Endangered palsa mire hoverflies (Diptera, Syrphidae) in northern Sweden

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SUMMARY

The hoverfly species *Platycheirus torei* Barkalov, 2013 is recorded from Europe for the first time. It was collected in a palsa mire in Seitajaure, northern Sweden, representing a westward extension of its potential range by 3,500 km. The properties of the palsa mire at Seitajaure are described and a list of additional hoverfly species recorded there is provided. A differential diagnosis of *Platycheirus torei* is provided, with all cited characters illustrated in the accompanying illustrations. An extensive discussion is given on palsa mires, with special attention to their predicted loss due to climate change, and the potential risk that represents for hoverfly species that depend on palsa mires for their survival in Europe.

KEY WORDS: climate change, Europe, fauna novum, habitat loss, IUCN Red List, *Platycheirus torei*.

INTRODUCTION

With more than 6,000 species worldwide, hoverflies are a species-rich family of Diptera. The family has received much attention concerning taxonomy and systematics during the last few decades (e.g., Doczkal *et al*. 2002, van Steenis *et al*. 2016, Young *et al*. 2016, Vujić *et al*. 2020). Hoverflies have also recently been recognised for their roles in pollination, pest control and in decomposing organic material (Bugg *et al*. 2008, Pineda & Marcos-García 2008, Ssymank *et al*. 2008, Rotheray & Gilbert 2011, Martínez-Falcón *et al*. 2012, Inouye *et al*. 2015, Klecka *et al*. 2018, Dunn *et al*. 2020, Moerkens *et al*. 2021). The large amount of biological data available for the family (e.g., Speight 2020, van Steenis *et al*. 2020), combined with the known relationship between declines of pollinators and plant communities (Biesmeijer *et al*. 2006), has led the IUCN to develop a European Red List for Syrphidae (IUCN 2018). The need for this Red List is even more urgent given the recent insights into massive losses of insects and specifically hoverflies over the last 50 years (Seibold *et al*. 2019, Hallmann *et al*. 2021, Wagner *et al*. 2021).

The genus *Platycheirus* Lepeletier & Serville, 1828 has a mainly boreo-alpine occurrence throughout the world, with about 250 species described (e.g., Vockeroth 1990, Bartsch *et al*. 2009, Nielsen 2016, Young *et al*. 2016, Nielsen & Barkalov 2017, van Steenis *et al*. 2019). *Platycheirus* species are slender to slightly robust flies with a black face, thorax and scutellum. The abdomen is black, often with paired yellowish or greyish to mica-coloured maculae, but sometimes entirely black or predominantly orange-yellow coloured. In the male, the legs and especially the front legs are characterised by distinct pile tufts or other modified pile or setae. Most species also have modified protibia and tarsus, in which widening to various degrees of one or both is most often seen.

Platycheirus has been divided into five species groups, of which the *albimanus* group is further divided into six subgroups (Vockeroth 1990, Young *et al*. 2016). The species within each species group tend to have similar habitat preferences (van Steenis & Zuidhoff 2013). Some species, especially those of the *Platycheirus peltatus* (Meigen, 1822) and *P. manicatus* (Meigen, 1822) species groups, are known to be found on barren hilltops and ridges: a behaviour called hilltopping. These hilltops are typically devoid of larval food plants, hosts, or other oviposition sites for the female, and function as arenas for males seeking females for mating (Skevington 2008).

Larvae have been reported to be aphidophagous on low-growing herbs but also on tall herbs and trees. Most of the larvae feed at night and prefer moist habitats. Some common species have never been found as larvae and possibly these species are predators in leaf litter (Heiss 1938, Goeldlin de Tiefenau 1974, Rotheray & Gilbert 1989, Rotheray 1993, Rotheray 1998, López-García *et al*. 2021).

Palsa mires (Figures 1, 2) are bog areas in the Holarctic region within the permafrost zone, whose southern limit coincides with areas of low precipitation and annual mean temperatures of -3 °C to -5 °C (Luoto *et al*. 2004a, Seppälä 2011, Markkula 2014). Palsas are peat hummocks with perennially frozen cores, visible as upheaved dried-out peat mounds of variable sizes and heights (Seppälä 1986, French 1996). The palsa goes through a cycle of five developmental stages (Wramner 1973, Seppälä 1986) from embryo to mature and finally the remnant palsa, more clearly defined by Zuidhoff & Kolstrup (2005). In this last phase the peat mound collapses creating a pond, or thermokarst lake, surrounded by a wall of peat (Zuidhoff & Kolstrup 2005). The wall slowly degrades and falls into the pond, which eventually fills with new peat, creating new opportunities for palsas to form (Seppälä 2006). Palsa mires thus form a unique habitat with large variation in vegetation structure over a small geographic area, and a unique flora and fauna connected to these different vegetation structures (Luoto *et al*. 2004b, Zuidhoff & Kolstrup 2005). Their cyclic development leads to a continuum in presence of all these vegetation structures across the entire mire and serves as a sustainable natural system with high floral and faunal value (Zuidhoff & Kolstrup 2005, Markkula 2014, Markkula *et al*. 2019). The palsa mire habitat is regarded as Critically Endangered at the European level (Tahvanainen *et al*. 2016).

Here the first records of *Platycheirus torei* Barkalov, 2013 are presented from Europe, collected in a palsa mire in northern Sweden. This species was formerly known only from its type locality; Russia, Taimyr peninsular, bank of river Zakharova Rassokha (Barkalov 2013).

METHODS

During a field expedition on palsa research (Zuidhoff & Kolstrup 2005), Syrphidae were collected by the author. The plant names are from Mossberg *et al*. (1992) and were checked for their current use in the plant list (WFO 2021).

Study site

Seitajaure or Sieidejávri (Figures 2, 3) is a palsa bog in a valley of 2 by 4 km at an elevation of 765 m a.s.l., situated at the west side of the Lake Sietajaure. It forms the lowest part of a wide valley of 3 by 10 km, about 15 km south of the village of Nikkaluokta in northern Lapland, Sweden (67° 44' N, 18° 52' E). The area consists of several small and two larger bogs of about 0.5–1 km^2 each. There are two river systems draining the valley running south and south-west, both flowing into the Kaitumälven River. Three higher mountains surround the valley, of which Urtičohkka (1,463 m a.s.l.) and Čeabetčohkka (1,358 m a.s.l.) are

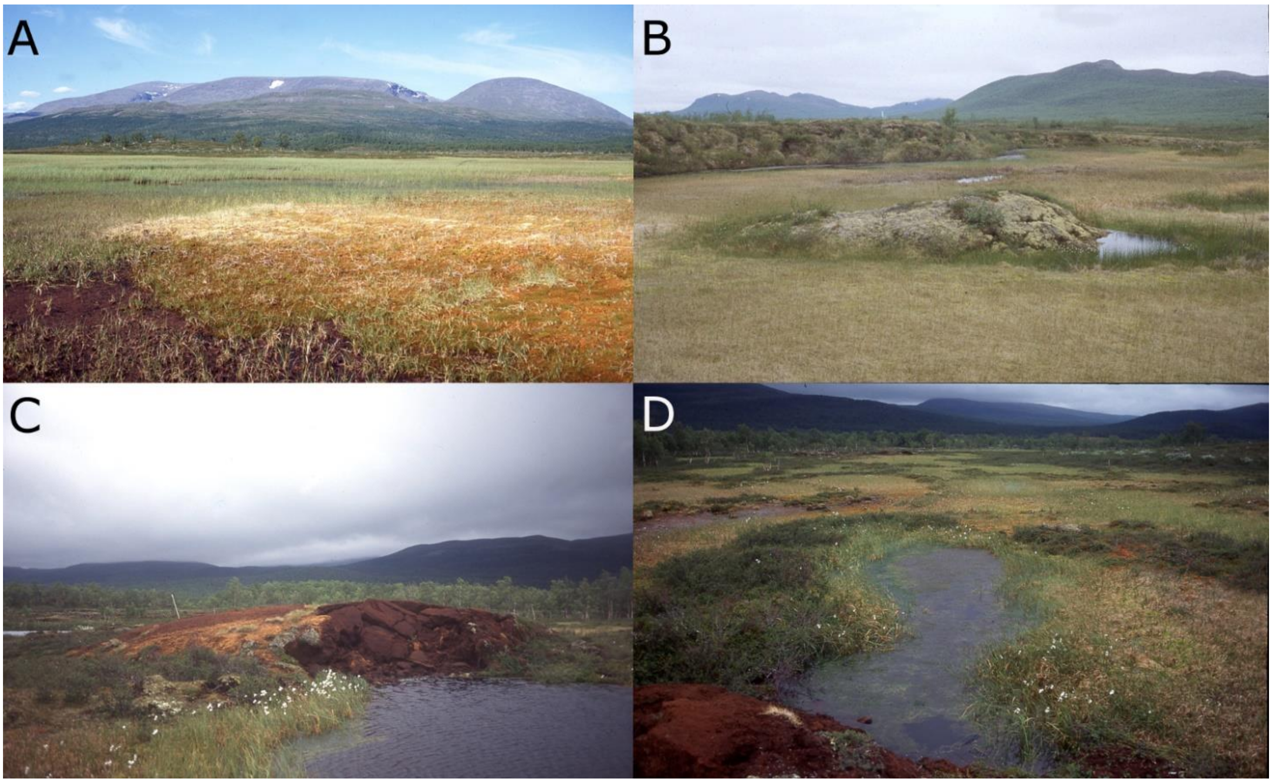

Figure 1. Palsa stages, Sweden: (A) Embryo, August 1996, Laivadalen; (B) Young (foreground) and mature (background) palsa, July 1996, Keinovuopio, Kätkijärvet; (C) Degrading palsa, August 1996, Laivadalen; (D) New peat formation in palsa pond with a remnant palsa in the foreground, August 1996, Laivadalen.

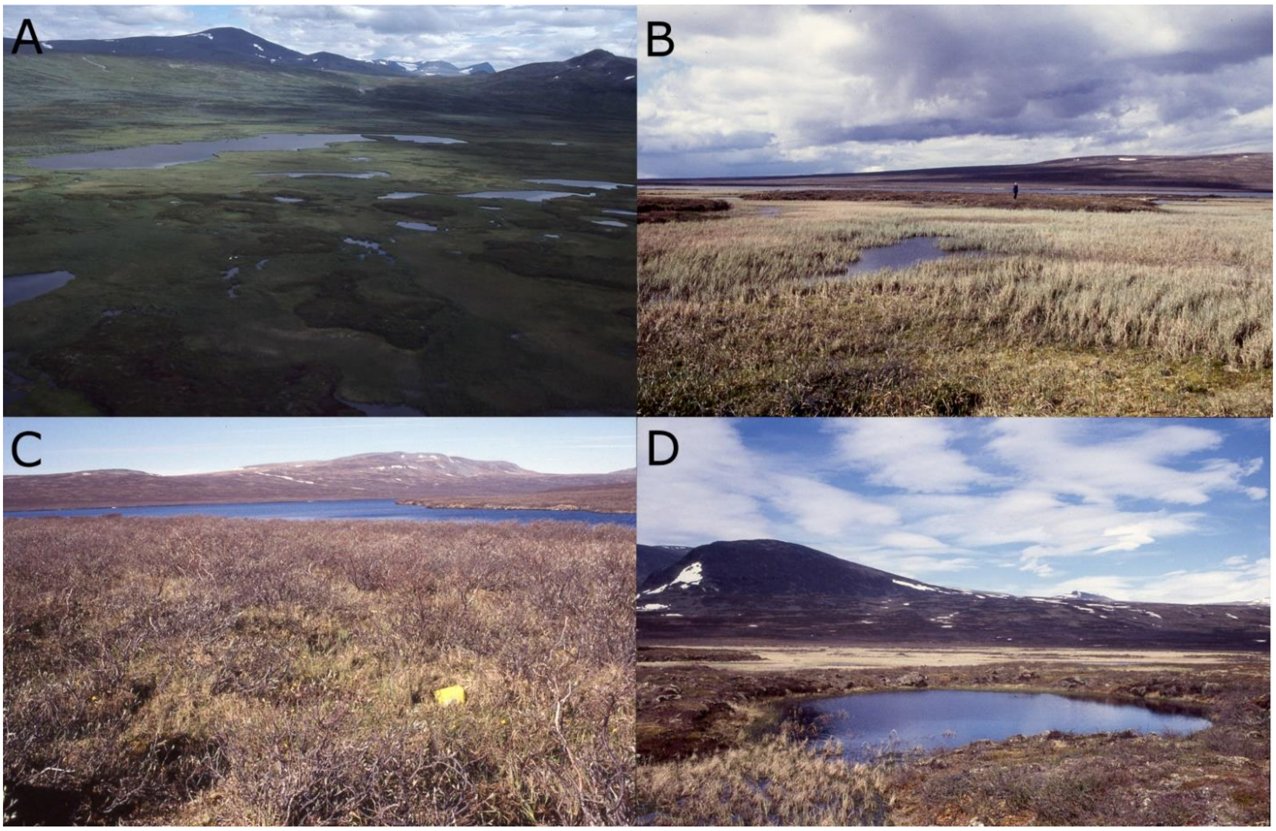

Figure 2. Habitat of *Platycheirus torei* in Seitajaure, Sweden: (A) Aerial photo of the Seitajaure palsa mire, July 1999; (B) mire with a large mature palsa, June 1996; (C) Willow shrub along the border of the palsa mire, with yellow pan trap, June 1996; (D) Remnant palsa with open pond, June 1996.

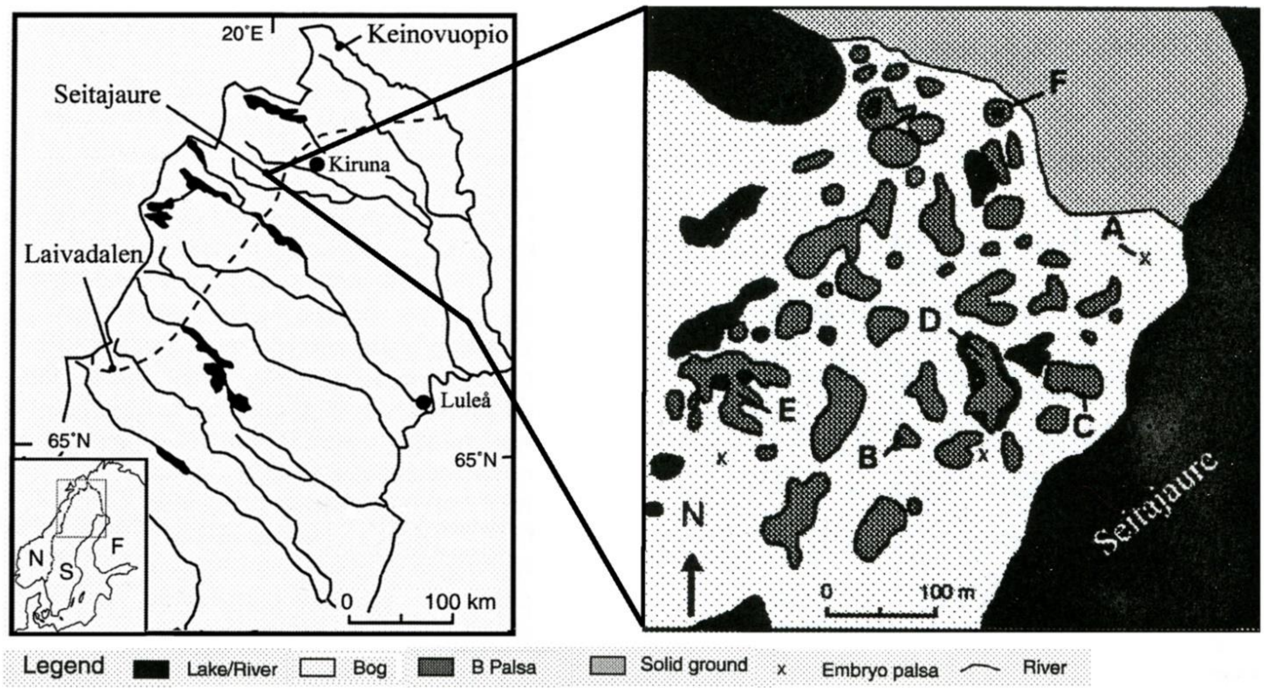

Figure 3. Map of the palsa mire in Seitajaure, Sweden. After Zuidhoff & Kolstrup (2005).

situated in the north and Gorjjačohkka (1,164 m a.s.l.) in the south (F.S. Zuidhoff unpublished data).

The valley has a geology of Cambric bedrock and consists of the Hypolitus series: shale (Schiffer), sandstone, conglomerate and arkose. East of the lakes in the valley the bedrock consists of 'Primaeval mountain rock' 2 billion years old and the bedrock is granite and syenite. West of the palsa bog the bedrock consists of the younger 'Skollberggrunden (Thrust rocks)' or Archaean rocks. The boundary between the mountain range and the Primaeval mountain rock is sharp. The higher mountains such as the Kebnekaise consist of the hard bedrock Amphibolite. Around 400–600 million years ago, during the Caledonian mountain formation, the 'schollen' from the younger bedrocks were moving over the 'Primaeval mountain rock' (Melander 1975, F.S. Zuidhoff unpublished data).

The underlying mineral soil consists mainly of sandy till with silty deposits along the lakes. The peat was formed after the last ice age, 8,000–10,000 years BP, and measures 75 to 160 cm in depth. The palsas, about 50 in total, are mostly plateau-like (34), with some dome-shaped palsas (3); the others are either embryo, growing or remnant palsas. They have a maximum surface of 100 by 60 m, and a height varying between 25 and 145 cm above peat level with a mean of 75 cm. All developmental stages of palsa growth were found in the bog; 1 embryo, 3 growing, 22 mature, and about 10 degrading and remnant palsas (Zuidhoff 2003, F.S. Zuidhoff unpublished data).

The valley is situated above the treeline, which lies at 750 m a.s.l. The surrounding peat consisted mainly of bryophytes such as *Calliergon stramineum* (Dick. ex Brid.) Kindb. and *Sphagnum lindbergi* Schimp. with *Carex rotundata* Wahlenb., *Epilobium palustre* L. and *Eriophorum angustifolium* Honck. On the palsa the peat contained moss peat (*Sphagnum fuscum* (Schimp.) H. Klinggr.) with remnants of *Betula nana* L., and *Empetrum nigrum* subsp. *hermaphroditum* (Hagerup) Böcher. The vegetation cover (Figure 4) of the palsa consisted of *Andromeda polifolia* L., *Betula nana*, *Empetrum nigrum* subsp. *hermaphroditum*, *Eriophorum angustifolium*, *E. vaginatum* L., *Polytrichum strictum* Menzies ex. Brid., *Rubus chamaemorus* L., *Vaccinium myrtillus* L., *V. uliginosum* L. and *V. vitis-idaea* L. (Zuidhoff,

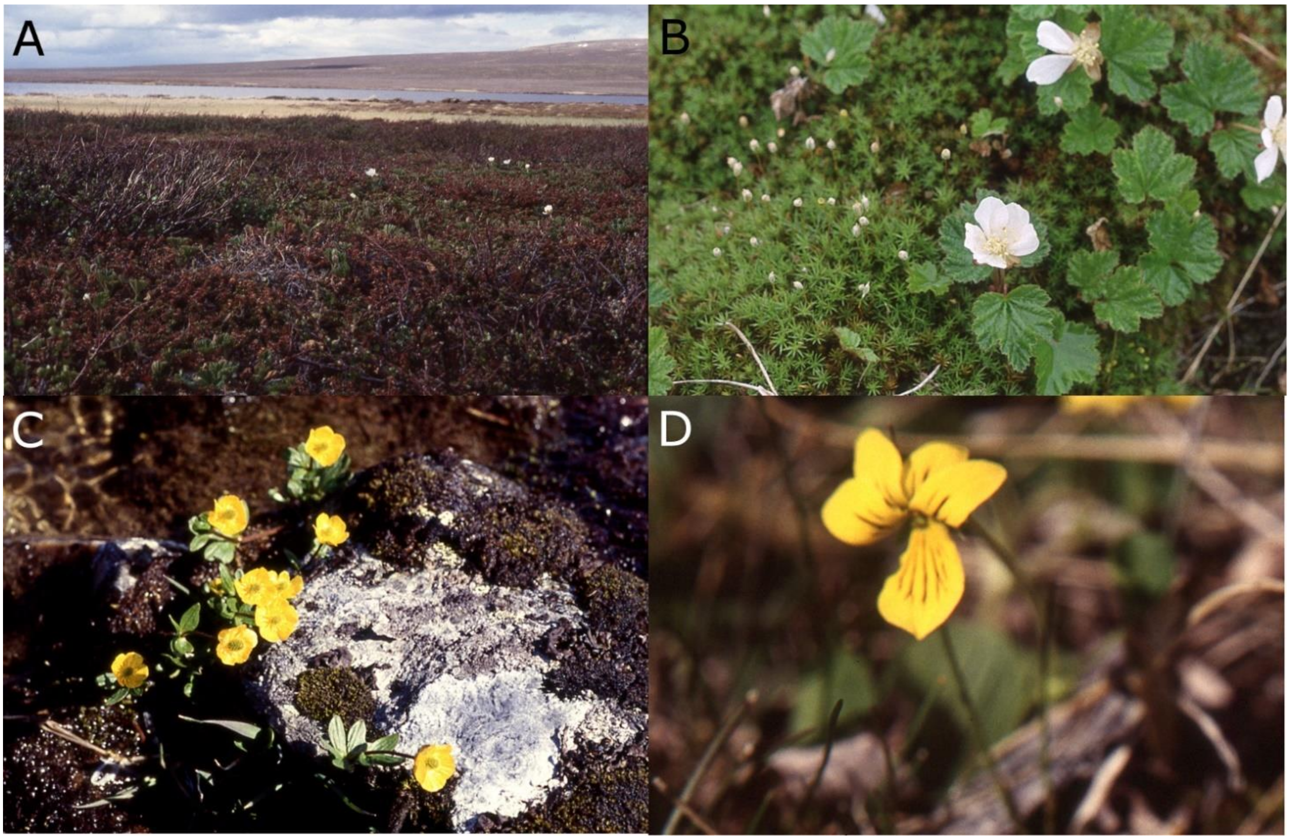

Figure 4. Flora of Seitajaure palsa mire: (A) Palsa with *Salix* sp., *Empetrum nigrum* subsp. *hermaphroditum* and flowering *Rubus chamaemorus*, June 1996; (B) *Rubus chamaemorus*, July 1996; (C) *Ranunculus nivalis*, June 1996; (D) *Viola biflora*, June 1996.

2003, Zuidhoff & Kolstrup, 2005, F.S. Zuidhoff unpublished data) and the mosses *Dicranum elongatum* Schleich. ex Schwägr., *Polytrichum strictum* Menzies ex. Brid. and *Ptilidium ciliare* (L.) Hampe (F.S. Zuidhoff unpublished data). The vegetation bordering the palsa mire is a *Betula nana* heath with a dominance of willow shrub transitioning to only willow and also wet heath. On the mountain slopes dominating plant species, besides *Betula nana* and *Salix reticulata* L., are *Carex capillaris* L., *C. atrofusca* Schkuhr, *Cassiope tetragona* (L.) D.Don, *Dryas octopetala* L., *Rhododendron lapponicum* (L.) Wahlenb., *Saxifraga oppositifolia* L., *S. aizoides* L., *Silene acaulis* (L.) Jacq. and in the high mountains a *Cassiope tetragona* heath with *Campanula uniflora* L. and *Pedicularis hirsuta* L. (F.S. Zuidhoff unpublished data).

The actual temperature in the palsa mire was measured during a 1.5-year period, with a temperature probe attached to a Tinytag logger (Gemini Data Loggers Ltd., UK). The data from the nearby weather station in Nikkaluokta (Alexandersson *et al*. 1991), 15 km to the north at an altitude of 470 m a.s.l., together with the actual measured temperatures in the mire, were used to estimate the weather in the palsa mire over the second half of the 21st century. The estimated mean annual temperature over the years 1960–1995 was -3.0 °C, with mean temperatures of 11.4 °C in July and -17.1 °C in January; mean annual precipitation of 508 mm and mean winter precipitation (November–April) of 188 mm. The measured temperatures from 20 July 1999 to 29 March 2001 were as follows (Figure 5): mean annual -1.4 °C, mean July 12.2 °C,

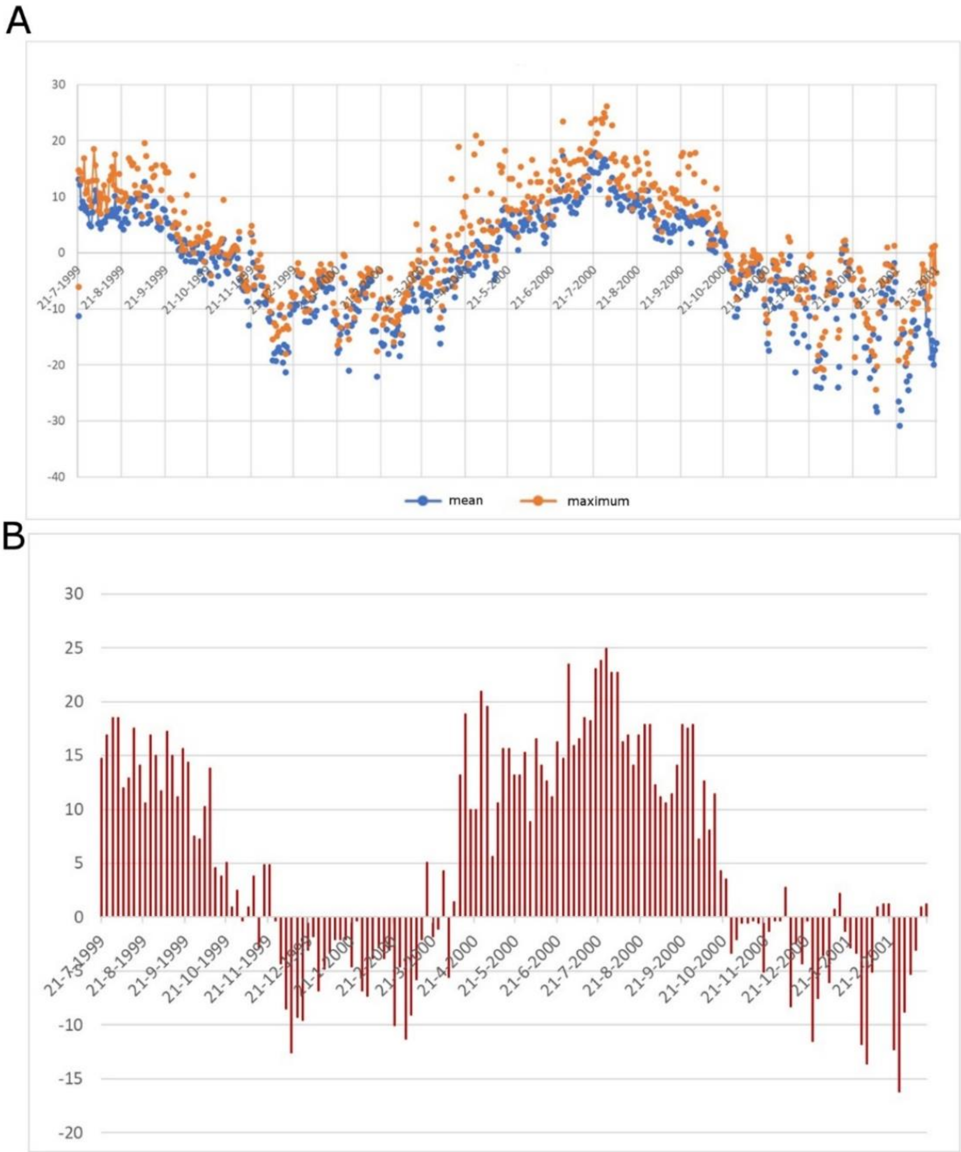

Figure 5. Temperature data from Seitajaure, from 21 July 1999 until 21 March 2001: (A) Mean and maximum day temperatures; (B) 4-day maximum temperatures in Celsius.

mean January -9.9 °C; minimum temperature -37.5 °C and maximum temperature 26.2 °C. Snow depth was measured once on 25 March 2001 in the bog, with a mean of 83 cm and a range of 40–105 cm, and on the palsa with a mean of 35 cm and a range of 20–70 cm, while under *Betula nana* the highest value of 70 cm was found. Thaw depth, measured on 29 palsas in June 1996 and August 1997, had a range of 16–43 cm (from Zuidhoff & Kolstrup 2005, F.S. Zuidhoff unpublished data).

Taxonomy

The species were studied using a Leica Wild M10 stereomicroscope with a graticule in one eyepiece. Photographs of the specimens were taken with a Canon EOS 6D camera attached to the microscope's phototube. Several photos were taken at multiple depths of field and combined with a stacking programme (Zerene Stacker 1.04). The combined photograph was further edited with the image editing programme GIMP 2.8.22 (Kimball & Mattis 2018). The figures of *Platycheirus torei* were made with a Canon EOS D6 with a Canon M-PE 1–5× macro lens and a Yongnuo ring light. The pictures were further edited with the stacking software Zerene Stacker and the image manipulation program GIMP. The specimens are deposited in the private collection of Jeroen van Steenis, Amersfoort, The Netherlands.

RESULTS

First records for Europe

Platycheirus torei **Barkalov, 2013**
Figures 6, 7C, 8C, 9C, 10C.

Material examined. "Sweden // Lule Lappmark // J. van Steenis", "Nikkaluokta // Seitajaure 765 m // RN 7517-1629 on: // *Rubus chamaemorus* // 28-VI-1996", 2♂.

Diagnosis. This species belongs to the *Platycheirus manicatus* group (Vockeroth 1990, Young *et al*. 2016) based on the profemur without modified pile; the rounded protibia with the apex at most narrowly broadened; the protarsus with first two tarsomeres broadened; mesofemur rounded; mesotibia usually with some pile tufts; antenna black; face slightly to strongly produced; abdomen with silvery or yellowish rectangular maculae.

This species is further very similar to *Platycheirus groenlandicus* Curran, 1927 (Figures 7A, 8A, 9A, 10A) and *P. subordinatus* (Becker, 1915) (Figures 7B, 8B, 9B, 10B) based on the small size and the silvery abdominal maculae. *Platycheirus subordinatus* differs from both of the other species in

Figure 6. Adult male habitus, dorsal view *Platycheirus torei*, Seitajaure, Sweden. Scale bar 1.0 mm.

the narrower metatarsus of the protarsus, the presence of 3–4 setae posteroventrally on the basal half of the profemur and the short pilose basal half of the mesotibia. *P. groenlandicus* differs from *P. torei* by the wider frons and eye angle, i.e. 120°, but in *P. subordinatus* around 110° and in *P. torei* 90°; metatarsomere of mesotarsus apico-posteriorly with yellowish setae, in *P. torei* some of these setae are black. The overall colour of the setae on the metatarsomere is variable within the species. Although checked in very few specimens, this might be in contrast with the original description (Barkalov 2013). Additional differences found were: posterior margin of metatarsomere of protarsus yellow setose in *P. torei*, while it is black setose in *P. goenlandicus*; pro- and mesotibia posteromedially long pilose in *P. torei*, while it is long pilose over most of its posterior margin in *P. goenlandicus*; mesotibia with dense white pile ventrally on apical half in *P. torei*, while it is present on two-thirds of its length in *P. groenlandicus*.

Distribution. Previously only known from its type locality (see Figure 1 in Barkalov 2013) on the Taimyr Peninsula, 72.7 °N, 101.0 °E, northern Siberia (Barkalov 2013); erroneously mentioned as from the Altai in Barkalov & Mutin (2018). The current record lies about 3,500 km west from the type locality and is a huge expansion of its known range.

Remarks. In the palsa mire and its surroundings only *P. torei* and *P. subordinatus* have been found. The nearest record of *P. groenlandicus* was from Nikkaluokta village some 15 km north of the palsa mire on the other side of the mountain range (“Sweden // Lule Lappmark // J. van Steenis”, “Nikkaluokta // meadow 450 m // RN 7532-1635 // on: *Caltha palustris* // 26-VI-1996”, 1♂”). At least one male specimen of *P. groenlandicus* is known from Laivadalen (see Figure 2), one of the southernmost palsa mires in Sweden (van Steenis & Zuidhoff 2013), implying that both species may be found in this habitat in Sweden.

Figure 7. Adult male, head and prolegs, dorsal view: (A) *Platycheirus groenlandicus*, Ammarnäs, Sweden; (B) *Platycheirus subordinatus*, Seitajaure, Sweden; (C) *Platycheirus torei*, Seitajaure, Sweden. Scale bars 0.5 mm.

Other Syrphidae collected in the Sietajaure palsa mire during the period 24–30 June 1996

Cheilosia melanopa **(Zetterstedt, 1843)**
1♂, 1♀, flower visiting *Caltha palustris* L. and *Salix* spp.

Eupeodes punctifer **(Frey, *in* Kanervo, 1934)**
3♂, flower visiting *Rubus chamaemorus* and *Salix* spp.

Melangyna arctica **(Zetterstedt, 1838)**
1♂, 1♀ flower visiting *Caltha palustris* and *Rubus chamaemorus*.

Parasyrphus tarsatus **(Zetterstedt, 1838)**
4♂, 4♀, flower visiting *Caltha palustris*, *Rubus chamaemorus* and *Salix* spp.

Platycheirus aeratus **Coquillet, 1900**
as *P. angustitarsis* (Kanervo, 1934) in van Steenis (1998). 2♂, flower visiting *Eriophorum* spp.

Platycheirus nigrofemoratus **Kanervo, 1934**
1♂, flower visiting *Ranunculus nivalis* L. (van Steenis 1998).

Platycheirus kittilaensis **Dusek & Laska, 1982**
1♂, 1♀, flower visiting *Caltha palustris* and *Rubus chamaemorus*.

Platycheirus subordinatus **(Becker, 1915)**
Figures 7B, 8B, 9B, 10B
15♂, 3♀, flower visiting *Caltha palustris*, *Ranunculus nivalis*, *Rubus chamaemorus* and *Salix* spp. Also collected in yellow pan traps in a *Salix* spp bush with flowering *Caltha palustris*, *Carex* spp. and *Vaccinium vitis-idaea* nearby.

Figure 8. Adult male proleg, dorsal view: (A) *Platycheirus groenlandicus*, Ammarnäs, Sweden; (B) *Platycheirus subordinatus*, Seitajaure, Sweden; (C) *Platycheirus torei*, Seitajaure, Sweden. Scale bar 0.5 mm.

DISCUSSSION

Syrphidae

The record of the High Arctic species *Platycheirus torei*, formerly only known from the Taimyr Peninsula, is remarkable not only due to the westward expansion of its occurrence by more than 3,500 km. The palsa-mire habitat where it was found in Sweden differs greatly from the type locality, a sandy bank of the river Zakharova Rassokha in Russia.

The males in Russia (Barkalov 2013) were collected on a sun-exposed sandbank sitting on the bare ground, flying short distances and feeding on flowers of *Dryas octopetala* (as *D. punctata* Juz. in Barkalov 2013). The surroundings of the river consisted of mossy tundra, mire and willow, dwarf birch and alder shrub (Lindquist & Makarova 2012, Pospelova & Pospelov 2014).

Palsa mires

Palsa mires are glacial relics in Sweden with a very special climatological, hydrological and faunistic profile (Zuidhoff & Kolstrup 2000, van Steenis & Zuidhoff 2013, Minayeva *et al*. 2016). It is possible that *Platycheirus torei* needs these special conditions to survive in Scandinavia, while it can occur in other habitats in colder areas like the Taimyr Peninsula.

Fenno-Scandian palsa mires have been investigated in detail: there has been an accelerating loss of this type of habitat during the last 50 years (Zuidhoff & Kolstrup 2000, Luoto *et al*. 2004b, Borge *et al*. 2017). The main cause of the loss is believed to be climate change, especially the warmer and wetter winters, which cause a decline in palsa growth (Zuidhoff & Kolstrup 2000, Olvmo *et al*. 2020). Recent insights into insect decline point out that, besides climate change indirectly causing habitat loss (Araújo *et al*. 2021), pollution and habitat

Figure 9. Adult male mesoleg, ventral view: (A) *Platycheirus groenlandicus*, Ammarnäs, Sweden; (B) *Platycheirus subordinatus*, Seitajaure, Sweden; (C) *Platycheirus torei*, Seitajaure, Sweden. Scale bar 0.5 mm.

degradation have the largest effect on this decline (Wilson & Fox 2020, Kehoe *et al*. 2021). In this light, human-influenced atmospheric precipitation with increased nitrogen and carbon dioxide, and even pesticides, could affect the hydrochemistry of the palsa mires, altering the vegetation cover and thus posing a threat to the survival of their fauna and flora (Luoto *et al*. 2004b, Tranvik 2011). Degradation and loss of the palsa mounds themselves leads to reduced habitat heterogeneity. The life cycle of the palsas, from embryo through to degrading mound, creates a variable landscape capable of supporting a wide range of specialised flora and fauna. If palsa formation ceases, the mire itself will still be present but the structure of peat mounds and ponds will disappear, along with its special fauna and flora: thus the cycle of development of palsas and the formation of thermokarst ponds is of eminent importance (Luoto *et al*. 2004b). Palsa decay seems to accelerate over time (Zuidhoff 2002, Olvmo *et al*. 2020). In 2000 one of the southern-most palsa mires degraded totally (Zuidhoff & Kolstrup 2000) and is thought to have ceased to be active, with the thermokarst ponds slowly turning into mires. One of the northern-most palsa mires in Sweden has undergone a decline of 30 % from 1955 to 2016 (Olvmo *et al*. 2020). Likewise in Norway, palsa mires are degrading rapidly with hardly any palsa activity left in the southern mountains (Matthews *et al*. 1997, Sollid & Sörbel 1998): in northern Norway the area of palsas declined by 30–70 % between 1950 and 2014 (Borge *et al*. 2017), and this decline is predicted to accelerate in the future (Fronzek 2013).

Rubus chamaemorus (cloudberry) is a very important food source for adult flies (e.g. Hippa *et al*. 1981, van Steenis & Zuidhoff 2013) which could be negatively affected by climate change. This plant will at first benefit from the degradation of palsa because it tends to have its optimum distribution on the degrading palsa, and it will also benefit from the release of nitrogen from the thawing permafrost (Zuidhoff & Kolstrup 2005, Keuper *et al*. 2017). However, cloudberry does not tolerate wet conditions, which will prevail at a later stage of the palsa cycle, eventually leading to a decrease in abundance if climate change continues (Zuidhoff & Kolstrup 2005, Gałka *et al*. 2017, Markkula *et al*. 2019).

Figure 10. Adult male mesoleg, anterior view: (A) *Platycheirus groenlandicus*, Ammarnäs, Sweden; (B) *Platycheirus subordinatus*, Seitajaure, Sweden; (C) *Platycheirus torei*, Seitajaure, Sweden. Scale bar 0.5 mm.

IUCN Red List

In this context, *Platycheirus torei* is not only extremely rare in Sweden, but also extremely threatened. Based on the IUCN Red List criteria, with a currently known maximum area of occupancy (AOO) of 8 km^2, a maximum extent of occurrence of 30 km^2, recorded to date only in one locality which could be destroyed by one single event in the next decade, an inferred decrease in AOO, and a decrease in the extent and quality of its habitat, it qualifies as Critically Endangered under criteria B2a, b(ii, iii) in Sweden, and thus in Europe. In a previous paper on the hoverfly fauna of a Swedish palsa mire (van Steenis & Zuidhoff 2013), two species were mentioned which strongly depend on palsa mires: *Eristalis gomojunovae* Violovitsh, 1977 and *Sericomyia jakutika* (Stackelberg, 1927). In light of the previous discussion on the possible Red List status of *Platycheirus torei*, these species need to be re-evaluated and possibly placed in a higher threat category of the European IUCN Red List than their present assessment of Vulnerable.

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Anatolii Barkalov (Novosibirsk, Russia) gave valuable information on Palaearctic *Platycheirus* species and verified one male of *P. torei*. The trip to Seitajuare was part of the PhD program of Frieda S. Zuidhoff (Amersfoort, The Netherlands) at Uppsala University, and she is acknowledged for the possibility of doing this research, the company during the fieldwork and the unpublished data used here. The collecting permission was issued by the county administrative board in Norrbottens län. Financial support for the collecting in Seitajaure was given by the Entomological Society in Uppland, Uppsala, Sweden. Francis Gilbert (Nottingham, UK) and Martin Speight (County Wicklow, Ireland) are acknowledged for their valuable comments and the English proofreading. Thanks to the two reviewers Andrew Young and Antii Haarto for improving this manuscript with their valuable comments.

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