STUDIES ON DISTRIBUTION AND DIVERSITY OF NEARSHORE EPHEMEROPTERA AND PLECOPTERA IN SELECTED LAKES OF GLACIER NATIONAL PARK, MONTANA

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ABSTRACT.—Surveys were performed to examine the diversity of Ephemeroptera and Plecoptera in selected lakes in Glacier National Park, Montana, and to generate data for use by the National Park Service. Shallow shoreline sites were sampled by disturbing the bottom and examining the substratum. Published records and previously collected reference specimens were examined. Data were obtained from a total of 29 lakes, but 3 yielded no mayflies or stoneflies. Twelve genera and 21 species of Ephemeroptera, and 11 genera and 5 species of Plecoptera, were found. Most lakes sampled had a diverse fauna of both orders.

RESUMEN.—Se realizaron monitoreos en donde se examinó la diversidad de la fauna de Ephemeroptera y Plecoptera en lagos seleccionados del Parque Nacional *Glacier*, Montana, con el fin de utilizar la información como material didáctico para estudiantes universitarios y para uso del Servicio de Parques Nacionales. Se tomaron muestras en lugares poco profundos de la costa alterando el fondo y examinando el sustrato. Se analizaron estudios ya publicados y especímenes de referencia colectados previamente. Se obtuvo información de un total de 29 lagos, en tres de los cuales no se registró la presencia de efemerópteros ni de plecópteros. Se hallaron doce géneros y 21 especies de Ephemeroptera y 11 géneros y 5 especies de Plecoptera. La mayoría de los lagos tenían una fauna muy diversa correspondiente a ambos órdenes.

In 2006 and 2007, students working in the REU Program (Research Experiences for Undergraduates), funded by the National Science Foundation and located at the University of Montana, were chosen to study the aquatic invertebrate fauna of selected lakes in Glacier National Park (GNP) in western Montana. Glacier National Park contains a diverse assortment of lentic habitats, such as lakes, reservoirs, ponds, and marshes (permanent and temporary; Table 1), but the lentic aquatic fauna has never been comprehensively studied (Stohlgren et al. 1991). Ginsberg (1994) noted that the legislative mandate of the National Park Service (NPS) states that the purpose of the parks is to “conserve the scenery and the natural and historic objects and the wildlife herein.” Thus, our sampling provided (1) an aquatic invertebrate inventory to help the NPS meet the objectives of its mandate and (2) valuable field experience to help students achieve their educational goals.

From the outset of our work, it was evident that aquatic resources in GNP could be negatively impacted by factors caused by climate change. Since its establishment in 1910, GNP

has lost most of its glaciers. Over two-thirds of the estimated 150 glaciers existing in 1850 had disappeared by 1980, and surviving glaciers were greatly reduced in area. The local annual mean temperature increased 1.66 °C between 1910 and 1980. Both of these events will influence aquatic habitats (Hauer et al. 1997, Hall and Fagre 2003, Pederson et al. 2006).

Many of the largest and more accessible lakes in GNP were selected for study. Results of the student studies were combined with additional sampling by the senior author (RLN). Volunteer collections, published reports, and other lake sampling data previously obtained by Anderson and Standford (2003) and Ellis et al. (2004) were included.

Scattered records exist of lentic Ephemeroptera from locations in GNP, with fewer records of stoneflies (Needham et al. 1935, Young 1935, Cornell University Collection internet records [CUIC]). The Illinois Natural History (INHS) internet collection had 7 reports from GNP from 1891 to 1946. Edwards (1957) provided some general observations on the insect fauna of GNP, and several master’s theses and doctoral dissertations have been completed

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TABLE 1. Inventory of all lakes (>2 ha) within Glacier National Park, determined by the U.S. Fish and Wildlife Service (1980). This inventory may include habitats Newell and Hossack (2009) classified as temporary wetlands, of which over 300 exist.

1. The North Fork of the Flathead River drainage has 139 lakes encompassing 2999 ha. The highest lake >2 ha is Gyrfacon Lake at 2219 m.
2. The Middle Fork of the Flathead River drainage has 124 lakes encompassing 3274 ha. The highest lake in this area is at the head of Muir Creek at 2299 m.
3. The Missouri River drainage has 87 lakes encompassing 555 ha. The highest lake >2 ha is Running Crane Lake at 2240 m.
4. The Hudson Bay drainage has 303 lakes encompassing 4119 ha. The highest lake >2 ha is unnamed and found below Ipasha Glacier at 2248 m.
5. In total, Glacier National Park has 653 lakes encompassing 10,944 ha. The longest drainage is Lake McDonald at 262 km. The highest water source is Lincoln/Harrison at 2365 m. The highest lake is Aurice Lake at 2234 m. The largest lake is Lake McDonald, which encompasses 2761 ha at 961 m elevation.

TABLE 2. Location and elevation of sampled lakes.

Lake	Coordinates	Elevation (m)
Avalanche	48°39'05"N, 113°47'04"W	1213
Bowman	48°50'08"N, 114°11'18"W	1261
Bullhead	48°47'10"N, 113°43'56"W	1607
Cerulean	48°52'21"N, 114°03'28"W	1441
Elizabeth	48°53'11"N, 113°44'01"W	1773
Fishercap	48°47'52"N, 113°41'10"W	1511
Glenns	48°53'25"N, 113°48'28"W	1583
Grinnell	48°45'51"N, 113°42'02"W	1509
Gyrfacon	48°50'21"N, 113°59'43"W	2219
Hidden	48°40'53"N, 113°44'57"W	1950
Iceberg	48°49'08"N, 113°44'29"W	1860
Josephine	48°46'59"N, 113°46'55"W	1490
Kintla	48°56'06"N, 114°20'44"W	1231
Logging	48°44'08"N, 114°08'03"W	1265
Lost	48°40'18"N, 113°37'33"W	1465
McDonald	48°32'37"N, 113°53'48"W	0961
Nahtaki	48°49'04"N, 113°40'04"W	2016
Ptarmigan	48°51'33"N, 113°41'56"W	2349
Quartz (upper)	48°49'17"N, 114°06'47"W	1698
Quartz (lower)	48°48'11"N, 114°10'21"W	1474
Red Eagle	48°39'13"N, 113°30'04"W	1442
Redrock	48°49'50"N, 113°42'27"W	1554
Shangri-La	48°48'34"N, 113°43'15"W	2019
Sherbourne	48°49'43"N, 113°35'16"W	1468
St. Mary Lake	48°41'49"N, 113°31'08"W	1370
Swiftcurrent	48°47'25"N, 113°39'40"W	1501
Trout	48°52'19"N, 113°54'43"W	1430
Two Medicine	48°28'39"N, 113°22'13"W	1586
Waterton	48°57'35"N, 113°53'18"W	1285

(Lehmkuhl 1966, Robson 1968, Howe 1974, Appert 1977). Varrelman (1992) was the only student who published (Varrelman and Spencer 1991) and left reference specimens, which we examined. Our preliminary survey was the second survey of the lentic fauna of GNP. The initial lentic mayfly surveys of Newell and Hossack (2009) and Hossack et al. (2010) were conducted in temporary wetlands as an adjunct to a study of amphibians (Hossack and Corn

2007). Newell and Hossack (2009) documented Ephemeroptera in many temporary wetlands. Ellis et al. (2004) and Anderson and Stanford (2003) also sampled some lakes in the park. Gaufin et al. (1972) and Baumann et al. (1977) included stonefly records from Montana (SMT) and the Rocky Mountains (SRM), including Glacier National Park. Finally, Newell et al. (2008) listed all known stoneflies recorded from GNP, and noted that many species had been collected along lakeshores.

Several mayfly species can occur in suitable lentic habitats: *Heptagenia solitaria* McDunnough, *Centroptilum bifurcatum* McDunnough, and *Paraleptophlebia heteronea* McDunnough are lotic species, and *Siphonurus phyllis* McDunnough, a lentic species, was first described from the Waterton Lakes area immediately adjacent to Glacier National Park in Alberta, Canada, by McDunnough (1924, 1926, 1934). Some normally lotic species can occur in suitable lentic environments. Donald and Anderson (1977) listed 3 stonefly species confined to lakes and other species found in both lentic and lotic habitats. Donald and Anderson (1980) also surveyed 58 lakes along the Continental Divide in southwestern Canada and collected 17 species of Plecoptera. Hoffman et al. (1996) surveyed 41 oligotrophic lakes in North Cascades National Park, Washington, collecting 8 genera of Ephemeroptera and 7 genera of Plecoptera. Data from 28 lakes were gathered or extracted in this study (Table 2).

Sampling was accomplished using a 500-micron mesh, long-handled circular net. A 100-m section of lakeshore was delineated. The collector waded along the littoral zone at various depths, disturbing the substratum while a companion swept the net through the

Fig. 1. Map of the study area showing the state of Montana (right) and study area (left) with major streams. Western Montana is highlighted, as is Waterton Glacier International Peace Park (Newell and Hossack 2009). The topography of western Montana is primarily conifer-forested mountain slopes interspersed with mountain valleys. Higher elevations reach alpine zones, primarily along the Continental Divide at nearly 2900 m elevation.

disturbed material until the 100-m section was completely surveyed. Occasionally rocks were removed and examined for nymphs, and any nymphs seen were collected. All captured nymphs were placed in 80% ethanol and returned to the laboratory for identification, except in 2 cases when late-maturing nymphs were collected. In one case, a very mature stonefly nymph was dissected, and in another instance, a mature nymph was returned to the laboratory and allowed to emerge. Both actions permitted species identification. Inlet and outlet stream habitats were avoided.

Taxa from other studies were not included unless the specimens could be examined (Varrelman's reference specimens) or unless the results had been previously published. All material from this survey is deposited at the University of Montana, Flathead Lake Biological Station. Immature specimens were identified to the lowest taxon, usually family or genus at best. Mature mayfly nymphs were usually identified to species and stoneflies to genus. Some lakes, like Lake McDonald, were

sampled several times. Sample lakes (Table 2) were either sites studied by volunteers or sites selected based on accessibility by road or a short hike. All identifications were reviewed, and questionable taxa were sent to one of the experts listed at the end of this note.

A previous inventory (USFWS 1980) yielded the following data for Glacier National Park (Table 1) and illustrated the number and diversity of the aquatic habitats of the study area for several drainage system headwaters (Fig. 1). This survey lists mayfly and stonefly taxa, as well as collection locations in selected lakes of Glacier National Park, including the portion east of the Continental Divide in Glacier County and the area west of the divide in Flathead County (Fig. 1). While GNP has not been systematically sampled, the neighboring park to the north, Waterton Lakes National Park (WLNP), has been relatively well studied for Ephemeroptera and Plecoptera, including taxa that can occur in lentic habitats. McDunnough was an early prolific Canadian taxonomist who published many papers in the 1920s

and 1930s. Recent authors include Anderson et al. (1972, 1976), Anderson and Donald (1976), and Donald (1975). It seems intuitive that most, if not all, of the species found in WLNP should be found in GNP. Some have been collected in GNP, but others have not. Some of the taxa listed are obvious lotic species, as noted previously. An annotated list of Ephemeroptera and Plecoptera found in the selected lakes, including locations, dates, and collector's initials, is given below. Full names of contributors are provided in the acknowledgments.

EPHEMEROPTERA

Ameletidae

Ameletus sp.: Lake McDonald (Varrelman 1992); Hidden Lake, 7-VII-06, RLN; Shangri-La Lake, 21-VIII-01, 21-VII-02, BE & MA; Ptarmigan Lake, 13-VIII-01, 1-IX-01, 6-X-01, BE & MA.

Ameletus celer: Grinnell Lake, 22-VI-06, AF & RLN, 18-VII-06, AF; Lake Josephine, 22-VI-06, AF & RLN; Waterton Lake, 19-VII-06, AF; Hidden Lake, 7-VII-06, RLN; Shangri-La Lake, 10-VIII-01, BE & MA.

Ameletus oregonensis: Lake McDonald, 3-V-91 (Varrelman 1992).

Ameletus similior: Grinnell Lake, 18-VII-06, AF; Ptarmigan Lake, 21-VII-02, BE & MA.

Ameletus velox: Lake Josephine, 22-VI-06, AF & RLN.

Baetidae

Baetis bicaudatus: Lake Sherburne, 18-VII-06, RLN.

Callibaetis sp.: Hidden Lake, 7-VII-06, RLN; Lake Sherburne, 18-VII-06, RLN; 31-VII-07, RH & RLN; Swiftcurrent Lake, 31-VII-07, RH & RLN; Trout Lake, 1-X-07, PM; Shangri-La Lake, 10-VIII-01, 7-X-01, adults 10-VIII-01, BE & MA; Ptarmigan Lake, 10-VIII-01, 7-X-01, BE & MA; Lost Lake, 7-VIII-01, 2-IX-01, BE.

Centroptilum conturbatum: Fishercap Lake, 17-VII-06, AF; Bowman Lake, 14-VIII-06, JC; 12-VII-07, CB; Lake Josephine, 18-VII-06, AF; Lake McDonald, 6-VIII-06, AF, 9-VII-07, RH & RLN; Kintla Lake, 6-VII-06, RLN.

Centroptilum sp.: Lake Josephine, 18-VII-06, AF; Bowman Lake, 12-VII-07, CB.

Procloeon pennulatum: Quartz Lake, 4-VIII-07, BB; Lake McDonald (Varrelman 1992).

Caenidae

Caenis amica: Lake McDonald (Varrelman 1992) reference specimen; Lake McDonald, adults 12-VII-06, RLN.

Caenis latipennis: Lake McDonald, 9-VII-07, RH & RLN.

Caenis youngi: Lake McDonald, 1-VIII-91 (Varrelman 1992), 6-VII-06, AF, 9-VII-07, RH & RLN; Lost Lake, 7-VIII-01, 2-IX-01, 8-VIII-02, BE.

Caenis sp.: Lake McDonald, 6-VIII-06, RLN.

Ephemerellidae

Ephemerella excrucians: Fishercap Lake, 17-VII-06; Swiftcurrent Lake, 22-VI-06, AF & RLN, 17-VII-06, AF; Waterton Lake, 19-VII-06, AF; Redrock Lake, 23-VI-06, AF & RLN; Lake Josephine, 22-VI-06, AF & RLN.

Ephemerella sp.: Lake Josephine, 22-VI-06, AF & RLN; Swiftcurrent Lake, 23-VI-06, AF & RLN, 17-VII-06, AF; Waterton Lake, 19-VII-06, AF; Shangri-La Lake, 7-X-01, BE & MA; Ptarmigan Lake, 7-X-01, BE & MA.

Ephemeridae

Ephemerella simulans: Lake McDonald, 1-VIII-92 (Varrelman 1992) reference specimen.

Heptageniidae

St. Mary Lake, 17-VII-06, AF & RLN; Waterton Lake, 19-VII-06, AF.

Ecdyonurus criddlei: Lake McDonald, VIII-92 (Varrelman 1992), 6-VII-06, AF, 12-VIII-06, RLN, 9-VII-07, RH & RLN; Bowman Lake, 14-VIII-06, JC, 12-VII-07, CB; St. Mary Lake, 17-VII-06, RLN, 31-VII-07, RH & RLN; Waterton Lake, 19-VII-06, AF; Kintla Lake, 6-VII-06, RLN; Quartz Lake, 4-VIII-07, BB.

Ecdyonurus simplicioides: Waterton Lake, 19-VII-06, AF.

Leptophlebiidae

Leptophlebia cupida: Lake McDonald (Varrelman 1992) reference specimen; 6-VII-06, AF; Bowman Lake, 12-VII-07, CB; St. Mary Lake, 17-VII-06, RLN.

Paraleptophlebia sp.: Lake McDonald, 6-VIII-06, RLN; Fishercap Lake, 18-VII-06, RLN; Josephine Lake, 18-VII-06, AF; Kintla Lake 6-VII-06, RLN; St. Mary Lake, 31-VII-07, RH & RLN; Trout Lake, 1-X-07, PM; Upper Quartz Lake, 11-X-07, PM; Lost Lake, 7-VIII-01, 2-IX-01, 8-VIII-02, BE.

Paraleptophlebia bicornuta: Lake McDonald (Varrelman 1992), 6-VIII-06, 9-VII-07, RH & RLN, adults 15-X-07, RLN; Fishercap Lake, 17-VII-06, AF, 12-VIII-06, RLN; Bowman Lake, 14-VIII-06, JC, 12-VII-07, CB; Two Medicine Lake, 16-VII-06, RLN; St. Mary Lake, 31-VII-07, RH & RLN; Lower Quartz Lake, 4-VIII-07, BB.

Paraleptophlebia debilis: Lost Lake, 7-VIII-01, 2-IX-01, 8-VIII-02, BE.

Paraleptophlebia heteronea: Lake Josephine, 22-VI-06, AF & RLN.

Paraleptophlebia vaciva: Lake Josephine, 22-VI-06, AF & RLN.

Siphonuridae

Siphonurus sp.: Lake McDonald (Varrelman 1992), 9-VII-07, RH & RLN; Fishercap Lake, 17-VII-06, RLN; Lake Josephine, 18-VII-06, AF; Lake Sherburne, 18-VII-06, RLN, 18-VII-06, AF, 12-VIII-06, RLN; Swiftcurrent Lake, 22-V-06, AF & RLN, 17-VII-06, AF; Two Medicine Lake, 16-VII-06, RLN; Avalanche Lake, 12-VII-06, AF & RLN; Bowman Lake, 12-VII-07, CB; St. Mary Lake, 17-VII-06, RLN; Cerulean Lake, 3-VIII-07, BB; Elizabeth Lake, 16-VII-08, PM.

Siphonurus autumnalis: Waterton Lake, 19-VII-06, AF; Lake Josephine, 18-VII-06, AF; Fishercap Lake, 17-VII-06, AF; Swiftcurrent Lake, 17-VII-06, AF.

Siphonurus occidentalis: Bowman Lake, 14-VIII-06, JC; Two Medicine Lake, 16-VII-06, RLN; Waterton Lake, 19-VII-06, AF; Swiftcurrent Lake, 17-VII-06, AF, 31-VII-07, RH & RLN; Lake Sherburne, 18-VII-06, RLN; Red Eagle Lake, 3-IX-08, PM; Cerulean Lake, 3-VIII-07, BB; Lake McDonald, adults 12-VII-06, RLN.

PLECOPTERA

Capniidae

Waterton Lake, 19-VII-06, AF; St. Mary Lake, 31-VII-07, RH & RLN; Cerulean Lake, 3-VIII-07, BB.

Capniidae/Leuctridae

Waterton Lake, 19-VII-06, AF

Bolshecapnia spenceri: Iceberg Lake (SRM).

Capnia sp.: Lake McDonald (Varrelman 1992) reference specimen; Nahtaki Lake, 6-VIII-01, BE & MA; Ptarmigan Lake, 6-V-01, 13-VII-01, 1-IX-01, 6-X-01, BE & MA.

Chloroperlidae

Paraperla sp.: Lake Josephine (SMT); Ptarmigan Lake, 20-VII-01, 13-VIII-01, BE & MA.

Suwallia sp.: Lake Josephine, 22-VI-06, AF & RLN; Lake McDonald, 6-VIII-06, AF; Waterton Lake, 19-VII-06, AF.

Sweltsa sp.: Hidden Lake, 8-VII-06, AF & RLN; St. Mary Lake, 31-VII-07, RH & RLN; Lower Quartz Lake, 4-VII-07, BB; Kintla Lake, 27-IX-07, PM; Ptarmigan Lake, 6-X-01, BE & MA; Nahtaki Lake, 6-VIII-01, BE & MA; Shangri-La Lake, 10-VIII-01, 21-VII-02, BE & MA.

Sweltsa revelstoka: (dissected nymph), Hidden Lake, 7-VII-06, AF & RLN; High altitude lakes (SRM); Shangri-La Lake, 10-VIII-01, BE & MA.

Nemouridae

Malenka sp.: Josephine Lake, 18-VII-06, RLN.

Zapada sp.: Nahtaki Lake, 6-VIII-01, BE & MA.

Perlodidae

Arcynopteryx dichroa: Teslenko (2012); Hidden Lake, 7-VII-06, AF & RLN; Glenss Lake (SMT, SRM).

Isoperla sp.: St. Mary Lake, 31-VII-07, RH & RLN.

Isoperla sobria: Lake Josephine, 22-VI-06, AF & RLN; Avalanche Lake, 14-VII-06, AF & RLN (male-reared).

Perlodid genus ?: St Mary Lake, 17-VII-16, RLN.

Perlidae

Calineuria californica: Kintla Lake, 27-IX-07, PM; Trout Lake, 1-X-07, PM.

Lake McDonald, yielded the greatest number of taxa; however, it was sampled the greatest number of times, and of all the sampled lakes, it is the largest, the lowest in elevation, and perhaps the most accessible through much of its length. Only 3 lakes were devoid of mayflies and stoneflies: Bullhead, Gyrfalcon, and Elizabeth lakes. Twelve genera and 21 species of Ephemeroptera were collected. Eleven genera and 5 species of Plecoptera were recorded. The most common mayfly species was *Paraleptophlebia bicornuta* (7 lakes), and the most common genus was *Siphonurus* (10 lakes). Newell and Hossack (2009) found

Siphonurus to be the most common mayfly in temporary ponds in GNP. *Sweltsa* was the most common stonefly genus found (7 lakes), and the most common species was *S. revestoka* (3 lakes). The total aquatic insect fauna was diverse and often very abundant, although exact counts were not kept. Expanded studies and additional funds are needed to determine the species of many of the Plecoptera. Many of the above taxa are lotic taxa, but they can exist in oligotrophic lakes with windswept shorelines that are similar in many respects to lotic habitats. This research illustrated a varied and diverse ephemeropteran and plecopteran fauna in the sampled lakes. These records should be valuable to the National Park Service in accomplishing their mandated inventory and in monitoring faunal change influenced by climate change.

Several students and volunteers collected specimens: Andrew Farwick (AF), Rachel Heth (RH), Phil Matson (PM), James Craft (JC), Blake Hossack (BH), and Bea Branch (BB). All specimens are archived at the University of Montana, Flathead Lake Biological Station. Specimen identification was aided by Pat McCafferty and Luke Jacobus, Purdue University (Ephemeroptera); Kenneth Stewart, North Texas State University (Plecoptera); and Boris Kondratieff, Colorado State University (Plecoptera). The reared specimen was studied at the Flathead Lake Biological Station. Susan Varrelman's reference specimens are stored at the Flathead Lake Biological Station. Collections were done under a collecting permit issued by the National Park Service.

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