remain unclear.



Fig. 3. Photo of a male *Sympetrum fonscolombii*, Moscow, October 28, 2020 (V.V. Onishko).

Рис. 3. Фото самца *Sympetrum fonscolombii*, Москва, 28.X.2020 (В.В. Онишко).

Note: The northernmost developmental site of *Sympetrum fonscolombii*.

On October 28, 2020, in the north-west of Moscow (Dendropark, Mnevnikovskaya floodplain, 55°45'26" N, 37°27'54" E, 132 m a.s.l.), a newly emergence male *S. fonscolombii* was caught (Fig. 3). This location is located 3.5 km southwest of loc. 3 in this article. At present, this is the northernmost location of the development of the species not only in Russia, but throughout the entire range.

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