

## Distribution and migration strategy of *Pantala flavescens* (Fabricius, 1798) (Odonata, Libellulidae) near the northern limit of its range in Transbaikalia and in the Far East of Russia

### Распространение и миграционная стратегия *Pantala flavescens* (Fabricius, 1798) (Odonata, Libellulidae) у северного предела ареала в Забайкалье и на Дальнем Востоке России

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**Ключевые слова:** *Pantala flavescens*, распространение, фенология, развитие, миграции, Забайкалье, Дальний Восток России.

**Abstract.** Data on distribution and phenology of migratory dragonfly *Pantala flavescens* at the northern limit of the range in Transbaikalia and the Far East of Russia are summarized on the basis of literature sources and collection material. *P. flavescens* flies during May and June from southern territories to the north in order to breed a so-called summer «temperate» generation, and only occurs in that region during the summer and autumn. The northernmost breeding locality registered for the dragonfly is Blagoveshchensk, 50°17'11" N, 127°30'52" E. In September the progeny presumably migrate to the south into a usually warm part of the areal. Hypothetically such a strategy is typical of some individuals while the majority of the population visiting Far East of Russia temporarily do not breed there.

**Резюме.** На основании литературных сведений и коллекционных материалов обобщены данные по распространению и фенологии стрекозы-мигранта *Pantala flavescens* у северного предела ареала в Забайкалье и на Дальнем Востоке России. Стрекозы обитают здесь только в летне-осенний период. В мае–июне они прилетают из южных участков ареала к северным его рубежам, где развивается летнее «температное» поколение. Установлено наиболее северное, из известных, место развития этих стрекоз (Благовещенск, Осташинские озера, 50°17'11" N, 127°30'52" E). В сентябре потомки иммигрантов предположительно мигрируют на юг в исходную тёплую часть ареала. Предполагается, что такая стратегия свойственна лишь части особей в популяции, а основная масса стрекоз лишь временно залетает на территорию Дальнего Востока России и не оставляет здесь потомства.

## Introduction

*Pantala flavescens* (Fabricius, 1798) has remarkable migration abilities and the most extensive cosmopolitan range among all odonates. Migrations of these dragonflies have been noted throughout the range, both over land and over the oceans, where they inhabit many islands [Corbet, 1999; Feng et al., 2006; Anderson, 2009; May, 2013; Borisov, 2015; Kalkman, Monnerar, 2015; Cao et al., 2018]. Moreover, they are record holders for the flight distance among all insects. For instance, it was established that they are able to migrate from the northern part of Indian subcontinent to East Africa, passing through the Maldives Islands. In so doing, they fly more than 6000 km, including the flight over the ocean with a length of 3500 km [Hobson et al., 2012].

It is known that in the tropical part of the range, *P. flavescens* uses prevailing seasonal winds, related to weather fronts in the Intertropical Convergence Zone (ITCZ). Thus, in ITCZ, not only favorable winds for migration are created, but also ephemeral freshwater ponds appear due to monsoon rains, which are the primary habitat for larvae of migratory dragonflies [Corbet, 1999; Holland et al., 2006; May, 2013]. Migrations of *P. flavescens* at the northern and southern periphery of the range are less known. In the spring-summer period, migratory dragonflies arrive from tropical and subtropical parts of the range to temperate latitudes, where «temperate» generation is developing rapidly. In autumn, dragonflies of this generation (the descendants of immigrants) supposedly migrate to the original «warm»

part of the range. Such seasonal latitudinal migrations have been noted in Central Asia [Borisov, 2012, 2015] and North-East Asia [Corbet, 1999; Feng et al., 2006; Cao et al., 2018]. Apparently, it is also common to *P. flavescens* in North America [Current topics... 1988; Corbet, 1999; May, 2013], and at the southern borders of the range — in Australia [Hawking, Ingram, 1994].

In North-East Asia, the northern border of the *P. flavescens* range is located in the territory of Russia. There are numerous literature data on finds of dragonflies of this species. But, at the same time, nature of their stay and phenology are poorly studied. In particular, to date, there is no information about possible development of this species.

Our research aims to summarize data on the distribution and to discover the features of migration strategy of *P. flavescens* near the northern limit of the range in Transbaikalia and in the Far East of Russia.

## Material and methods

The original data of E.I. Malikova on the development of *P. flavescens* in the Amur Region is used. The list of localities and data on the phenology are based on literature data and materials from the collection funds of the following institutions: 1) The Zoological Institute of the Russian Academy of Sciences, Sankt-Peterburg (hereinafter — ZI); 2) The Institute of Animal Systematics and Ecology of the Siberian Branch of the Russian

Academy of Sciences, Novosibirsk (hereinafter — ISEA); 3) The Amur regional collection of insects of the Blagoveshchensk State Pedagogical University, Blagoveshchensk (hereinafter — BGPU); 4) The Biological and Soil Institute of the Far Eastern Branch of the Russian Academy of Sciences, Vladivostok (hereinafter — BPI).

The geographic coordinates of location sites were defined using Google Earth, in cases where it was absent from primary sources (literature data and information from the labels of collection specimens), and are given in parentheses. If exact location could not be determined, then it is given without the number and with the (-) sign.

Where possible, the physiological state of dragonflies is indicated according to P. Corbet [1999]: «teneral» — insects with chitinous cover, that has not yet gotten stronger after emergence, and poorly developed coloring (this condition typically lasts for at least 24 hours after emergence) and “post-teneral” — insects with chitinous cover that has already gotten stronger, but still with «fresh» sparkly wings and yellow coloring (without red!) on the body, reflecting the relatively recent emergence.

The location sites are shown on the maps. Its numbering is given in accordance with the list of localities. In addition to the main map (Fig. 1), more detailed distribution map of *P. flavescens* in the South Primorye is provided (Fig. 2).

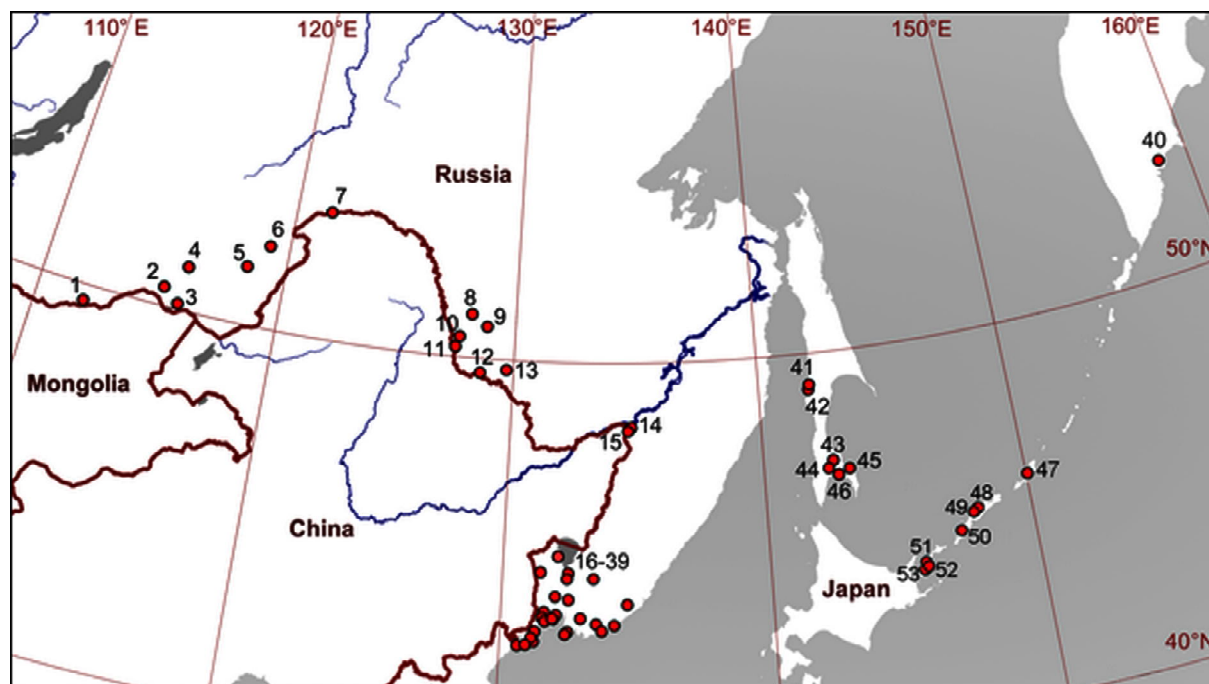


Fig. 1. Locality map with localities of *Pantala flavescens* in Transbaikalia and the Far East of Russia. Numbers interpretation see List of localities, in text.

Рис. 1. Карта с местонахождениями *Pantala flavescens* в Забайкалье и на Дальнем Востоке России. Номера локалитетов соответствуют таковым в Списке местонахождений.

**List of localities for *Pantala flavescens***

## TRANSBAIKAL REGION (ZABAİKALSKY KRAI)

**Loc. 1.** [Kosterin et al., 2004]: Sokhondinsky Nature Reserve, Kyra (49°34'02" N, 111°58'44" E), 26.VII.1996, 1 specimen, leg. E. Maximenko.

**Loc. 2.** [Kosterin, 2004]: Daurisky State Nature Reserve, surroundings of Nizhny Tsasuchey, (about 50°30' N, 115°05' E), 11.VII.1996, 3♂♂, 15.VII.1996, 1♂ (visually), 10.VIII.1996, 1♀, 19.VII.1997, 2♂♂ (visually), 1♀ (visually) (oviposition!).

**Loc. 3.** [Kosterin, 2004]: Daurisky State Nature Reserve, northwest shore of Lake Zun-Torei, Chihalan (50°09'38" N, 115°48'11" E), 12.VII.1996, 1♀.

**Loc. 4.** [Kosterin, Korsun, 2012]: Olovyanninsky distr., Edinenie (51°10'25" N, 11°58'24" E).

**Loc. 5.** [Kosterin, 2004]: The Gazimur River above Gazimursky Zavod (about 51°32' N, 118°19' E), 24.VIII.1997, one individual visually.

**Loc. 6.** [Kosterin, Korsun, 2006]: The Gazimur River at the bridge at Kurleya village, 52°11' N, 119°07' E, 24.VII.1997, visually, was flying above the Gazimur River.

**Loc. 7.** [Selys-Longchamps, 1887; Ris, 1913]: Pokrofska (now Pokrovka) (53°20'36" N, 121°30'55" E) 10.VIII.1883, 1♂, 1♀, leg. L. Graeser.

## AMUR REGION (AMURSKAYA OBLAST)

**Loc. 8.** [Malikova, 2008]: Moskvitino village, Svobodny distr., lakes on Zeya River floodplain (51°09'45" N, 128°06'12" E), 3.VIII.2007, 1♀ (post-teneral), leg. E. Malikova.

**Loc. 9.** [Malikova, 2008]: Pryadchino village, Blagoveshchensk distr., lakes on Zeya River floodplain (50°52'15" N, 128°47'33" E), 3.VIII.2007, 1♂, 1♀ (post-teneral), leg. E. Malikova.

**Loc. 10.** Mukhinka, Blagoveshchensk distr., 50°32'59" N, 127°39'04" E, 1.IX.2000, 1♀ (post-teneral), leg. E. Malikova (BGPU).

**Loc. 11.** [Malikova, 1993]: Blagoveshchensk, Ostashinsk lakes (50°17'11" N, 127°30'52" E).

(Same as loc. 11). Blagoveshchensk, Ostashinsk lakes, 50°17'11" N, 127°30'52" E, 07.VIII.1989, 2♀♀ (teneral), 3 larvae (last instar); *ibid.*, 21.VIII.1989, 6 exuvia; *ibid.*, 30.VIII.1990, 2♂♂ (post-teneral), 3♀♀ (post-teneral), exuvia series; *ibid.*, 12.IX.1990, 2♂♂, leg. E. Malikova (BGPU).

**Loc. 12.** [Malikova, 2008]: Poyarkovo village, Mikhailovka distr., Zavitaya River (49°37'45" N, 128°36'24" E), 27,28.VII.2007, 1♂ (post-teneral); *ibid.*, Lake Zolotukhina (49°37'32" N, 128°31'09" E), 28.VII.2007, 1♂ (post-teneral), leg. E. Malikova.

**Loc. 13.** [Malikova, Streltsov, 2015]: Kivdinskoye Water Reservoir, Progress village (49°45'10" N, 129°40'59" E), 25.VI.2013, 1♂ (post-teneral), leg. E. Malikova, A. Streltsov.

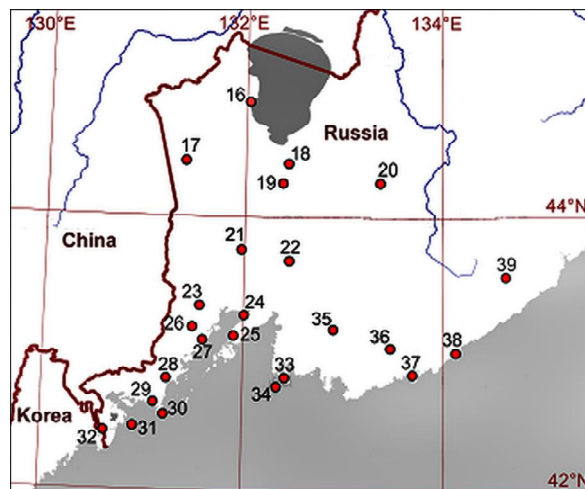


Fig. 2. Map with localities (16-39) of *Pantala flavescens* in South Primorye. Numbers interpretation see List of localities, in text.

Рис. 2. Карта с местонахождениями *Pantala flavescens* в Южном Приморье. Номера локалитетов соответствуют таковым в Списке местонахождений.

## KHABAROVSKY KRAI

**Loc. 14.** [Malikova et al., 2007]: Bolshekhokhtsirskii State (Nature) Reserve, the Bychikha village environs, 48°17–18' N, 134°48–50' E, 18, 27.VIII.2006, 1♂, 1♀, leg. V. Dubatolov.

**Loc. 15.** [Malikova et al., 2007]: Bolshekhokhtsirskii State (Nature) Reserve, the area of the Chirki River mouth, 48°11–12' N, 134°41' E, 20.VII.2007, 1♀, leg. V. Dubatolov.

## PRIMORSKY KRAI

**Loc. 16.** [BARTENEV, 1956]: Lake Khanka, Troitskoe village (44°50'11" N, 132°01'30" E), 22.VIII.1932, 1♂, leg. A.I. Kurentsov.

**Loc. 17.** Pogranichnyi, 60 km south-west of Lake Khanka (44°24'09" N, 131°23'07" E), 25.VIII.1972, 4♀♀, leg. N. Kostina (ISEA); *ibid.*, Grodekovo (same Pogranichnyi), 23.VIII.1962, 1♂, leg. E. Stepanchuk (ISEA).

**Loc. 18.** Ilistaya River, 600 m from the road Vadimovka-Chernigovka (44°23'35" N, 132°25'56" E), 25.VII.1997, 1♀, leg. P.Ivanov (BPI).

**Loc. 19.** Lake Ilistoye, Chernigovsky distr. (44°14'52" N, 132°22'27" E), 12.VII.1962, 1♂ (post-teneral), 1♀ (teneral), leg. E. Stepanchuk (ISEA).

**Loc. 20.** Novosysoevka (44°15'06" N, 133°21'48" E), 23.VII.1992, wings of 5 individuals, leg. Streltsov (ISEA).

**Loc. 21.** [Belyshev, 1956]: Ussuri region, Voroshilov neighborhood (modern city of Ussuriysk, 43°45'45" N, 131°57'56" E), 18.IX.1923, 4♂♂, 2♀♀.

(Same as loc. 21). Ussuriysk, 08.IX.1993, 1♂, 1♀, leg. E. Malikova (BGPU).

(Same as loc. 21). The mouth of the river Rakovka, 3.IX.1997, 1♂, leg. Vshivkova (BGPU).

**Loc. 22.** [Gorb, 1991]: Ussuriysky Nature Reserve, Suputinka River between Kaimanovka and Kamenushka villages (about 43°41' N, 132°27' E), 31.VII.1989, 1♂, leg. S. Kulchitsky.

(Same as loc. 22). Ussuriysky Nature Reserve, 29.IX.1962, 1♂, 1♀, leg. A. Velizhanin (ISEA).

**Loc. 23.** 7 km north-west of Zanadvorovka vill., Gusevsky mine (43°21'02" N, 131°33'24" E), 23–30.VII.1998, 1♂, 1♀, leg. Streltsov (BGPU); *ibid.*, 20–23.VII.1999, 1♂, 1♀, leg. E. Malikova, A. Streltsov (BGPU).

**Loc. 24.** The De-Fries Peninsula (about 43°17' N, 132°00' E), 26.VIII.1998, 4♂♂, 1♀, leg. Ivanov (BPI).

**Loc. 25.** Vladivostok (43°08' N, 131°54' E), 20.IX.1977, 1♀, leg. A.Yu. Berezintsev (ISEA).

(Same as loc. 25). 4–8.IX.1975, 1♀, leg. Grigoriev (BPI).

(Same as loc. 25). 4.VII.1998, 1♀, 15.X.2000, 2 larvae, leg. P.Ivanov (BPI).

(Same as loc. 25). Sedanka River, 8.IX.1985, 1♂, leg. V. Dubatolov (ISEA).

**Loc. 26.** [Belyshev, 1966]: Mongugai (= Barabashevka) River valley (about 43°11' N, 131°29' E), from 15.VI. till the end of field work, e.g. 30.VIII.1962.

(Same as loc. 26). Mongugai (= Barabashevka) River valley, 9.VIII.1962, 1♂ (post-teneral), leg. B. Belyshev (ISEA).

(Same as loc. 26). Mongugai (= Barabashevka) River valley, 7–09.VIII.1962, 2♂♂ (post-teneral), leg. E. Stepanchuk (ISEA).

(Same as loc. 26). [Belyshev et al., 1971]: Kedrovaya Pad' Nature Reserve, 27.VII.1961, 2♀♀, leg. A.G. Pankratiev.

(Same as loc. 26). Kedrovaya Pad' Nature Reserve, Head Office (Barabash), 3.08.IX.1977, 2♂♂ (post-teneral), leg. B.P.Kondakov (ISEA).

(Same as loc. 26). Kedrovaya Pad' Nature Reserve, 24.IX.1996, 1♂, 2♀♀, leg. V. Dubatolov (ISEA).

(Same as loc. 26). [Gorb, Fursov, 1990]: «Kedrovaya Pad'», Wide and open sandy glade, surrounded by deciduous forest; at the confluence of a small stream and the Kedrovaya River, 19,23.VIII.1989, 1♂, 1♀.

**Loc. 27.** Primorskyi vill., Khasansky distr. (43°05'56" N, 131°35'31" E), 27.VII.1961, 2♀♀, leg. A.G. Pankratiev (ISEA).

**Loc. 28.** [Gorb, Fursov, 1990]: Ryazanovka (42°48'57" N, 131°14'17" E), 25.VIII.1989, 1♂, 1♀, leg. S. Gorb, V. Fursov.

(Same as loc. 28). Ryazanovka, 25.VI.1998, 1♂, 3♀♀, leg. P.Ivanov (BPI).

**Loc. 29.** Vityaz' (42°36'13" N, 131°11'13" E), 15.VII.1978, 1♂ (to the light); *ibid.*, 12–14.VIII.1978, 1♂, 3♀♀; *ibid.*, 24.VIII.1978, 4♀♀, leg. A.V. Barkalov (ISEA).

**Loc. 30.** Gamov peninsula (42°33'22" N, 131°13'02" E), 22.VIII.1993, 1♀, leg. V. Dubatolov (ISEA).

**Loc. 31.** Furugelm Island (42°27'55" N, 130°55'08" E), 15.VII.1975, 2♂♂, 3♀♀ (to an artificial light source);

*ibid.*, 17.VII.1975, 1♂, 1♀; *ibid.*, 23.VII.1975, 1♂, 1♀; *ibid.*, 29.VII.1975, 2♂♂, 5♀♀; *ibid.*, 01.VIII.1975, 3♀♀, leg. A. Velizhanin (ISEA).

**Loc. 32.** Khasan station (42°25'37" N, 130°37'43" E), 15–25.IX.1978, 11♂♂, 3♀♀, leg. A.Yu. Haritonov (ISEA).

**Loc. 33.** [Belyshev, 1964]: Putyatin Island (42°50' N, 132°25' E), 19.IX.1959, 1♂, leg. N.N. Kondakov. (The same exemp.). Putyatin Island, 19.IX.1959, 1♂ (teneral), leg. N. Kondakov (ISEA).

(Same as loc. 33). Putyatin Island, 06.IX.1969, 1♂; *ibid.*, 19.IX.1969, 1♂; *ibid.*, 20, 21.IX.1969, 8♂♂, 3♀♀, leg. G. Zolotarenko (ISEA).

**Loc. 34.** [Belyshev, Kurentsov, 1964]: Japanese Sea, Askold Island (42°46' N, 132°20' E), 18.VIII.1952, 1♀, leg. A.I. Kurentsov.

**Loc. 35.** [Bartenev, 1930]: on the way from Derzhanovo St.[ation] to Tigrovaya St. of Suchan. railway (upper stream of Sitza (=Tigrovaya) River) (about 43°11' N, 132°54' E), 3.IX.1928, 1♂, leg. A.I. Kurentsov.

**Loc. 36.** [Belyshev et al., 1971]: Lazovsky Distr., Tachin-Guan Range (now: Partizanskii Range, about 43°03' N, 133°28' E), 18.VIII.1961, 1♂, leg. H. Remm.

**Loc. 37.** [Malikova, 2007]: Lazovsky Nature Reserve, Zapovednoe, 42°51'17" N, 133°41'29" E, 15.VIII.1998, 3♀♀, leg. P.Ivanov (BPI).

**Loc. 38.** [Malikova, 2007]: Lazovsky Nature Reserve, Tachingouza outpost (Prosyolocny), Prosyolocnaya River, 43°00'54" N, 134°07'30" E, 04.VII.2006, 3♂♂, 1♀, leg. E. Malikova (BGPU).

**Loc. 39.** [Belyshev et al., 1971]: Olginskii distr., Shcherbakovka vill. (43°34'04" N, 134°37'50" E), 30.VIII.1961, 2♂♂, 1♀, leg. H. Remm.

#### KAMCHATKA PENINSULA (KAMCHATSKY KRAI)

**Loc. 40.** [Hagen, 1856]: (*Libellula flavescens*) Kamtschatka, Petropavlovsk (53°01' N, 158°39' E).

(Same). [Dumont et al., 2005]: Petropavlovsk. (The only female specimen with the label «Kamtschatka» is preserved in the ZI RAS, Sankt-Peterburg).

(Same). Kamtschatka (Kamchatka), 1♀ (without further label data) (ZI). Probably this is an exemplar of Hagen.

#### SAKHALIN ISLAND (SAKHALINSKAYA OBLAST)

**Loc. 41.** [Fukui, 1992]: Shakhtersk (Sakhalin) (49°08'41" N, 142°03'48" E), 29.VII.1992, 4♂♂.

**Loc. 42.** [Fukui, 1992]: Ulegorsk (Sakhalin) (49°03'36" N, 142°02'07" E), 29.VII.1992, 1♂; *ibid.*, 30.VII.1992, 2♂♂.

**Loc. 43.** [Asahina, 1949]: Konuma (=Novoalexandrovsk, 47°03'092" N 142°43'41" E), 24.VIII.1923, 1♂ (Coll. H[okkaido] U[niversity]).

**Loc. 44.** [Fukui, 1992]: Yuzhno-Sakhalinsk (46°57' N, 142°44' E), 28.VII.1992, 3♂♂.

**Loc. 45.** [Matsumura, 1911]: Tonnai tscha (Okhotskoe, Lake Tunaicha, 46°51'31" N, 143°09' 20" E).

**Loc. 46.** [Matsumura, 1911]: Solowiyofka (46°43'49" N, 142°45'02" E), 2 ex.

(Same as loc. 46). [Asahina 1949]: Itinosawa (=Solvjevka), 9.VII, 1♀.

(-) [Oguma, 1932]: Karafuto (same Sakhalin).

#### KURILE ISLANDS (SAKHALINSKAYA OBLAST)

**Loc. 47.** [Okumura, 1941, 1942 in Asahina, 1958]: Kurile Islands, Urup (about 45°56' N, 150°02' E).

**Loc. 48.** [Paulson et al., 1998]: Iturup, Reidovo, Reidovoye Lake (45°16'14" N, 148°01'44" E), 18.VIII.1994, 1♀, leg. R.I. Gara, N. Minakawa.

**Loc. 49.** [Asahina, 1958]: Iturup Island, Shana (modern city of Kurilsk, 45°15'12" N, 147°53'12" E), 1–3.IX.1940, 1♀, 4.IX.1940, 1♂, 1♀, leg. Kinoshuta.

(-) [Asahina, 1958]: Iturup Island, Toshimoe, 29–30.VIII.1940, 5♂♂, 2♀♀, leg. Kinoshuta.

**Loc. 50.** [Belyshev et al., 1974]: Iturup, Lesozavodsk (44°46'04" N, 147°11'20" E), 16.VIII.1968, 1♀, leg. A. Velizhanin. (The same exemp.) Kuriles, Iturup, 16.VIII.1968, 1♀, leg. A. Velizhanin (ISEA).

**Loc. 51.** [Paulson et al., 1998]: Kunashir, Lake Aliger (44°02'59" N, 145°44'18" E); 31.VII.1994, 1♂, 1♀, leg. R.I. Gara, N. Minakawa, V.V. Teslenko.

**Loc. 52.** [Belyshev et al., 1974]: Kunashir, Sernovodsk (43°55' N, 145°38' E), 01.VIII.1968, 1♂, leg. G. Zolotareno. (The same exemp.) Kuril (Kurile) Islands, Kunashir, 1.VIII.1968, 1♂, leg. G. Zolotareno (ISEA).

**Loc. 53.** (Zaika, 1980): Kunashir, Lake Goryachee in the caldera of Golovnina volcano (43°52' N, 145°30' E).

(-) [Okumura, 1942]: Kurile Islands.

## Results and discussions

#### THE NORTHERN LIMITS OF *P. FLAVESCENS* DISTRIBUTION

The *P. flavescens* range at its northern limit in the eastern part of the Asian continent covers following areas: the southern steppe zone of Transbaikalia; the southern border areas with China in Amur Region, Khabarovsk Krai and South Primorye; and also the southern half of Sakhalin Island and three southernmost islands of Kurile Ridge — Urup, Iturup and Kunashir. In the southern part of Kamchatka Peninsula, the species is known for the single find (Fig. 1, 2). The northernmost point of the *P. flavescens* range is Pokrovka Village at the confluence of the Shilka and Argun rivers in Transbaikalia — 53°20'36" N (loc. 7).

Therefore, in Eastern Asia, the most northern localities of *P. flavescens* exceed 52–53° N. In the New World, this species also penetrate far to the north. Numerous finds of *P. flavescens* are known in the north of the USA and the south of Canada. The most northern of it lies in the south of Canada in Alberta (51°15' N) [pers. obs., supported by records from Odonata Central, 2019] and Manitoba (Husavick, 51°30' N) [Walker, Corbet, 1975].

*P. flavescens* is not typical to Europe as a whole and its finds are pretty rare here [Buczyński et al., 2014; Kalkman, Monnerar, 2015]. Thus, to date, the northern-

most localities of these dragonflies are known from Eastern Europe. Only one individual fell into the ornithological trap at the Fringilla observatory on Curonian spit in the Kaliningrad Oblast' (55°05' N) [Buczyński et al., 2014]. Further north, this species was noted near Lytkarino Village in the vicinity of Moscow (55°35'52" N) [Skvortsov, 2010], but this data is questionable, and the author provide it with a question mark.

#### THE NORTHERN LIMIT OF THE *P. FLAVESCENS* DEVELOPMENT

In general, in the study region, the oviposition of *P. flavescens* was noted only once by O.E. Kosterin in Transbaikalia. On 19 July 1997, an ovipositioning pair was noted in Daurysky State Nature Biosphere Reserve above the anabranch of Onon River, which was dried out to the wet soil [Kosterin, 2004] (in the present paper — loc. 2).

The development of *P. flavescens* has been determined only in one place. On 7 August 1989, E.I. Malikova found larvae of last instar and recently emerged imagoes on the little pond near Ostashinskies lakes within the city of Blagoveshchensk (50°17' N, loc. 11). On 21 August, exuvia were collected over here. On 30 August 1990, on the same pond, exuvia series of *P. flavescens* and some freshly emerged imagoes, were again collected.

At present, Blagoveshchensk is the northernmost point of the range, where the development of preimaginal phases of *P. flavescens* is noted, and it lies approximately 5 degrees latitude north of the previously known site of the development in the New World in southern Canada (45°25' N) [Trottier, 1967].

In Japan, the development of *P. flavescens* is known on the entire territory [Corbet, 1999; Ichikawa et al., 2017], that is, including Hokkaido Island — up to 44–45° N. In the South Primorye, the species develops at the same latitudes (42°–45° N) [this paper]. At the same time, in Central Asia, the development of these dragonflies is not yet known north of 39° N [Borisov, 2012]. In the Southern Hemisphere, the southernmost point of the *P. flavescens* development was noted in Australia at 37°14' S [Hawking, Ingram, 1994].

#### PHENOLOGY OF *P. FLAVESCENS* AT THE NORTHERN LIMITS OF THE RANGE

In general, imagoes of *P. flavescens* are noted in Transbaikalia, Priamurye and Khabarovsk Krai (approximately between 48° and 53° N) from 25 June to 1 September. Thus, on 27 July, «fresh» individuals (post-teneral) were caught approximately at the 50th parallel (loc. 12).

In the South Primorye (42°–45° N), adult insects were recorded from 15 June to 29 September. Larvae were found only once on 15 October in Vladivostok (loc. 25). Judging by such a late date, their development to imagoes doesn't seem possible. Male and female, which recently acquired wings, were caught here on

12 July (loc. 19). These specimens are well preserved in the collections of ISEA. The female's wings are sparkly and not fully strong; its abdomen is slightly wrinkled due to drying.

Such early finds of juvenile specimens suggest that the first migratory dragonflies arrive to the northern boundaries of the range for oviposition much earlier than the dates known so far, that is, not in the middle of June, but approximately a month earlier.

It is known that the preimaginal phases of *P. flavescens* develop rapidly — from 30 [Suhling, pers. comm. May, 2013] to 65 days [Suhling et al., 2004]. It can be assumed that the period of their development is the longest at the northern limits of the range. The development of *P. flavescens* takes about 2 months on paddy fields in Tajikistan [Borisov, 2012], the average period of the development in Northern India is about 50-60 days [Kumar, 1984; Current topics... 1988] and in South Australia (the southern boundary of the range) — 51 days [Hawking, Ingram, 1994].

Assuming that the period of the preimaginal development of *P. flavescens* on the northern limit of the range takes about 50–60 days, and the emergence is noted from 12 July, then oviposition could take place here in the second half of May. This presumption is consistent with the data on the timing of dragonfly migrations on Beihuang Island in Bohai Strait in Northern China [Cao et al., 2018]. Long-term observation here of *P. flavescens* nocturnal migrations, using radar and searchlight trap for dragonflies, show that the earliest flights to the north start from 10 May. Beihuang Island (38°23' N, 120°55' E) is located about 1000 km from the southern part of Primorye and 1400 km from Blagoveshchensk in Amur Region. It is likely that dragonflies can cover this distance in a few days. Studies on this island show that speed of flight of migratory dragonflies reaches 5–11 m/s with a favorable wind, and they are able to cover 150–400 km during the night [Feng et al., 2006].

Similar data on the phenology of *P. flavescens* are provided for North America. In May and June, these dragonflies reach the southern regions of Canada, and the development of temperate generation is completed by September [Current topics... 1988].

#### MIGRATION STRATEGY OF *P. FLAVESCENS* NEAR THE NORTHERN LIMIT OF THE RANGE

Thermophilic larvae of *P. flavescens* are not able to tolerate low temperatures and to hibernate at high latitudes. It is known that in Japan larvae die at temperatures below 4 °C and are not able to hibernate even on the southern island of Honshu [Nagase, 1983 in Corbet, 1999]. It is considered that they are not able to hibernate in North America north of 40° N [Wissinger, 1988; Corbet, 1999]. Such alleged latitude of hibernation seems clearly too high. In Central Asia, this species is not able to hibernate at 36–37° N [Borisov, 2012, 2015]. There is also no data on hibernation of these dragonflies

in the more southerly regions — in the Middle East, Iran, Afghanistan and Pakistan. In northern India in the Dehra Dun Valley (30–31° N), *P. flavescens* live only in the summer-autumn period [Kumar, 1972]. In China, apparently, the winter generation of *P. flavescens* can develop only in tropics and subtropics on the south [Feng et al., 2006; Cao et al., 2018].

Therefore, near the northern limits of the range, *P. flavescens* live only in the warm summer-autumn period. In this case, the migration strategy of dragonflies can be described as «avoidance of cold» according to the terminology of P. Corbet [1999]. Migratory dragonflies arrive to Transbaikalia and the Far East of Russia from the tropical and subtropical parts of the range, apparently, in the second half of May. The first imagoes of «temperate» generation in South Primorye appear in the middle of July (12 July), and in Amur Region — at the end of July (27 July). In autumn, dragonflies of this generation migrate to the south, apparently, to the original «warm» subtropical and tropical parts of the range. In the northern regions (Transbaikalia, Amur Region and Khabarovsk Krai), *P. flavescens* «disappear» in early September, and in South Primorye — in late September (but larvae, as mentioned above, were found here on 15 October!).

Interesting results were obtained through long-term studies of *P. flavescens* migrations on Beihuang Island in Bohai Strait in northern China [Cao et al., 2018]. Stable isotope analysis method was applied to determine the places of origin of migratory dragonflies. A comparison of the obtained data with the timing and directions of migrations show that along with flights in the northern (in early summer) and southern (in late summer-autumn) directions, «wandering» across North China is typical for many individuals during the monsoon season [Cao et al., 2018]. Apparently, such wandering (or vagrancy) is also common for many individuals in the Far East of Russia. Probably, in July and August, a majority of them only temporarily arrive here from adjacent territories and don't leave any progeny. In particular, this can explain pretty rare cases of the *P. flavescens* development, which were determined here, as long as there are a relatively high number of imagoes in summer.

In conclusion, it should be noted that the moderately monsoon climate is more or less common to regions which is covered by the *P. flavescens* range in the Far East of Russia. Monsoonal effect is insignificant in steppe Transbaikalia and Amur Region, but it is the moderately monsoon climate in South Primorye, where *P. flavescens* is most abundant. North-Eastern China and its border areas belong to the most northern zone in the world, which is reached by monsoons of the Intertropical Convergence Zone (ITCZ). These monsoons contribute to latitudinal migrations of dragonflies in North-East Asia, as well as in the tropics [Belyshev, 1968; Johnson, 1969; Corbet, 1999; Feng et al., 2006; Cao et al., 2018].

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