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STONEFLIES (INSECTA: PLECOPTERA) IN THE BOREAL HIGHLANDS OF CAPE BRETON, NOVA SCOTIA, CANADA, WITH NOTES ON NEW SPECIES RECORDS

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ABSTRACT

Adult and larval stoneflies were surveyed from 12 headwater streams in the boreal highland area of Cape Breton Island, Nova Scotia, between May 2005 and November 2006, to determine diversity and life history patterns. Approximately 3,400 stonefly specimens were collected, with eight of the nine Nearctic families represented. Thirty-one taxa were identified from the study streams, with five taxa reported in Nova Scotia for the first time: *Leuctra truncata* Claassen, 1923, A*mphinemura palmeni* (Koponen, 1917), *Isoperla dicala* Frison, 1942, *Cultus* spp., and *Malirekus iroquois* Stark & Szczytko, 1988.

Keywords: Plecoptera, new records, Cape Breton Island, Nova Scotia, Canada

INTRODUCTION

Cape Breton Island is a large (10,311 km^2) island in northern Nova Scotia, located in eastern Canada. The boreal highlands of Cape Breton reach elevations of 300 to 500 m and represent true boreal forest habitat, which is rare in Nova Scotia (Neily et al. 2003). The climate of the region is influenced by the higher elevations, strong ocean winds and heavy blankets of dense fog that occur during spring and summer. The headwater streams of the highland regions flow over a primarily ancient metamorphic and granitic dominated geologic landscape, originating from cool springs or draining acidic, sphagnum bogs (Webb & Marshall 1999, Neily et al. 2003). The forest is dominated by even-aged balsam fir (*Abies balsamea* (L., 1753)), representing the only area in Nova Scotia with balsam fir as climax forest (Webb & Marshall 1999). The boreal highland region has been historically subject to repeated insect infestations and has been extensively managed for timber and wood fiber since the early 1900s, resulting in a large network of roads through many areas of the highland landscape.

Stoneflies (Plecoptera) are a major component of the biodiversity and aquatic communities of most stream ecosystems. Stonefly larvae and adults provide a direct food source for many predatory organisms and play an important role in the nutrient and dissolved mineral cycles within the stream ecosystem (Stewart & Stark 2002). Detritivorous stoneflies are particularly important in small headwater streams that are well shaded by streamside vegetation and have food webs that are dominated by leaf litter detritus (Stewart & Stark 2008). Little is known about the stonefly fauna of Cape Breton Island. Previous insect studies within the highland ecosystem on Cape Breton have focused on forest pests or on general surveys conducted mainly in lower elevations and not in the boreal region. Works that include Plecoptera distribution information for Atlantic Canada (e.g., Ricker 1948, 1964, Harper & Hynes 1971a, 1971b, 1971c, 1971d, Peterson & van Eeckhaute 1992, Kondratieff & Baumann 1994, Giberson & Garnett 1996) have focused on lower elevation streams and not in the Nova Scotia boreal zone. Prior to this study, 51 stonefly taxa were reported as valid records in the faunal list for Nova Scotia in DeWalt et al. (2018), a small proportion of the 120 reported in northeastern North America.

The objective of this study was to describe the species richness, abundance and flight periods of the stonefly assemblage of headwater streams of the Cape Breton highland region. Of particular interest was the identification of new species additions to the known fauna of Nova Scotia.

MATERIALS AND METHODS

Study area. Twelve low order streams of similar size, vegetative cover and habitat type were chosen using a combination of topographical maps (1: 50,000 scale) and site visits. All streams were located on Hunters Mountain (46° 26.3'N, 60° 47.2'W) in the central portion of northwest Cape Breton Island, Nova Scotia covering a total land area of approximately 350 km² (Fig. 1).

Each stream site included a riffle zone and a slower water zone within a 15-20 m reach. Water temperature was monitored continuously in each stream between mid-May and early November 2005 and 2006, using Hobo® water temperature-Pro data recorders. pH and conductivity were measured in mid-August 2006, using a Hanna multi-parameter meter. Channel characteristics were measured in mid-August 2006, providing information on stream width, summer and bank full flow, and substrate particle size composition. Watershed area was determined by delineating watershed boundaries on 1:50,000 topographical maps, and calculating the area upstream of the sample site using MapInfo® v.7 (MapInfo Canada, 26 Wellington St. E., Ste. 500, Toronto, ON). Ogden (2011) provides a detailed description of sites including stream physical characteristics and images of each stream.

Stonefly sampling. Adult and larval stoneflies were sampled during the snow-free months of 2005 and 2006, resulting in 10 sampling times between May 2005 and November 2006. Adults were collected using a combination of suspended cone-shaped emergence traps (Chmielewski & Hall 1993, Giberson & Garnett 1996), light traps, stream-side pan traps and vegetation sweeps (Giberson & Garnett 1996). Emergence traps were set in the spring and emptied three to four times each season. During 2005, stream-side light traps (modified CDC mosquito light traps) and terrestrial sweep sampling (7-10 min. streamside sweeps) were also used to obtain adults. All specimens were preserved in 70% ethanol.

Stonefly larvae were collected each year in mid-June, late-July, and early October by means of a standardized 60-second kick sample, using a 200 µm mesh D-shaped kick net (Hornig & Pollard 1978, Lenat & Crawford 1994, Willacker et al. 2009). Habitats within the 15-20 m study reaches included riffles, pools, undercuts, and snags. The entire contents of the kick net were placed directly into 80% ethanol for later sorting.

Plecoptera were sorted from the debris using a dissecting microscope, and were identified using keys found in Ricker (1952), Harper & Hynes (1971 a, b, c, d), Hitchcock (1974) and Stewart & Stark (2002). Voucher specimens were confirmed by Dr. B.C. Kondratieff (Colorado State University, Fort Collins, Colorado, USA), the late Dr. S.W. Szczytko (University of Wisconsin - Stevens Point, Wisconsin,

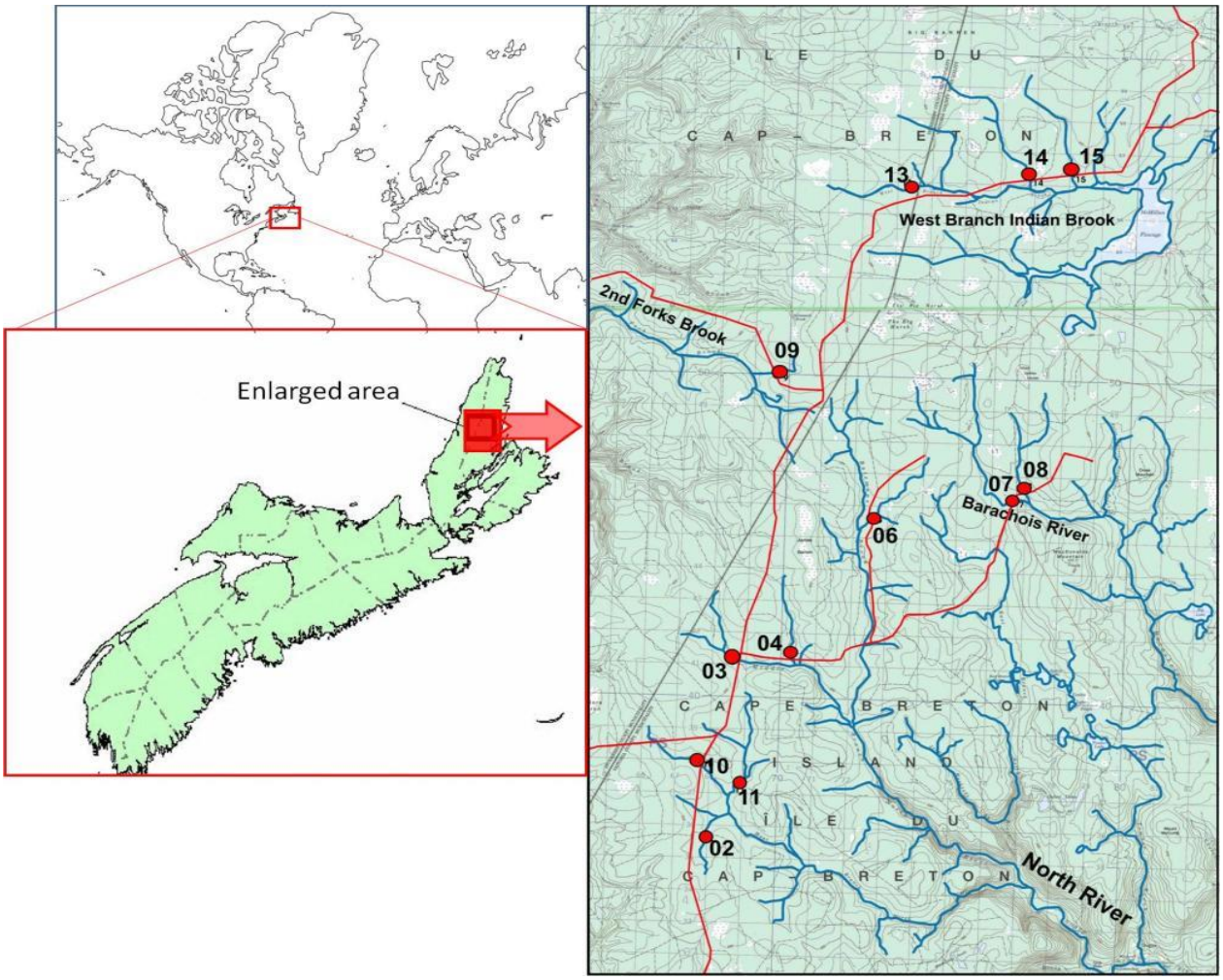

Fig. 1. Location of study sites sampled during 2005 and 2006, Cape Breton, Nova Scotia, Canada.

USA) or Dr. R.W. Baumann (Brigham Young University, Provo, Utah, USA). All specimens were identified to the lowest possible taxon. In some instances, early instar larvae could only be identified to family and adult females of some genera (e.g. *Leuctra* and *Isoperla*) could only be identified to genus due to lack of taxonomic keys for these groups. Voucher specimens are housed in the Nova Scotia Museum, Halifax, the Nova Scotia Department of Natural Resources Insect Reference Collection, Shubenacadie and in the personal collection of the author.

RESULTS

All but one of the twelve stream sites were heavily shaded and generally cool, most averaging below 12°C during the summer months (Table 1). Alternatively, site 7 was warmer than the others, averaging 14.1°C. Streams were generally small (approximately 2-4.5 m wide), with median particle sizes between 3.3 and 12.3 cm and of moderate gradient. Again, site 7 was different, being slight wider at 5.3 m wide, higher gradient, and dominated by larger particle sizes than most other streams (Table 1). Most streams had exceedingly low conductivity and were slightly acid in pH (6.3-

6.8), though site 10 showed a pH of 5.8, and sites 9 and 11 were circumneutral (Table 1).

A total of 3,401 Plecoptera specimens (2,773 larvae and 628 adults) were collected over the two sampling seasons. Thirty-one taxa were identified, with eight of the nine Nearctic families represented (number of species in parentheses): Capniidae (1), Leuctridae (6), Nemouridae (7), Taeniopterygidae (1), Chloroperlidae (3), Perlidae (3), Perlodidae (9) and Pteronarcyidae (1) (Table 2). Only the Peltoperlidae was not recorded.

Species richness ranged from eight to 12 stonefly taxa in each site (Table 1). Abundance ranged from a low of 88 specimens at site 7 (the largest and warmest site) to > 500 individuals in the smaller, cooler streams (Table 1). Overlap of taxa in small streams ranged from 60% to 80%

Shredders dominated the stonefly abundance for all streams, often making up more than 80% of the total specimens collected (Table 2). The shredders also provided the highest species richness of any of the functional feeding groups: *Leuctra* (5 spp.) and *Amphinemura* (3 spp.). Although predators made up less than 20% of the total abundance, they contributed up to 47% of the total species richness (Table 2). Site 7, in contrast to the small streams, was dominated by predator species and supported relatively few shredder species (Table 2).

Adult flight periods could only be assessed for the 21 species whose adults were present during our sampling (Table 2). Three stoneflies, *Leuctra ferruginea* (Walker, 1852), *L. tenella* Provancher, 1878, and *Amphinemura nigritta* (Provancher, 1876) showed long emergence periods, with adults captured throughout most of the season, whereas most other taxa had emergence over only one or two of the sampling periods (Table 2).

Table 1: Physical and summer chemical characteristics, stonefly species richness, and combined larval and adult abundance from 12 study streams of the highland region of Cape Breton, Nova Scotia, Canada sampled during 2005-2006. See Fig. 1 for site locations.

Site	Width (m)	Mean July Discharge (m^3/s)	Reach Gradient (%)	Median Substrate Particle size (cm)	pH	Conductivity (µS/cm)	Mean Summer Temperature (°C)	Taxa Richness	Total number collected (larvae + adults)
2	2.8	0.08	1	6.0	6.4	20	8.7	10	401
3	3.6	0.22	0.4	6.3	6.8	30	9.3	12	264
4	2.0	0.08	0.6	5.7	6.4	20	11.5	8	380
6	3.4	0.10	3.5	8.7	6.5	30	10.5	9	327
7	5.3	0.24	3.5	60.0	6.3	30	14.1	12	88
8	2.5	0.07	2.1	10.3	6.3	30	11.9	12	225
9	4.3	0.07	1.3	5.3	7.2	30	7.7	12	530
10	3.9	0.16	1.7	3.3	5.8	30	8.3	9	192
11	2.4	0.24	1.4	8.3	7.2	40	9.2	9	192
13	4.5	0.11	0.3	6.3	6.5	20	11	8	210
14	3.8	0.18	0.7	9.3	6.5	20	11.3	10	290
15	3.1	0.07	1.6	12.3	6.6	20	10.2	9	302

Table 2. Flight periods and numbers collected by stage for stoneflies from 12 Cape Breton highlands streams, May-October 2005-2006. The grey bars indicate periods when adults were captured. "*" Denotes a new Nova Scotia record.

Taxon	V	VI	VII	VIII	IX	X
Capniidae						
Allocapnia spp. (437L)						
Leuctridae						
Leuctra spp. (1,031 L, 112 A)						
Leuctra duplicata Claassen (3A)						
Leuctra ferruginea (Walker) (240A)						
Leuctra tenella Provancher (28A)						
Leuctra tenuis (Pictet) (3A)						
**Leuctra truncata* Claassen (2A)						
Paraleuctra sara (Claassen) (1A)						
Nemouridae						
Amphinemura spp. (437L, 2A)						
**Amphinemura palmeni* (Koponen) (9L)						
Amphinemura nigritta (Provancher) (15L, 129A)						
Amphinemura wui (Claassen) (11L, 29A)						
Nemoura spp. (111L)						
Nemoura arctica Esben-Petersen, 1910 (15A)						
Ostrocerca spp. (10 L)						
Podmosta macdunnoughi (Ricker) (1A)						
Zapada katahdin Baumann & Mingo (17L)						
Taeniopterygidae						
Taeniopteryx spp. (133L)						
Chloroperlidae						
Alloperla spp. (1A)						
Alloperla atlantica Baumann (7A)						
Sweltsa spp. (355L)						
Sweltsa naica (Provancher) (6A)						
Sweltsa onkos (Ricker) (11A)						
Perlidae						
Acroneuria spp. (1L)						
Agnetina capitata (Pictet) (19L, 5A)						
Paragnetina media (Walker) (8L, 4A)						
Perlodidae						
Isoperla spp. (155L, 2A)						
**Isoperla dicala* Frison (4A)						
Isoperla frisoni Illies (4A)						
Isoperla holochlora Klapálek (10A)						
Isoperla orata Frison (2A)						
Isoperla signata (Banks) (1A)						
Isoperla transmarina (Newman) (3L, 4A)						
**Cultus* spp. (2A)						
Isogenoides spp. (4L)						
**Malirekus iroquois* Stark & Szczytko (7L)						
Pteronarcyidae						
Pteronarcys biloba Newman (10L)						

DISCUSSION

Species patterns by family

Capniidae (Snowflies). Capniidae were well represented as larvae in the study streams, but were not collected as adults, since they generally emerged in late winter or early spring, outside of our sampling period (Stewart & Stark 2002, Harper & Hines 1971b). Lack of access to the sample sites in winter due to heavy snow made it impossible to obtain the mature nymphs or adults needed for species determinations. *Allocapnia* is the only genus reported from Nova Scotia in DeWalt et al. (2018). Ross & Ricker (1971) report six *Allocapnia* species from the province. *Allocapnia* larvae were common in all sites in the Cape Breton highland streams that were sampled, but due to their small size and lack of adult specimens, species determination was not possible. Harper et al. (1991) also found that identifiable stages of capniids were rare in summer sampling in Quebec.

Leuctridae (Needleflies). Leuctrids are common stoneflies in small to medium-size streams in Atlantic Canada (e.g., Peterson & van Eeckhaute 1992, Garnett & Giberson 1996, Dobrin & Giberson 2003, Eedy & Giberson 2007). Six species have been previously reported from Nova Scotia: five *Leuctra* and one *Paraleuctra* (Harper & Hynes 1971a, DeWalt et al. 2018). *Leuctra* was the most abundant stonefly in all streams sampled, with five species collected. *Leuctra truncata* Claassen, 1923 was collected for the first time in Nova Scotia in this study. It is known from New Brunswick (Giberson & Garnett 1996) and Quebec (Harper & Hynes 1971a). We collected a single adult specimen of *Paraleuctra sara* (Claassen, 1937) at site 14.

Nemouridae (Forestflies). Nemouridae is the most diverse detritivorous stonefly family in the northeastern region of Canada and the United States, based on examination of the lists in DeWalt et al. 2018). Eleven species in seven genera are listed for Nova Scotia in DeWalt et al. (2018). The results of this survey showed relatively low nemourid diversity in the highlands of Cape Breton, with only four species in four genera collected. One of these, *Nemoura arctica* Esben-Petersen, 1910 was originally identified in Ogden 2011 as *Nemoura trispinosa* Claassen, 1923, which is now recognised as a junior synonym of *N. arctica* (Grubbs et al. 2018). We also reported larvae of *Ostrocerca*, but they were too immature for species identification. One species is reported for the first time in Nova Scotia from this study (A*mphinemura palmeni* (Koponen, 1917)).

Taeniopterygidae (Willowflies). Members of this family also emerge during winter and late spring. Nine species in five genera are reported from northeastern North America, but only *Taenionema atlanticum* Ricker & Ross, 1975 has been previously reported from Nova Scotia (Stanger & Baumann 1993). Ricker & Ross (1968) and Harper & Hynes (1971c) have previously reported unidentified *Taeniopteryx* spp. from Nova Scotia, including Cape Breton, and small, unidentifiable larvae of *Taeniopteryx* were collected in all but one of our Cape Breton highlands study streams.

Chloroperlidae (Sallflies). Chloroperlidae is a diverse family of predatory stoneflies commonly found throughout northeastern North America, including Nova Scotia. Chloroperlids are the most diverse family of stoneflies in Nova Scotia, with three genera and 12 species reported (*Alloperla* (9), *Haploperla* (1) and *Sweltsa* (2) (Surdick 2004). Only *Sweltsa* and *Alloperla* were collected in this study. *Sweltsa* larvae were commonly collected at all study sites, generally as unidentifiable early instars. Adults of two *Sweltsa* species (*S. naica* (Provancher, 1876) and *S. onkos* (Ricker, 1936)) were collected but were uncommon. In contrast, *Alloperla* larvae were collected only at a single small headwater stream and were uncommon. *Alloperla atlantica* Baumann, the only species determined from adult specimens, was collected between mid-June and mid-August from the same stream.

Perlidae (Summer stoneflies). Perlidae is a family of large predatory stoneflies commonly found in northeastern North America, most often associated with mid- to high-order streams and rivers. Twelve species in seven genera are known from Atlantic Canada, but only five species in four genera have been reported from Nova Scotia: *Acroneuria lycorias* (Newman, 1839), *Agnetina capitata* (Pictet, 1841), *Paragnetina media* (Walker, 1852), *Perlinella drymo* (Newman, 1839), *Neoperla occipitalis* (Pictet, 1841) (Ricker 1964, Peterson & van Eeckhaute 1992, Stark 2004). Several specimens of *A. capitata* and *P. media*

and a single *Acroneuria* larva were collected during this study.

Perlodidae (Spring stoneflies). Perlodidae is another family of primarily predaceous stoneflies commonly found throughout North America. Larvae feed on a variety of small aquatic invertebrates, while some immature instars also feed on plant material (Stewart & Stark 2008). With 27 species in seven genera in northeastern North America (Kondratieff 2004, Szczytko & Kondratieff 2015), Perlodidae is the most diverse stonefly family in the region. It is the second-most diverse stonefly family in Nova Scotia, with ten species in two genera reported prior to this survey. Despite their relatively low abundance (only about 6% of the total stoneflies collected), Perlodidae were the most diverse stonefly family in our high elevation Cape Breton Island streams, with nine taxa collected from four genera. Three of these had not been previously listed for Nova Scotia (Szczytko & Kondratieff 2015, Kondratieff 2004, Myers & Kondratieff 2009): *Isoperla dicala* Frison, 1942, *Cultus* spp. and *Malirekus iroquois* Stark & Szczytko, 1988.

Pteronarcyidae (Salmonflies). Pteronarcyidae contains some of the largest of the North American stoneflies. Pteronarcyids are most commonly encountered in large, high order streams, and are the largest of all the shredding detritivorous species (Nelson 2000). *Pteronarcys* is the only genus found in northeastern North America, with four species occurring in the region and a single species (*P. biloba* Newman, 1838) reported from Nova Scotia (Nelson 2000). *Pteronarcys biloba* was uncommon in the study streams, with only ten larvae collected from one of the small, cool headwater streams.

New species records

This study resulted in four new species records for Nova Scotia: *Leuctra truncata*, *Amphinemura palmeni*, *Isoperla dicala*, and *Malirekus iroquois*. One new generic record for *Cultus* sp. is also presented.

***Leuctra truncata* Claassen, 1923 (Leuctridae).** Two adult specimens of *L. truncata* were collected during this study. It has been collected in cold water streams in most of northeastern North America (Harper & Hynes 1971a). This species was first recorded from the Canadian Maritimes in Catamaran Brook, New Brunswick (Giberson & Garnett 1996). *Leuctra truncata* is a late summer species, and the two adults collected in this study were collected in emergence traps between August and October.

***Amphinemura palmeni* (Koponen, 1917) (Nemouridae).** Larvae of this species were originally identified as *A. linda* Ricker, 1952, now a junior synonym of *A. palmeni* (Boumans & Baumann 2012). It has been recorded from cold water streams in parts of central North America. The nearest records to Nova Scotia (as *A. linda*) were from central Quebec (Harper & Hynes 1971d). Nine larvae were collected from site 9. It is not clear why it was absent from the other streams, despite similarities in physical and chemical characteristics.

***Isoperla dicala* Frison, 1942 (Perlodidae).** *Isoperla dicala* is broadly distributed in medium-sized streams in most of its northeastern North American range (Heimdal et al. 2004, Szczytko & Kondratieff 2015) and has been previously recorded from New Brunswick and Maine (DeWalt et al. 2018). *Isoperla dicala* was restricted to site 7 and represented by only four adults swept from stream-side foliage.

***Cultus* sp. (Perlodidae).** Two *Cultus* species have been listed from northeastern North America: *C. d. decisus* (Walker) and *C. verticalis* (Banks, 1920) (DeWalt et al. 2018, Myers & Kondratieff 2009, Stark et al. 1988). *Cultus d. decisus* (Walker, 1852) has been found in north-central New Brunswick (Giberson & Garnett 1996) and *C. verticalis* has been reported from Quebec and the eastern seaboard of the USA (Myers & Kondratieff 2009). The larvae of *C. d. decisus* prefer larger streams and rivers, while those of *C. verticalis* are found more commonly in small to medium sized streams (Myers & Kondratieff 2009). Two adult *Cultus* sp. were collected from a single small, headwater stream (site 3) during this survey and a *Cultus* sp. larva was collected from a nearby stream. The adults were sent to Boris Kondratieff who recommended that they be listed as *Cultus* sp. and that the larva be identified to *Cultus*/*Isoperla*. More material is needed to provide a specific determination.

***Malirekus iroquois* Stark & Szczytko, 1988 (Perlodidae).** This species was described by Stark & Szczytko (1988) from specimens collected in the

northern Appalachians of the USA. *Malirekus iroquois* has been previously recorded in Canada from cold headwater streams of Quebec (Stark & Szczytko 1988). It was another rarely collected stonefly species from small, cool streams in the Cape Breton Island highland region, with nine larvae collected from three sites in late summer and fall.

Overall species patterns

The species that were found in most of the streams of this study were typical of headwater streams in northeastern North America. The species possessed similar larval growth and adult emergence phenology to published studies (Ricker 1948, 1964, Harper & Pilon 1970, Harper & Hynes 1971a, 1971b, 1971c, 1971d, Harper 1989, Kondratieff & Baumann 1994, Giberson & Garnett 1996). Species found in small, cold springs must be able to complete development despite cool temperatures, limiting the species that can develop in them (Dobrin & Giberson 2003, Danks 2007). These streams are generally dominated by shredders of autumnal leaf fall (Newbold et al. 1980, Stout et al. 1993, Danehy et al. 2007), a pattern confirmed in this study.

For some species, development appeared to be delayed or prolonged, possibly due to the cool waters of the Cape Breton highland streams; a pattern consistent with Dobrin and Giberson (2003). These species had shorter and more defined emergence periods in other nearby locations, such as Quebec (Harper &Pilon 1970), than those collected in the Cape Breton streams. For example, *S. onkos*, *P. media*, and *I. transmarina* (Newman, 1838) all had emergence periods extended from June to July in Quebec (Harper &Pilon 1970), while the same species were still collected well into mid-August in our study streams. This delay in development also seemed apparent in *P. sara*; it was collected in late June 2005 at site 14 of our study, compared to March-April in other parts of the region, including mainland Nova Scotia (Harper & Hines 1971a). For most species recorded however, emergence was similar to those collected in studies conducted within the Maritimes (Dobrin & Giberson 2003, Giberson & Garnett 1996).

Prior to this study, 51 stonefly taxa had been listed for Nova Scotia (see DeWalt et al. 2018, and references listed therein). An additional three taxa previously reported in the literature for Nova Scotia were found in our study streams: *Zapada katahdin* Baumann & Mingo, 1987 (Grubbs et al. 2015), *Paragnetina media* (Walker, 1852) (Ricker 1964, Peterson & van Eeckhaute 1990), and *Taeniopteryx* sp. (Ricker & Ross 1968 and Harper & Hynes 1971c) bringing the Nova Scotia total to at least 55. We add five additional Plecoptera taxa from streams of the Cape Breton Highlands, bringing the total for the province to at least 59 species. The 31 taxa found here likely underestimate the species richness for Cape Breton Highlands, since we sampled only on low order, headwater streams. Had we included larger streams we predict that more of the large predatory Perlidae and Perlodidae would have been found (Stewart & Stark 2002, Kondratieff & Baumann 1994). In addition, we may have missed other species due to their particular emergence habits if these result in them migrating out of the riffles (to pools or streamside vegetation) to emerge (Harper &Pilon 1970).

Another factor that may have contributed to underestimates of diversity was the difficulty in species identification for particular life stages in some taxa. Common shredder species in genera such as *Leuctra* (Leuctridae) were easily collected from all sites sampled but species determination was not possible for immatures and adult females (Harper & Harper 1997). Our efforts completely missed the emergence of adult winter stoneflies, the life stage required for species level identification. Roads are often impassable during winter in the Cape Breton Highlands due to heavy snow fall.

Further work is necessary to better determine the species composition of stoneflies within the boreal highlands of Cape Breton and throughout Nova Scotia. Comprehensive examination of entire drainages, from headwaters to mouth, across the province is needed. Information gained from such studies, both large scale and small, would provide a better understanding of the provincial fauna as a whole.

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