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THE PLECOPTERA AND TRICHOPTERA OF THE ARCTIC NORTH SLOPE OF ALASKA

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ABSTRACT.—The Arctic is currently experiencing changes in climate more rapid than in any other biome. This warming trend has resulted in significant abiotic changes to the seasonal patterns of freshwater ecosystems. Thorough inventories of freshwater insect communities are required to provide benchmarks for the detection of range shifts in response to a warming climate. Though statewide studies have been conducted for Trichoptera and Plecoptera, species accounts for these orders in Arctic Alaska have received relatively little attention. We surveyed Plecoptera and Trichoptera of Alaska's Arctic North Slope at a variety of habitat types over an 11-year period. We document new and historical collection records for 24 species of Plecoptera and 33 species of Trichoptera on Alaska's North Slope. Among these are 19 new North Slope records for Trichoptera (4 new state records) and 2 new North Slope records for Plecoptera. Our assessment of these taxa reveals communities of stoneflies and caddisflies that are distinct to Alaska's North Slope and should be of clear conservation concern. Two major factors contributing to these unique communities include the function of the North Slope as a Beringian refuge from continental ice sheets and the occurrence of spring streams as refuge from seasonal winter ice. The North Slope of Alaska is predicted to undergo changes in climate and industrialization in coming years, and this species list will aid our understanding of how aquatic insect communities may respond to future changes in Arctic Alaska.

RESUMEN.—El Ártico atraviesa actualmente cambios climáticos más rápidos que cualquier otro bioma. Esta tendencia al calentamiento ha resultado en cambios estacionales abióticos significativos en los patrones de los ecosistemas de agua dulce. Se requieren minuciosos inventarios de comunidades de insectos de agua dulce para proporcionar puntos de referencia que permitan la detección de cambios en el nivel de respuesta a un calentamiento climático. Si bien se han conducido estudios de Trichoptera y Plecoptera en todo el estado, recuentos de las especies de estos órdenes en el Ártico en Alaska han recibido relativamente poca atención. Examinamos la plecópteros y tricópteros de la ladera norte del Ártico en Alaska en una variedad de hábitats durante un período de 11 años. Documentamos nuevos e históricos registros de colecciones de 24 especies de Plecoptera y 33 especies de Trichoptera en la ladera norte de Alaska. Entre ellos se encuentran 19 nuevos registros de Trichoptera de la ladera norte (4 nuevos registros de estado) y 2 nuevos registros de Plecoptera en la ladera norte. Nuestra evaluación de estos taxa revela comunidades de insectos del orden Plecoptera distintos de los de la ladera norte de Alaska y deberían evidentemente ser de preocupación de conservación. Dos factores principales que contribuyen a estas comunidades únicas incluyen la ladera norte como un refugio Beringiano de las placas de hielo continental y la existencia de corrientes primaverales como refugio de la estación de hielo invernal. Se prevé que la ladera norte de Alaska sufrirá cambios en el clima e industrialización en años venideros y esta lista de especies ayudará a nuestro entendimiento de cómo las comunidades de insectos acuáticos pueden responder a futuros cambios en el Ártico de Alaska.

Climate change is currently altering ecosystem structure and function in Arctic ecosystems, where temperatures are rising due to the polar amplification of greenhouse warming (Hinzman et al. 2005, Chapin et al. 2006, Martin et al. 2009). This warming trend has already resulted in significant changes in the seasonality of freshwater habitats in Arctic and Boreal North America, where the spring breakup of winter river ice has showed successively earlier dates over the past 6 decades (White et al. 2007, de Rham et al. 2008, Tape et al. 2011). Increasing temperatures are highly correlated with the range extensions of many insect species (Chen et al. 2011), and it is thus likely that populations of freshwater insects in the Arctic are undergoing range adjustments in response to climate warming (ACIA 2005). Similarly, it is anticipated that lower-latitude species will eventually expand their ranges into the Arctic (ACIA 2005). Thorough inventories of freshwater insect communities are thus required to provide benchmarks for the detection of range shifts of species in response to a warming climate. Unfortunately, records documenting the

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distributions of freshwater insect species of the Arctic regions of Alaska are limited. The distribution of the Ephemeroptera (McCafferty 1985, Randolph and McCafferty 2005), Plecoptera (Stewart and Oswood 2006), and Trichoptera (Nimmo 1986) in Alaska have been documented at the statewide level. Few studies, however, have focused exclusively on the Arctic. Weber (1950), for example, is the only relatively comprehensive source that includes records for the occurrence of freshwater insect taxa while specifically treating the North Slope, where changes in the ranges of Alaskan insects as a result of climate warming are anticipated to be most significant.

Herein we provide an updated synopsis of new and historical distribution records of the Plecoptera and Trichoptera of the Arctic North Slope (including the Noatak River basin) of Alaska. It is our intent that this synopsis will provide a readily available benchmark for the detection of future changes in the ranges of freshwater invertebrates in this region.

METHODS

We conducted this study on the central and eastern North Slope of Arctic Alaska. The North Slope is a relatively large region with an area roughly equal to that of Nebraska (~200,000 km^2) and is bounded on the north by the Arctic Ocean and on the south by the Brooks Range. It is subject to average monthly air temperatures of –30 to –27 °C in January (warmer temperatures near the coast of the Arctic Ocean; colder temperatures inland) and 5 to 13 °C in July (colder temperatures near the coast; warmer temperatures inland). The North Slope typically receives a minimum of 150 mm of annual precipitation near the coast and 550 mm of precipitation in some areas of the Brooks Range; snowfall is possible on any day of the year (Huryn and Hobbie 2012). This treeless tundra region is underlain by a continuous layer of permafrost and is covered by vegetation dominated by cottongrass (*Eriophorum*), dwarf birches (*Betula*), willows (*Salix*), mosses (primarily *Sphagnum*), sedges (*Carex*), and lichens (Huryn and Hobbie 2012). Stoneflies (Plecoptera) and caddisflies (Trichoptera) were collected during the summer periods of 2001–2012. Adults were collected by hand and aerial net along rivers, streams, springs, wetlands, ponds, and lakes in habitats ranging from alpine to coastal plain from locations primarily in the Kuparuk, Sagavanirktok, Ivishak and Noatak River drainages of the central and eastern North Slope (Table 1). Larvae were collected in the same habitats and locations by use of kicknets and other sampling devices. Light traps, which are extremely effective for collecting adult caddisflies, could not be used due to continuous daylight during summer. As a consequence, sticky traps (n = 12) were deployed in the riparian zones of 8 streams along the North Slope section of the Dalton Highway (30 June–9 August 2011) and recovered at ~1-week intervals. These traps consisted of standard overhead projector transparencies that were coated with Tanglefoot® (The Tanglefoot Company, Grand Rapids, MI). Voucher specimens from this collection will be available through Brigham Young University's insect collection (R. Baumann personal communication).

SPECIES LIST

New and historical records documenting the occurrence of Plecoptera and Trichoptera are provided in the following list. The family-level structure of the list follows Stewart and Oswood (2006) for the Plecoptera and Wiggins (1996) for the Trichoptera. Records taken from the literature, and not from our 2001–2012 collections, are indicated by the following superscripts:

[a]Stewart and Oswood 2006
[b]Nimmo 1986
[c]Weber 1950
[d]Wiggins and Richardson 1986
[e]Schmid 1964
[f]Wiggins 1998
[g]Glesne and Deschermeier 1984
[h]Hershey et al. 1997
[i]Zenger and Baumann 2004
[j]Stewart and Ricker 1997
[k]Wiggins and Parker 1997

Previously undocumented Alaskan North Slope records are preceded by an asterisk (*), while new Alaska state records are preceded by 2 asterisks (**). Date format is dd/mm/yyyy, and specimens are characterized as "m" for males and "f" for females. Names of species documented from the Arctic north slope drainages of the Yukon Territory, Canada are preceded by a double dagger (‡) and are included for reference, but only Alaska specimens are included in further analyses.

TABLE 1. Location of collection sites inventoried from 2001 to 2012. Sites where sticky traps were deployed are indicated by an asterisk (*).

Site name	Latitude	Longitude
Barrow Environmental Observatory	71.277075°	–156.639441°
Cobblestone River *aufeis*[a]	68.6404°	–150.59554°
Dan Creek*	69.098067°	–148.8331°
Echooka Spring	69.266944°	–147.203056°
Franklin Bluffs near Dalton Highway Milepost 386	69.785596°	–148.654633°
Galbraith Lake	68.465235°	–149.434191°
Galbraith Lake "west" *aufeis*	68.454833°	–149.455083°
Galbraith Lake "campground spring"	68.4529°	–149.480367°
Happy Valley Creek*	69.15065°	–148.835333°
Hershey Creek*	68.644399°	–149.412706°
Holden Creek	68.406117°	–149.325333°
Imnavait Creek	68.619069°	–149.318544°
Ivishak Hot Spring	69.029444°	–147.664167°
Krugurak Spring	67.623917°	–155.622533°
Kuparuk River* (Dalton Highway bridge)	68.638933°	–149.393067°
Kuparuk River "lower" *aufeis*	68.988017°	–149.731433°
Kuparuk River "upper" *aufeis*	68.59295°	–149.357867°
Lake E-1 outlet* near Toolik Lake	68.6359°	–149.584717°
Lake E5 near Toolik Lake	68.645067°	–149.460183°
Lake I-3 outlet stream near Toolik Lake	68.575233°	–149.582915°
Lake I-6 headwater outlet stream near Toolik Lake	68.584031°	–149.62409°
Lupine Creek*	69.305983°	–148.741967°
May Creek spring and *aufeis*	68.682778°	–150.418611°
Mosquito Lake	68.447303°	–149.367817°
Oil Spill Hill, Dalton Highway	68.942975°	–148.86843°
Oksrukuyik River*	68.687217°	–149.09535°
Percy Pingo	70.005645°	–148.76337°
Ribdon River spring	68.473889°	–148.149444°
Roche Moutonnee Creek	68.372773°	–149.31905°
Sagavanirktok River "glacier tributary"	68.361111°	–149.077222°
Sadlerochit Spring	69.664722°	–144.414444°
Tea Lake	68.423106°	–149.375748°
Toolik Lake	68.63115°	–149.608117°
Toolik River near Dalton Highway	68.647283°	–149.319217°
Toolik River *aufeis*	68.121283°	–149.320083°
Wolf Creek*	68.670517°	–149.127583°

[a]*Aufeis* are spring-associated ice fields (see discussion).

PLECOPTERA

Capniidae

Capnia confusa Claassen, 1936

NEW RECORDS.—Toolik Lake, 1f, 28/6/2001; Ivishak Hot Spring stream, 1m & 2f, 15/7/2002, 1m & 4f, 23–28/6/2002; Ivishak River, main stem near Ivishak Hot Spring, 2m, 28/5/2008; Cobblestone River *aufeis*, 1m, 8/6/2012; May Creek *aufeis*, 1m & 1f, 8/6/2012.

HISTORICAL RECORDS.—Anaktuvuk River, 1949[a,c]; Shublik Spring, 1966[a]; Echooka Spring, 1971[a]; Canning River, unnamed spring, 1972[a].

Capnia nearctica Banks, 1918

NEW RECORDS.—Toolik Lake, 1m & 6f, 29/6/2001, 1f, 21/7/2001; May Creek spring, 1f, 8/7/2001; Toolik River *aufeis,* 1f, 11/7/2001; Kuparuk River "upper" *aufeis*, 2m & 7f, 29/6/2007; Ivishak River near Ivishak Hot Spring, 4f, 28/5/2008; Ivishak River, main stem near Ivishak Hot Spring, 8m, 28/5/2008; Galbraith Lake "west" *aufeis*, 1 brachypterous 1m & 3f, 3/6/2012; Kuparuk River "lower" *aufeis*, 1m & 8f, 8/6/2012; May Creek spring, 1f, 1/6/2012, 5m, 8/6/2012; Toolik River *aufeis*, 1 brachypterous male, 8/6/2012; Kuparuk River (Dalton Highway bridge), 1 brachypterous male, 22/6/2012; Kuparuk River "lower" *aufeis*, 1 brachypterous male, 10/8/2012.

HISTORICAL RECORDS.—Umiat, 1948[a]; Anaktuvuk River, 1949[a,c]; Toolik Lake, 1979[a].

‡*Capnia pileata* Jewett, 1966

HISTORICAL RECORDS.—Philip Creek, Arctic slope of Yukon Territory, Canada (no date)[j].

Isocapnia abbreviata Frison, 1942

HISTORICAL RECORDS.—Noatak River, 1973[i].

Isocapnia crinita (Needham & Claassen, 1925)

NEW RECORD.—Cobblestone River *aufeis*, 2f, 8/6/2012.

HISTORICAL RECORDS.—Noatak River, 1973[i].

Isocapnia grandis (Banks, 1907)

NEW RECORDS.—Ribdon River spring, 2m, 1/7/2001; Cobblestone River *aufeis*, 1f, 8/6/2012.

HISTORICAL RECORDS.—Canning River, spring tributary, 1972[a].

**Isocapnia* cf. *integra* Hanson, 1943

NEW RECORDS.—Cobblestone River *aufeis*, 1f, 8/6/2012.

Mesocapnia oenone (Neave, 1929)

HISTORICAL RECORDS.—Anaktuvuk Pass, 1949[c].

Mesocapnia variabilis (Klapálek, 1920)

NEW RECORDS.—Echooka Spring, 1f, 4/7/2001; Kuparuk River (Dalton Highway bridge), 3f, 20/7/2001, 2m & 3f, 3/8/2001; Sadlerochit Spring, 2f, 22/7/2002; Kuparuk River (Dalton Highway bridge), 2f, 3/8/2012; Galbraith Lake "west" *aufeis*, 1f, 22/8/2012; Kuparuk River "upper" *aufeis*, 5m, 10/8/2012; Toolik River *aufeis*, 2m & 5f, 10/8/2012.

HISTORICAL RECORDS.—Anaktuvuk River, 1948[a]; Cape Thompson, 1960[a]; Canning River, 1972[a]; Cache Creek, 1972[a]; Atigun Pass, 1980[a]; Atigun River, 1980[a]; Pump Station 4, Dalton Highway, 1980[a]; Roche Moutonnee Creek, 1980[a]; Sikrelurak River, 1982[a].

Nemouridae

‡*Nemoura arctica* Esben-Peterson, 1910

NEW RECORDS.—Sagavanirktok River "glacier tributary," 2m & 1f, 10/6/2001; Toolik Lake, 1m, 26/6/2001, 2m & 2f, 28/6/2001; Ribdon River spring, 1f, 1/7/2001; Echooka Spring, 1m & 2f, 4/7/2001; Kuparuk River (Dalton Highway bridge), 1m & 1f, 4/7/2001, 1m & 1f, 11/7/2001, 1m, 20/7/2001, 1f, 9/8/2001; Kuparuk River "upper" *aufeis*, 1m & 2f, 20/7/2001; Ivishak Hot Spring stream, 1f, 23–28/6/2002; Ivishak Hot Spring stream, 1f, 26/5/2008; Ivishak Hot Spring, hillslope source, 36m & 25f, 26–29/5/2008; Kuparuk River (Dalton Highway bridge), 1f, 18/6/2012, 1m & 6f, 19/6/2012, 1m & 8f, 22/6/2012, 1m & 16f, 23/6/2012; Oksrukuyik Creek, 1f, 5/7/2012; Lupine Creek, 2f, 9/7/2012; Holden Creek, 1f, 11/7/2012; Roche Moutonnee Creek, 1f, 11/7/2012.

HISTORICAL RECORDS.—Anaktuvuk Pass, 1948–1949[c]; Point Barrow, 1949[a]; Point Barrow, 1955[a]; Cape Lisburne, 1957[a]; Contact Creek, 1957[a]; Umiat, 1959[a]; Cape Thompson, 1960[a], 1961[a]; Cape Lisburne, 1965[a]; Shublik Spring, 1969[a]; Anaktuvuk Pass, 1968[a]; Ribdon River (S. Fk.), 1971[a]; Section Creek, 1971[a]; Echooka River, 1971[a]; Echooka Spring, 1971[a]; Cane Creek, 1972[a]; Sadlerochit Spring, 1972[a]; Canning River tributaries, 1972[a], 1973[a]; Kikitaliorak Lake, 1973[a]; Feniak Lake, 1973[a]; Schrader Lake, 1973[a]; Galbraith Lake, 1976[a]; Atigun River and tributaries, 1977[a]; Kuparuk River (Dalton Highway bridge), 1978[a]; Toolik Lake, 1979[a]; Atigun River and tributaries, 1980[a]; Pump Station 4, Dalton Highway, 1980[a]; Teshekpuk Lake, 1980[a]; Oksrukuyik Creek, 1980[a]; Roche Moutonnee Creek, 1980[a]; Okerokovic River, 1982[a]; Jago River, 1982[a]; Kaktovik, 1982[a]; Aichilik River, 1982[a]; Angun River, 1982[a]; Oksrukuyik Creek, 1982[a]; Storkerson Point, 1982[a]; Peters Lake, 1982[a]; Nuvgapak Point, 1982[a]; VABM Mars, 1982[a]; Roche Moutonnee Creek, 1986[a]; Toolik River, no date[a]; Philip Creek, Arctic slope of Yukon Territory, Canada (no date)[j].

Nemoura normani (Ricker, 1952)

HISTORICAL RECORDS.—Anaktuvuk River, 1949[a].

Podmosta decepta (Frison, 1942)

HISTORICAL RECORDS.—Umiat, 1959[a].

Podmosta weberi (Ricker, 1952)

NEW RECORDS.—Kuparuk River "lower" *aufeis*, 1m & 1f, 11/6/2001, 1f, 19/6/2004; Galbraith Lake "campground spring," 1m & 3f, 24/6/2007, 10m & 8f, 29/6/2007; Kuparuk River "lower" *aufeis*, 1m & 1f, 10/8/2012.

HISTORICAL RECORDS.—Anaktuvuk Pass, 1949[a]; Anaktuvuk River, 1949[a].

Soyedina sp.

HISTORICAL RECORDS.—Kikitaliorak Lake, larvae, 1973[a].

Zapada columbiana (Claassen, 1923)

HISTORICAL RECORDS.—Shublik Spring, 1968, 1969; Echooka Spring, 1971[a]; Ribdon

River, spring tributary, 1971[a]; Canning River, 1972[a]; Shublik Spring, 1982[a].

Zapada haysi (Ricker, 1952)

NEW RECORDS.—Echooka Spring, 1f, 4/7/2001, 1f, 18/7/2004; Ivishak Hot Spring stream, 2f, 9/7/2001, 3m & 8f, 23–28/6/2002, 1m & 1f, 30/7/2002 [Dolly Varden char (*Salvelinus malma*) gut contents]; Ivishak River tributary nr. Ivishak Hot Spring, 19m, 28/5/2008; Ivishak River nr. Ivishak Hot Spring, 10m & 11f, 28/5/2008; Ivishak Hot Spring stream, 14m & 6f, 26/5/2008.

HISTORICAL RECORDS.—Anaktuvuk River 1949[c]; Shublik Spring, 1966[a]; Lupine River, spring tributaries, 1971[a]; Echooka Spring, 1971[a], 1972[a]; Canning River, Marsh Fork 1972[a]; Echooka River, 1972[a]; Shublik Spring, 1972[a]; Canning River, spring tributary, 1972[a], 1973[a].

Taeniopterygidae

Taenionema pacificum (Banks, 1900)

NEW RECORDS.—Ivishak Hot Spring stream, 2m & 2f, 23–28/6/2002; Ivishak River, main stem nr. Ivishak Hot Spring, 19m & 23f, 28/5/2008.

HISTORICAL RECORDS.—Canning River, spring tributaries, 1973[a]; Ribdon River, South Fork, 1971[a].

Chloroperlidae

Alaskaperla ovibovis (Ricker, 1965)

NEW RECORDS.—Kuparuk River (Dalton Highway bridge), 18m & 12f, 20/7/2001, 4m & 4f, 3/8/2001; Lupine Creek, 1m, 9/7/2012.

HISTORICAL RECORDS.—Kuparuk River, larvae, no date[h].

‡*Plumiperla diversa* (Frison, 1935)

NEW RECORDS.—Echooka Spring, 3m, 4/7/2001; Ivishak Hot Spring stream, 2m, 9/7/2001, 1m, 6/8/2001; Kuparuk River "lower" *aufeis*, 2m, 11/7/2001; Ribdon River spring, 3f, 15/7/2001; Kuparuk River (Dalton Highway bridge), 1m & 2f, 11/7/2001, 3m & 1f, 23–28/6/2002; Ivishak Hot Spring stream, 1m, 30/7/2002 (among *S. malma* gut contents); Sadlerochit Spring, 1m, 22/7/2002; Kuparuk River "lower" *aufeis*, 2f, 19/6/2004; Ivishak Hot Spring stream, 2m, 2–6/7/2007; Ivishak River tributary nr. Ivishak Hot Spring, 1m, 5/7/2007.

HISTORICAL RECORDS.—Anaktuvuk River, 1949[a,c]; Ribdon River, 1971[a]; Ribdon spring tributary, 1971[a]; Lupine River, 1971[a]; Echooka River, 1971[a]; Echooka Spring, 1971[a]; Canning River, spring tributaries, 1972[a], 1973[a]; Oksrukuyik Creek, 1980[a]; Shublik Spring, 1982[a]; Philip Creek, Arctic slope of Yukon Territory, Canada (no date)[j].

Suwallia autumna (Hoppe, 1938)

HISTORICAL RECORDS.—Sadlerochit Spring, 1974[a].

Suwallia starki Alexander & Stewart 1999

NEW RECORDS.—Cobblestone River *aufeis*, 2m, 8/6/2012; Kuparuk River "lower" *aufeis*, 1m, 10/8/2012.

HISTORICAL RECORDS.—Anaktuvuk River, 1949[a]; Echooka Spring, 1971[a]; Umiat, 1959[a].

**Paraperla frontalis* (Banks, 1902)

NEW RECORDS.—Ribdon River spring, 3m, 1/7/2001, 1m, 15/7/2001.

Perlodidae

Isoperla decolorata (Walker, 1852)

HISTORICAL RECORDS.—Umiat, 1959[a]; Echooka Spring, 1971[a].

Isoperla petersoni Needham & Christenson 1927

NEW RECORDS.—Echooka Spring, 5m & 7f, 4/7/2001; Ivishak Hot Spring stream, 1m, 9/7/2001, 1f, 6/8/2001, 1m, 15/7/2002, 2m & 2f, 23–28/6/2002; Sadlerochit Spring, 9m, 22/7/2002; Ivishak Hot Spring stream, 1m, 26/5/2008; Ivishak Hot Spring, hillslope source, 2 larvae, 26–29/5/2008.

HISTORICAL RECORDS.—Shublik Spring and Creek, 1969[a]; Echooka River, 1971[a]; Echooka Spring, 1971[a]; Ribdon spring tributaries, 1971[a]; Marsh Fork of Canning River, 1972[a]; Sadlerochit Spring, 1972[a]; Shublik Spring and Creek, 1972[a]; Canning River, spring tributary, 1972[a], 1973[a].

Arcynopteryx dichroa (McLachlan, 1872) (= *A. compacta* McLachlan, 1872)

NEW RECORDS.—Ribdon River spring, 1m, 1/7/2001; Echooka Spring, 2m & 3f, 4/7/2001; Lake E5 near Toolik Lake, 1m, 11/7/2001; Toolik Lake, 5f, 21/7/2001; Kuparuk River "lower"

aufeis, 4m & 8f, 19/6/2004; Galbraith Lake "campground spring," 10m, 24/6/2007; Ivishak Hot Spring, hillslope source, 6m, 26–29/5/2008; Kuparuk River (Dalton Highway bridge), 1f, 23/6/2012; Kuparuk River "lower" *aufeis*, 23/6/2012, 3m, 1f & 2 larvae, 10/8/2012; Toolik Lake, 1 brachypterous m, 30/6/2012, 1f, 1/7/2012.

HISTORICAL RECORDS.—Anaktuvuk River, 1949[a,c]; Kukpuk River, 1961[a]; Sadlerochit Spring, 1966[a]; Shublik Spring, 1966[a]; Echooka River, 1971[a]; Ribdon spring tributary, 1971[a]; Echooka Spring, 1971[a], 1972[a]; Canning River, 1972[a]; Marsh Fork of Canning River, 1972[a]; Shublik Spring, 1972[a]; Canning River, spring tributaries, 1972[a], 1973[a]; Feniak Lake, 1973[a]; Shrader and Peters Lakes, 1973[a]; Toolik Lake, 1976[a]; Atigun River, 1977[a]; "Oil Spill Lake" near Toolik Lake, 1978[a]; Toolik Lake, 1979[a].

TRICHOPTERA

Glossosomatidae

**Glossosoma intermedium* (Klapálek, 1892)

NEW RECORDS.—Ivishak Hot Spring stream, 1m, 23–28/6/2002, 2m & 2f, 26–29/5/2008; Ivishak Hot Spring, hillslope source, 3m & 10f, 26–29/5/2008.

**Glossosoma* sp.

NEW RECORDS.—Sadlerochit Spring, numerous larvae and pupae, 22/7/2002; Kuparuk River (Dalton Highway bridge), larvae, 2/8/2012, 27/8/2012.

Hydroptilidae

***Agraylea cognatella* McLachlan, 1880

NEW RECORDS.—Toolik Lake, 18m & 4f, 21/7/2001, numerous m & f, 6/7/2012; Dan Creek, 2m, 30/6/2012.

NOTES.—The range of *Agraylea cognatella* is restricted to the Yukon, Alaska, and Asia (Wiggins and Parker 1997).

**Ochrotrichia logana* (Ross, 1941)

NEW RECORDS.—Krugurak Spring, Noatak River drainage, many mf metamorphotypes, 18/7/2003.

NOTES.—Ruiter (1999) first reported *O. logana* from southern Alaska (Katmai Pennisula). Our Noatak River drainage record establishes the presence of this wide-ranging species (northern Mexico to Alaska; Ruiter 1999, Bueno-Soria 2009), in the North American Arctic.

**Oxyethira* sp.

NEW RECORDS.—Toolik Lake, Lake I-3 outlet stream near Toolik Lake, larvae, 15/7/2005; Lake I-6 Headwater outlet stream near Toolik Lake, larvae, 15/7/2005.

NOTES.—*Oxyethira araya* Ross, 1941 has been recorded from the northern Yukon Territory, Canada (Wiggins and Parker 1997).

Rhyacophilidae

***Rhyacophila mongolica* Schmid, Arefina & Levanidova 1993

NEW RECORDS.—Kuparuk River (Dalton Highway bridge), larvae, 20/7/2001, larvae, 11/7/2001, 22m, 14/7/2001; Oksrukuyik Creek, 1m from arctic grayling (*Thymallus arcticus*) gut content, 8m, 21/7/2003; Oksrukuyik Creek, 1m, 9/6/2011; Hershey Creek, 9m, 15/7/2011, 13m, 9/7/2012, 3m, 27/7/2012; Dan Creek, 25m, 7/7/2012, 6m, 21/7/2012, 2m, 29/7/2012; Happy Valley Creek, 5m, 7/7/2012, 1m, 29/7/2012; Kuparuk River (Dalton Highway bridge), 10m, 2/7/2012, 1m, 15/7/2012, 1m, 27/7/2012.

NOTES.—*Rhyacophila mongolica* has been reported from the Yukon (Wiggins and Parker 1997). Prior to that record, this species was only reported for Europe, northeastern Asia, and Mongolia (Chuluunbat and Morse 2007).

Apataniidae

Apatania zonella (Zetterstedt, 1840)

NEW RECORDS.—Galbraith Lake "campground spring," abundant larvae, pupae and adult females, 24/6/2007, abundant larvae, pupae and adult females, 27/6/2008, abundant larvae and pupae, 30/5/2008.

HISTORICAL RECORDS.—Anaktuvuk Pass, 1949[b,c]; Point Barrow, 1949[b,c].

**Apatania stigmatella* (Zetterstedt, 1840)

NEW RECORDS.—Lupine Creek, 1m, 11/8/2011; Franklin Bluffs at Dalton Highway Milepost 386, 1m, 12/8/2012.

Apatania. sp.

NEW RECORD.—Kuparuk River "upper" *aufeis*, larva, 8/6/2012.

Brachycentridae

Brachycentrus americanus (Banks, 1899)

NEW RECORDS.—Kuparuk River (Dalton Highway bridge), 5m & 3f, 20/7/2001; Sadlerochit Spring, larvae, 5m & 1f, 22/7/2002; Dan Creek, 2m, 7/7/2012, 1m, 30/6/2012.

HISTORICAL RECORDS.—Atigun River, 1979[b]; Kuparuk River, 1984–1986[h].

‡*Micrasema gelidum* McLachlan, 1876

NEW RECORDS.—Kuparuk River (Dalton Highway bridge), 21m & 12f, 20/7/2001; Lake E-1 outlet near Toolik Lake, 1m, 9/6/2011; Kuparuk River (Dalton Highway bridge), 3m, 2/7/2011, 1m, 15/7/2011, 1m, 4/7/2012; Hershey Creek, 2m, 15/7/2011, 3m, 9/7/2012; Dan Creek, 1m, 7/7/2012; Wolf Creek, 1m, 21/7/2012.

HISTORICAL RECORDS.—Nanushuk River, 1949[b,c]; Pt. Barrow, 1949[b,c] (as *M. scissum* McLachlan); Pt. Barrow, 1975[b], 1979[b]; Arctic slope of Yukon Territory, Canada (no date)[k].

Leptoceridae

Mystacides sepulchralis (Walker, 1852)

NEW RECORDS.—Toolik Lake, 3m, 12/7/2011; Dan Creek, 1m, 7/7/2012, 2m, 21/7/2012.

HISTORICAL RECORDS.—3.2 km above mouth of Kuguroruk River, 5/8/1981[b].

Limnephilidae

Arctopora trimaculata (Zetterstedt, 1840)

HISTORICAL RECORD.—Symbol on distribution map (Fig. 19, Wiggins and Parker 1997) indicates a record from the vicinity of the lower Colville River; exact location not reported.

***Asynarchus aldinus* (Ross, 1941)

NEW RECORDS.—Imnavait Creek, 1m, 27/7/2011; Happy Valley Creek, 1m, 29/7/2012; Lupine Creek, 1m, 11/8/2012.

NOTE.—*Asynarchus aldinus* is widely distributed along the Rocky Mountains (Wiggins and Parker 1997) from the foothills of the North Slope of Alaska south to Utah.

*‡*Asynarchus lapponicus* (Zetterstedt, 1840)

NEW RECORDS.—Wolf Creek, 3m, 4/8/2011, 1m, 10/8/2011; Kuparuk River (Dalton Highway bridge), 1m, 31/7/2012.

HISTORICAL RECORDS.—Arctic slope of Yukon Territory, Canada (no date)[k].

**Asynarchus montanus* (Banks, 1907)

NEW RECORDS.—Dan Creek, 1m, 29/7/2012.

**Dicosmoecus obscuripennis* Banks, 1938

NEW RECORDS.—May Creek spring, larvae, 8/7/2001; Kuparuk River (Dalton Highway bridge), 1m, 20/7/2001, 1m, 9/8/2001; Kuparuk River "lower" *aufeis*, pupal aggregation (photographed), 19/6/2004; Hershey Creek, 2m, 9/7/2012, 1m, 15/7/2012; Kuparuk River (Dalton Highway bridge), 1m, 15/7/2012, 4m, 27/7/2012; Dan Creek, 3m, 21/7/2012; Wolf Creek, 1m, 21/7/2012, 1m, 9/7/2012, 3m, 7–14/7/2012.

Dicosmoecus sp.

HISTORICAL RECORDS.—Jago River, larvae, 1982–1983[g].

Ecclisomyia conspersa Banks, 1907

NEW RECORDS.—Echooka Spring, 1m, 4/7/2001; Ivishak River tributary nr. Ivishak Hot Spring, 1m, 23–28/6/2002; Sadlerochit Spring, 1m, 22/7/2002; Toolik Lake, 1m, 26/6/2001, 1m, 29/6/2001, 1m, 28/6/2001; Ivishak Hot Spring stream, 1m, 2–6/7/2007, 1m, 22/4/2008, 1m, 26/5/2008; Ivishak River tributary nr. Ivishak Hot Spring, 1m, 28/5/2008; Ivishak River, main stem nr. Ivishak Hot Spring, 1m, 28/5/2008; Ivishak Hot Spring, hillslope source, 1m, 26–29/5/2008; Kuparuk River, "lower" *aufeis*, 1m, 8/6/2012; Cobblestone Spring, 1m, 8/6/2012; Galbraith Lake, 1m, 15/6/2012.

HISTORICAL RECORDS.—Wrench Creek, Noatak River drainage, 4/8/1981[b].

Ecclisomyia sp.

HISTORICAL RECORDS.—Jago River, larvae, 1982–1983[g]; Canning River, larvae, 1982–1983[g]; Carter Creek, larvae, 1982–1983[g].

Grammotaulius alascensis Schmid, 1964
(= *G. subborealis* Schmid, 1964)

NEW RECORDS.—Percy Pingo, 1m, 31/7/2011.

HISTORICAL RECORDS.—Umiat, 31/7/1959[e]; Jago Lake, 1m, 2/8/1957[e].

Grammotaulius sp.

NEW RECORDS.—Toolik River at Dalton Highway, 1 larva, 3/7/2001.

Grensia praeterita (Walker, 1852)

NEW RECORDS.—Toolik Lake, 1m, 28/6/2001; Kuparuk River "upper" *aufeis*, 1f, 29/6/2007; Barrow Environmental Observatory, 2m & 1f, 18/6/2011; Toolik Lake, 1m, 3/6/2012; Lupine Creek, 2m, 6/6/2012; Galbraith Lake, 3m, 6/6/2012; May Creek *aufeis*, 2f, 8/6/2012; Kuparuk River (Dalton Highway bridge), 5m, 10/6/2012; Tea Lake, 1m, 26/6/2012; Dalton Highway Mile Post 386, 3m, 4/9/2012.

HISTORICAL RECORDS.—Anuktuvuk Pass, 1948[b,c]; Meade River, 1950[b]; Ogutoruk Creek, Cape Thompson, 1966[b]; Inaru River, 28/9/no year[b,c]; Prudhoe Bay, no year[b].

‡*Lenarchus expansus* Martynov, 1914

HISTORICAL RECORDS.—Point Barrow, 1898[b], 1958[b]; Arctic slope of Yukon Territory, Canada (no date)[k].

**Hydatophylax variabilis* (Martynov, 1910)

NEW RECORDS.—Kuparuk River, "lower" *aufeis*, 2f, 8/6/2012; May Creek *aufeis*, 1m, 8/6/2012.

NOTES.—*Hydatophylax variabilis* has been previously reported from Sweden to eastern Siberia in Eurasia, as well in the coastal regions of southeastern Alaska. It is thus the only essentially Palearctic trichopteran species also known to occur in southern Alaska but nowhere else in North America (Nimmo 1986, Wiggins and Parker 1997). Our record from the North Slope is the first to document the presence of *H. variabilis* in Beringia.

**Limnephilus argenteus* Banks, 1914

NEW RECORDS.—Oksrukuyik Creek, 1m, 9/6/2011.

***Limnephilus diphyes* McLachlan, 1880

NEW RECORDS.—Kuparuk River (Dalton Highway bridge), 1m, 4/7/2012.

NOTE.—*Limnephilus diphyes* has previously been reported from Scandinavia eastward through northwestern Siberia to the Yukon Territory, Canada (Wiggins and Parker 1997).

**Limnephilus femoralis* Kirby, 1937

NEW RECORDS.—Lake E-1 outlet near Toolik Lake, 1m, 9/6/2011.

**Limnephilus fenestratus* (Zetterstedt, 1840)

NEW RECORDS.—Franklin Bluffs near Dalton Highway Milepost 386, 1m, 12/8/2012; Dalton Highway Milepost 355, 1m, 12/8/2012.

‡*Limnephilus kennicotti* Banks, 1920

HISTORICAL RECORDS.—Arctic slope of Yukon Territory, Canada (no date)[k].

**Limnephilus nigriceps* (Zetterstedt, 1840)

NEW RECORDS.—Dan Creek, 2m, 23/8/2012; Kuparuk River (Dalton Highway bridge), 1m, 24/8/2012.

‡*Limnephilus pallens* Banks, 1920

HISTORICAL RECORDS.—Arctic slope of Yukon Territory, Canada (no date)[k].

*‡*Limnephilus picturatus* McLachlan, 1875

NEW RECORDS.—Franklin Bluffs near Dalton Highway Milepost 386, many males, 22/7/2012.

HISTORICAL RECORDS.—Arctic slope of Yukon Territory, Canada (no date)[k].

**Limnephilus sansoni* Banks, 1918

NEW RECORDS.—Kuparuk River (Dalton Highway bridge), 1f, 24/8/2012; Mosquito Lake, 1m, 1/8/2012.

Onocosmoecus unicolor (Banks, 1897)

NEW RECORDS.—Sadlerochit Spring, numerous larvae and adults, 22/7/2002.

HISTORICAL RECORDS.—Wrench Creek, Noatak River drainage, 4/8/1981[b]; Noatak River near confluence with Kuguroruk River, 31/7/1981[b]; Sadlerochit Spring, no year[d].

Molannidae

**Molannodes tinctus* (Zetterstedt, 1840)

NEW RECORDS.—Dan Creek, 1m, 29/7/2012.

Phryganeidae

‡*Agrypnia obsoleta* (Hagen, 1864)

HISTORICAL RECORDS.—Arctic slope of Yukon Territory, Canada (no date)[k].

‡*Agrypnia pagetana* Curtis, 1835

HISTORICAL RECORDS.—Noatak River, 1m & 1f, 25/6/1973[f]; Arctic slope of Yukon Territory, Canada (no date)[k].

Agrypnia sahlbergi (McLachlan, 1880)

HISTORICAL RECORD.—Noatak River, 1m, 2/8/1973[f].

Agrypnia sp.

NEW RECORDS.—Percy Pingo, 1 larva, 31/7/2011.

Banksiola crotchi Banks, 1944

HISTORICAL RECORDS.—Noatak River near confluence with Charley River, 1f, 14/6/1974[f].

Banksiola sp.

HISTORICAL RECORDS.—Point Barrow 1949[b,c].

Oligotricha lapponica (Hagen, 1864)

NEW RECORDS.—Oil Spill Hill near Dalton Highway, 1f, 28/6/2007; Kuparuk River "upper" *aufeis*, 1f, 29/6/2007.

HISTORICAL RECORDS.—Pt. Barrow, 1f, 29/7/1949[f].

DISCUSSION

Previous studies have summarized reported occurrences of Trichoptera and Plecoptera from the entire state of Alaska (Nimmo 1986, Stewart and Oswood 2006). Here we update these lists for the North Slope region of Alaska with 2 new species records of Plecoptera and 19 new records of Trichoptera (4 new state records). New state records for Trichoptera include *Agraylea cognatella, Rhyacophila mongolica, Asynarchus aldinus,* and *Limnephilus diphyes.* New records of Trichoptera for the North Slope include *Glossosoma intermedium, Ochrotrichia logana, Oxyethira* sp., *Apatania stigmatella, Asynarchus lapponicus, A. montanus, Dicosmoecus obscuripennis, Hydatophylax variabilis, Limnephilus argenteus, L. femoralis, L. fenestratus, L. nigriceps, L. picturatus, L. sansoni,* and *Molannodes tinctus.* New records for Plecoptera on the North Slope include *Isocapnia* cf. *integra* and *Paraperla frontalis.*

Our species list for the North Slope contains a total of 24 and 33 species of Plecoptera and Trichoptera, respectively. If records from the physiographically equivalent area of the Yukon Territory are included (Wiggins and Parker 1997), the total richness of this region is 25 species of stoneflies and 36 species of caddisflies. Compared to the "north slope" of the Yukon, which includes the northward flowing drainages of the Arctic Coastal Plain, the British Mountains, and the Arctic Plateau (Wiggins and Parker 1997), the North Slope region of Alaska has a substantially higher species richness of these groups. Alaska North Slope richness is 24 for Plecoptera and 33 for Trichoptera, compared to richness on the Yukon "north slope," which is 3 for Plecoptera and 8 for Trichoptera. Because a significant investment in biotic inventories has been made in the Yukon Territory (e.g., Wiggins and Parker 1997, Stewart and Ricker 1997), we attribute this difference to factors such as greater habitat diversity due to a much greater geographical area on Alaska's North Slope rather than to differences in collecting effort in the different regions.

Although taxonomic inventories will almost always be incomplete, our assessment of the stoneflies and caddisflies seems sufficient to support 2 major conclusions about factors underlying the level of biodiversity documented. First, the role of Beringia (i.e., the region encompassing eastern Siberia, the Bering land bridge, and most of present-day Alaska and the Yukon Territory during much of the Pleistocene) as a biogeographic refuge during the Pleistocene has had a significant effect on the taxonomic structure of the freshwater insects of the North Slope. There has been much interest in the role of Beringia in determining patterns of Arctic biodiversity (e.g., Wiggins and Parker 1997, Stewart and Ricker 1997). Because this region remained largely ice-free during the Pleistocene, it functioned as a refuge for taxa that were extirpated by continental glaciers elsewhere. Caddisfly species showing such distributions include *Agraylea cognatella, Rhyacophila mongolica, Arctopora trimaculata, Dicosmoecus obscuripennis, Grammotaulius alascensis, Grensia praeterita, Hydatophylax variabilis, Lenarchus expansus, Limnephilus diphyes, L. fenestratus, Agrypnia obsoleta, A. sahlbergi,* and *Oligotrichia lapponica* (36%). Species of Plecoptera showing ranges that are either Beringian or Palearctic-Beringian include *Mesocapnia variabilis, Nemoura normani, Podmosta weberi,* and *Alaskaperla ovibovis* (17%).

Although the contribution of Beringian taxa to the plecopteran fauna of the North Slope is modest, the contribution of such taxa to the trichopteran fauna is substantial. These results can be compared with species lists from Churchill Manitoba, Canada, where 66 species of caddisfly and 16 species of stonefly were found (Zhou et al. 2010). Of the 66 caddisflies found at Churchill, only 17 of the same species

are also found in our list. Of the 16 species of stoneflies found at Churchill, only 3 species are also found in our list. The structure of the trichopteran species diversity of the North Slope therefore represents a little known but relatively unique biogeographic heritage that should be of clear conservation concern given the rapidly changing climate of the Arctic (ACIA 2005).

The second major conclusion about factors underlying the level of plecopteran and trichopteran biodiversity of the North Slope is the critical effect of freshwater habitats associated with perennial springs. A number of spring streams found along the northern foothills of the Brooks Range flow year-round due to winter water temperatures ranging from 4 to 11 °C, whereas other freshwater habitats with depths <1.5 m freeze solid. Although perennial spring streams provide a negligible amount of habitat (<1% of total stream length) on the North Slope, they have important consequences for biodiversity because they provide 100% of flowing stream habitat during winter (Huryn et al. 2005, Huryn and Hobbie 2012). This habitat is critical for stream organisms that occur on the North Slope but which are unable to tolerate freezing, including a number of freshwater insects, the Dolly Varden char (*Salvelinus malma*), and the American Dipper (*Cinclus mexicanus*), a semiaquatic songbird. Another important habitat related to the presence of springs is *aufeis.* An *aufeis* is a mass of ice formed by the successive freezing of overlying sheets of water that flow from a spring. The volume of an *aufeis* can be enormous, ranging up to 5+ meters thick and many square kilometers in area. Sediments underlying an *aufeis* remain saturated with unfrozen water year-round and, like the spring streams, provide significant habitat for aquatic insects. Stonefly species that are closely associated with *aufeis* fields where their larvae inhabit interstitial habitats (e.g., Stanford and Gaufin 1974) include *Capnia confusa, C. nearctica, Isocapnia crinita, I. grandis, I.* cf. *integra, Plumiperla diversa, Suwallia autumna, S. starki,* and *Paraperla frontalis.* Stonefly species that are primarily found in association with spring streams include *Podmosta weberi, Zapada columbiana, Z. haysi, T. pacificum, Isoperla decolorata, I. petersoni,* and *Arcynopteryx dichroa.* Although no trichopteran species are specifically associated with *aufeis* fields, *Glossosoma intermedium, Ochrotrichia logana, Hydatophylax variabilis,* and *Oncosmoecus unicolor* have been found only in perennial spring habitats on the North Slope. Although comprising <1% of the total stream length of the North Slope, perennial spring and *aufeis* habitats contain about 70% of the known stonefly species and 10% of the known caddisfly species.

The 2 major factors contributing to the unique aquatic insect communities of Alaska's Arctic North Slope include the North Slope as a Beringian refuge from continental ice sheets and the occurrence of spring streams as refuge from seasonal winter ice. The North Slope of Alaska is predicted to undergo changes in climate and extent of industrialization in the coming years. This species list, which represents numerous new records for Alaska's North Slope, will aid in our understanding of how aquatic insect communities may respond to these predicted, yet unknown, changes on Alaska's North Slope.

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