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PAROCHLUS KIEFFERI (GARRETT, 1925) IN NEBRASKA (DIPTERA: CHIRONOMIDAE)

Barbara Hayford
Wayne State College, bahayfo1@wsc.edu

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Barbara Hayford

Wayne State College
1111 Main Street
Wayne, NE 68787
bahayfol@wsc.edu

ABSTRACT—A rare species of nonbiting aquatic midge, *Parochlus kiefferi* (Garrett, 1925), was discovered in Squaw Creek in the Pine Ridge of northwest Nebraska. *Parochlus* is a genus of midge found throughout the Southern Hemisphere and is only represented by this one species in the Northern Hemisphere. The typical North American species distribution of *P. kiefferi* includes high alpine and northern latitude streams, so the collection of *P. kiefferi* from a low elevation and low-latitude stream in Nebraska represents a range extension for the species. A survey for *P. kiefferi* from 83 samples from 53 stream sites in northern Nebraska yielded only four specimens of *P. kiefferi*, indicating that this species has a limited distribution. The stream survey was combined with a review of historical data dating back to the 1980s for stream macroinvertebrates from Nebraska, and the results confirmed that *P. kiefferi* is a rare species in the state.

Key Words: Chironomidae, freshwater conservation, rare species, stream ecology

INTRODUCTION

Parochlus kiefferi (Garrett, 1925) was collected from a small stream in the Pine Ridge of Nebraska during the early spring of 2008. The species belongs to a genus of podonomine nonbiting midges (Diptera: Chironomidae) known for its interesting distribution. The genus is found primarily in the Southern Hemisphere, with one species found in islands of Antarctica and another, *P. kiefferi*, found as far north as the 65th parallel, giving the genus a nearly bipolar distribution (Brundin 1966; Cranston et al. 2010; Medelytė 2010). *Parochlus kiefferi* is the only one of 51 *Parochlus* species to be found in the Northern Hemisphere, where it has a patchy distribution (Brundin 1966; Ashe and O'Connor 2009). Typically, it is rare to minimally abundant at ecological study sites where it is collected as a larva or pupa (Ruse et al. 2000; Brabets and Whitman 2002; Aagaard et al. 2004; Lencioni et al. 2007; Medelytė 2010). *Parochlus kiefferi* is found at high elevations in mountainous regions or at high latitudes in the western United States (Wirth and Sublette 1970; Brundin 1989). It has been designated a cold obligate, favoring habitats such as mountain streams, cold springs, and fern bogs (Wirth and Sublette 1970; Brundin 1989; Lindegaard 1995).

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Pupal exuviae, the cast-off exoskeletons, of *P. kiefferi* were collected from Squaw Creek in the Nebraska Pine Ridge, which is located at the relatively low latitude of 42° and at an elevation of 1,237 m above sea level, placing the Nebraska population outside the species' known range of high latitudes and elevations (Brundin 1966; Brundin 1989; Cranston et al. 2010). Its unique geographical location relative to other populations within the species and the typical rarity of the species led to a survey for *P. kiefferi* in Nebraska. The goals of this survey were to (1) establish the range of *P. kiefferi* in Nebraska, (2) determine whether it is a rare species in Nebraska, and (3) describe habitat for populations of the species within the state. The ecology and biogeography of *P. kiefferi* are discussed in relation to conservation of the species.

METHODS AND MATERIALS

Historical Data

No records of *P. kiefferi* from the Great Plains had been published as of 2004 (Hayford and Bouchard 2004). At least one population has been reported from Saskatchewan (Ashe and O'Connor 2009), but it is unclear whether the record is from the northern Great Plains. The author and personnel from the Nebraska Department of

Environmental Quality (NDEQ) and the Nebraska Game and Parks Commission (NGPC) searched the historical data on incidence of larval Chironomidae, ranging from 1984 to the present, for records of the species in Nebraska. These records can be found in unpublished documents gathered by the Central Plains Center for Bioassessment (CPCB) and by NDEQ and NGPC.

Study Sites

Nebraska has an estimated 81,573 stream miles, of which 17,783 are perennial (American Rivers 2011). In order to focus the search effectively, survey sites mainly included habitats similar to those in which *P. kiefferi* has been commonly found, such as small perennial streams and cold spring seeps. Furthermore, survey sites were restricted to the northern third of the state because the species is more common in northern latitudes, and this would maximize the chance of finding more populations in Nebraska. The survey included 27 sites from the Pine Ridge, 12 sites from the Verdigris and Bazile Creek watersheds, six streams in the northern Sandhills, five streams in the central Sandhills, and three streams in eastern Nebraska (Fig. 1). Most sites were sampled during late winter or early spring or mid- to late autumn. Sites in the central Sandhills and eastern Nebraska were sampled during late summer and autumn. Streams were sampled from 2001 to 2010, with most sites sampled during 2006–2010.

Collection and Identification Methods

The surface-floating pupal exuviae (SFPE) method, used to collect cast-off exoskeletons of Chironomidae, was effective at finding *P. kiefferi* in Nebraska. The SFPE method (modified from Ferrington 1987), was used to designate a 25–50 m reach along each stream site. Surface-floating pupal exuviae (SFPE) were collected by dipping a small white pan into the flow of the water along regions of the stream where exuviae accumulate, such as eddies and overhanging blades of grass. The SFPE samples were collected from downstream to upstream along the reach. The contents of the pan were poured through a sieve with a 250 μm mesh pore diameter. Exuviae and all other macroinvertebrates were collected from the sieve into jars and preserved in the field, preserved in 80% ethanol, and labeled. Specimens were sorted from debris in the laboratory and specimens were examined at 4′ magnification using a Leica MS5 stereo dissecting microscope. Permanent slide mounts of *P. kiefferi* were prepared using Euparal slide-mounting medium; slides were labeled and specimens were identified using dichotomous keys by Brundin (1986) followed by confirmation using Brundin (1966). Voucher specimens were sent to the Academy of Natural Sciences of Philadelphia.

Water-quality data were collected for the following parameters: conductivity (μS/cm), air and water temperature (°C), pH (IU), and salinity (ppm). A Horriba multiparameter field meter and probe were used to collect in situ water-quality data.

RESULTS AND DISCUSSION

A total of 10,073 specimens of Chironomidae SFPE were examined from 81 stream samples in the search for *P. kiefferi* in Nebraska (Fig. 1). Only four specimens of SFPE *P. kiefferi* were collected from Squaw Creek from four different dates, two in autumn and two in early spring (Table 1). Squaw Creek is singular among the 53 stream sites surveyed by being the only site to support a small population of *P. kiefferi,* but Squaw Creek's physical properties, habitat, and water quality are similar to those of the other sites, particularly in the Pine Ridge. For example, average conductivity (366 μS/cm) in Squaw Creek was within the range of conductivity (277–656 μS/cm) for streams in the Pine Ridge. Many other streams in the Pine Ridge were characterized by cobble substrate, like Squaw Creek (Table 1). The only observable difference was that cobble at the Squaw Creek site was not embedded in sediment.

Review of over 20,000 historical records of Chironomidae yielded no records of *P. kiefferi* from Nebraska prior to the specimens collected from Squaw Creek. These specimens represent the first record of *P. kiefferi* from Nebraska and from the southern Great Plains ecoregion as defined by Omernik (1988). The species is rare and has an extremely limited distribution in Nebraska (Fig. 2). The single known habitat for the species in Nebraska, Squaw Creek, is a narrow, first-order stream flowing through ponderosa pine (*Pinus ponderosa*) and deciduous woodland (Schneider et al. 2005). The stream is characterized by cobble and gravel substrate; is fed by spring seeps; and exhibits moderate levels of conductivity, low salinity, and has neutral to slightly acidic water (Table 1). Collection of SFPE of *P. kiefferi* in mid-autumn and early spring indicates that the species emerges during the colder months of the year, and it may emerge as an adult over the entire winter season. Adults of *P. kiefferi* have been collected throughout the spring, summer, and fall months in the United States (Wirth and Sublette 1970; Anderson and Anderson 1995; Ferrington 1998)

Figure 1. Sites surveyed in the search for *Parochlus kiefferi* in Nebraska. Circles indicate sampling sites. The cluster of sites in the western part of the state is in the Pine Ridge region. It represents 47 different sampling events from 27 different sampling sites. The cluster of sites in the northeastern part of the state is in the Bazile Creek and Verdigris Creek watersheds. It represents 20 different sampling events from 12 different sampling sites.

TABLE 1
WATER QUALITY, PHYSICAL, AND HABITAT DATA FOR SQUAW CREEK

Site information					
Sampling date	3/20/2007	3/23/2008	10/25/2008	4/5/2010	10/9/2010
Air temperature (°C)	3.0	0.0	15.0	9.0	13.0
Water temperature (°C)	8.9	10.6	10.4	15	13.1
Conductivity (µS/cm)	422	366	390	399	390
pH	ND	ND	7.65	6.86	7.71
Salinity (ppm)	0.00	0.01	0.00	0.01	0.01
Substrate type (%)					
Cobble (64–256 mm diameter)	62	65	54	61	50
Gravel (2–64 mm diameter)	12	10	10	9	8
Sand (0.06–2 mm diameter)	5	2	3	5	2
Silt (0.004–.06 mm diameter)	10	10	16	20	20
Clay (<0.004 mm diameter)	0	0	0	0	0
Course particulate organic matter	2	5	6	2	12
Fine particulate organic matter	9	8	11	3	8
Green algae (coverage in study reach)	25	ND	40	ND	35
Parochlus kiefferi	Absent	Present	Present	Present	Present

Note: ND = no data.

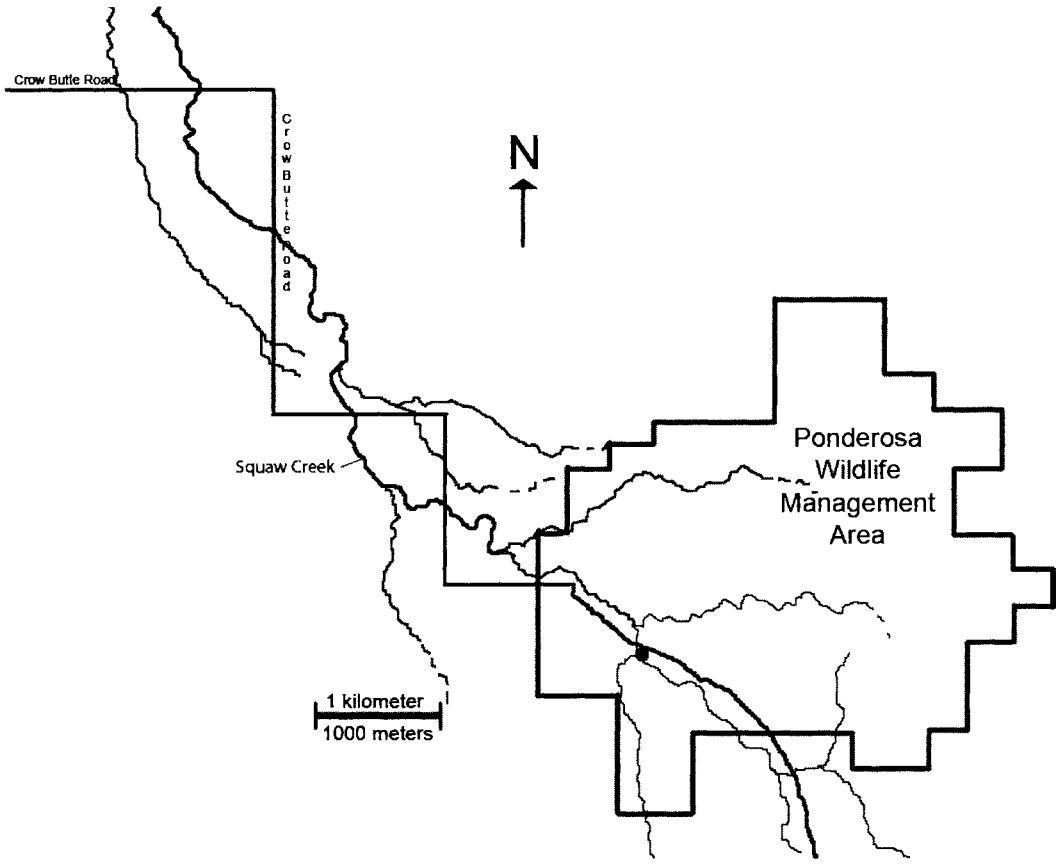

Figure 2. Squaw Creek watershed, Dawes County, Nebraska. The Squaw Creek site where *Parochlus kiefferi* specimens were collected is marked by a solid circle. The stream site is located in the Ponderosa Wildlife Management Area.

and throughout the ice-free season in Europe and Canada (Brundin 1966). Some specimens have been observed emerging only during a period of time just past snowmelt in Germany (Brundin 1966), perhaps showing a similar emergence window to the population in Nebraska. Further research on the phenology of *P. kiefferi* from Squaw Creek is needed to establish if it emerges over the winter months. Restriction to a fall through early spring emergence may be an adaptation of the species to the warmer temperatures of the lower-latitude and lower-elevation habitat of Squaw Creek.

Parochlus belongs to the subfamily Podonominae, an ancestral subfamily of Chironomidae that has a Southern Hemisphere distribution (Brundin 1966). The most species-rich genus of Podonominae is *Parochlus,* of which only *P. kiefferi* is found in the Northern Hemisphere (Ashe and O'Connor 2009). Phylogenetic analysis of the subfamily supports the hypothesis that *P. kiefferi* diverged from other species in the *Parochlus auraucanus* group, which is found in the northern Andes of South America (Cranston et al. 2010). *Parochlus* currently has a gap in distribution with other species in the *P. auraucanus* group found in the northern Andes and points south (Ashe and O'Connor 2009) and *P. kiefferi* found only as far south as the mountainous areas of southern Arizona and California (Wirth and Sublette 1970). The species may have dispersed along high-elevation habitats from the Andes into the southern mountains of western North America (Brundin 1966). The most geographically proximate locations of the species to the population of *P. kiefferi* found in Nebraska are in the Bighorn Mountains of Wyoming, where adults were collected above 2,400 m above sea level, and the Rocky Mountains west of Boulder in Colorado, where adults were collected also above 2,400 m above sea level (Wirth and Sublette 1970). These high alpine sites are dominated by coniferous forests, whereas the site in the Pine Ridge of Nebraska is characterized by a mixture of ponderosa pine and deciduous forest and is 1,163 m closer to sea level. The Pine Ridge site exhibits far warmer temperatures, as air temperatures can reach above 43°C in the Pine Ridge during summer months. Despite the differences between the Pine Ridge and the Rocky and Bighorn mountains, the three regions share a common past. Rocky Mountain pine and boreal forests

spread across Nebraska to mix with eastern hardwood deciduous forests by the end of the Pleistocene glaciations. This period, characterized by extension of the pine and boreal forests across Nebraska, was followed by a warmer, dryer climate at the end of the last glacial maximum (~12,000 years ago) (Ratcliffe and Hammond 2002). The drier climate favored loss of the boreal forest and extension of grassland prairie, which was accelerated by cultural practices of Native American tribes that included burning the landscape to attract prey (grazers) and to deter enemy tribes (Schmidt and Wardle 1998; Ratcliffe and Hammond 2002). Prairie, and subsequently agricultural lands, eventually came to surround relic islands of pine and hardwood forests that still exist today along the Pine Ridge. The pattern of glaciations followed by retraction of the pine and hardwood forests has produced an interesting modern biogeography of insects in Nebraska (Ratcliffe and Hammond 2002). North American populations of *Parochlus kiefferi* probably originated between 1 and 10 million years ago (Cranston et al. 2010). Therefore, it is plausible that they could have extended into the Great Plains by the time of the Pleistocene glaciations. The Wisconsin Glacier only covered the eastern third of the state (Ratcliffe and Hammond 2002). Hence, *P. kiefferi* could have extended across Nebraska in small streams and spring seeps in the cold regions below and to the west of the glacier, which suggests its current presence in the Nebraska Pine Ridge may represent a relic population.

Parochlus kiefferi is rare in most collections of both adult and immature stages in North America (Colbo 1991; Anderson and Anderson 1995; Ferrington 1998; Ruse et al. 2000). However, an interesting pattern appears when examining ecological studies of the species across the Holarctic region. *Parochlus kiefferi* is rare in ecological studies in the western Nearctic (Ruse et al. 2000; Brabets and Whitman 2002), is listed as less abundant but certainly not rare in some studies on habitats in the Northwest Palaearctic (Aagaard et al. 1997; Aagaard et al. 2004; Medelytė 2010), and appears to be quite rare in the first record from the Italian Alps (Lencioni et al. 2007). Establishing biogeographic patterns related to ecological abundances would be useful in studying such a rare and interesting species. The creation of an ecological data repository (e.g., Reichman et al. 2011), particularly one that listed species by latitude, longitude, and date of collection, would facilitate research and understanding of *P. kiefferi*'s rarity as well as the rarity of other species. Such data can be found on websites such as the Global Diversity Information Facility, but the freshwater invertebrate data are miniscule relative to data for many species of vertebrates, and ecological data are not included in the databases.

Paucity of information makes it difficult to determine the rarity of a species of freshwater invertebrates at a time when biodiversity of aquatic ecosystems is in precipitous decline (Dudgeon et al. 2006; Strayer 2006). Freshwater ecosystems represent only 0.01% of all water and 0.8% of land surface on Earth, making them insular habitats surrounded by land. In fact, freshwater may be the most endangered type of ecosystems on Earth, with a rate of loss greater than in terrestrial ecosystems. Freshwater animals are being lost at a rate of 4% per decade in North America (Dudgeon et al. 2006). The isolated nature of freshwater habitat may be nowhere more apparent than in grassland biomes of the Great Plains and Nebraska, which can be characterized as a sea of grass dissected by ~18,000 perennial stream miles (American Rivers 2011) and covered by scattered wetlands and lakes in the Sandhills (Bleed and Ginsberg 1990).

Aquatic ecosystems in Nebraska face threats from nitrates in groundwater (Gurdak and Qi 2006) as well as surface runoff and atmospheric deposition of pesticides (Frankforter 1995; Goldsborough and Crumpton 1998), but perhaps the greatest threat to freshwater in Nebraska is reduced water availability. Groundwater levels have dropped as much as 46 m in the area south of the Pine Ridge since presettlement times and have dropped as much as 12 m between 1980 and 1999 (McGuire 2001, 2009). Streams in the Pine Ridge, particularly streams in the headwaters of the White River such as Squaw Creek, are hydrologically connected to their source of groundwater, the Arikaree Aquifer. Groundwater input from the aquifer stabilizes the streams in the Pine Ridge, creating perennial flow (UNWNRD 2004), which is necessary to support populations of *P. kiefferi*. Stressors such as increased use of groundwater by irrigation can deplete water in the Arikaree Aquifer and affect base flow of streams in the Pine Ridge (UNWNRD 2004). Thus, Squaw Creek is at risk of becoming an intermittent stream, and if it does it will no longer support populations of *P. kiefferi* and other species that depend on perennial streamflow.

Strayer (2006) suggested that protecting and conserving freshwater invertebrates should be linked to conservation of broad, regional actions to protect and conserve water for human use. Conservation strategies for regions of Nebraska have already been suggested or employed by the Nebraska Natural Legacy Plan (Schneider et al. 2005). The plan lists the Pine Ridge as one of its "biologically unique landscapes" of Nebraska, and a survey on the

flora of the region has already been conducted to produce data for use by future legacy plan practitioners (Steinauer 2008). Another sign of hope is that the Upper Niobrara–White Natural Resources District is tasked with monitoring groundwater use in the area and as of 2009 had designated the groundwater in the region in and around the Pine Ridge as fully appropriated. This designation resulted in a continuation and spatial extension of the moratorium on construction of new water wells in the region (UNWNRD 2009), which should help conserve the groundwater that not only feeds Squaw Creek and other streams in the region but also supplies drinking water to the residents of northwest Nebraska.

This unique and rare species deserves conservation status in Nebraska. Its presence represents perennial, spring-fed streamflow and a healthy stream habitat. Perhaps the best way to protect *P. kiefferi* is to support existing strategies to conserve its habitat, support drinking water in the Pine Ridge, and to create or maintain good-quality recreation in the region.

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