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Faunistics of stoneflies (Plecoptera) in Finnmark, northern Norway, including DNA barcoding of Nemouridae

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During a large-scale survey in the Norwegian county of Finnmark in 2010, insects were collected with Malaise traps and manual collecting techniques. Almost 6000 specimens of stoneflies collected during this survey are reviewed, and the incidence and abundance of the northern Scandinavian species are discussed. The species composition at the sites of the Malaise traps is explained by stream characteristics like width and velocity, rather than the altitude and continentality of the trap sites. The morphological distinction between the rare Arctic stonefly *Amphinemura palmeni* (Koponen, 1917) and the common *A. standfussi* (Ris, 1902) is discussed, and both species as well as the Fennoscandian endemic *Nemoura viki* Lillehammer, 1972 are illustrated with colour photographs. Initial results from DNA barcoding of Norwegian stoneflies show that *A. standfussi* colonised the Scandinavian Peninsula from the south as well as the northeast. Comparison with North American barcode data reveals that *A. palmeni* and *Nemoura sahlbergi* Morton, 1896 have a Holarctic distribution.

Key words: Plecoptera, Norway, Finnmark, faunistics, habitat preferences, Nemouridae, *Amphinemura, Nemoura*.

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Introduction

In 2010 entomologists from the universities of Trondheim, Bergen and Oslo carried out a large-scale inventory of aquatic insects in the Norwegian county of Finnmark, using Malaise traps and manual collecting methods (Ekrem *et al*. 2012). This inventory was primarily designed for the collection of aquatic Diptera, but large numbers of stoneflies were also collected. The Scandinavian Plecoptera fauna is depauperate relative to central and southern Europe and only 35 species are known from Norway. However, unlike the situation in many animal and plant taxa, within Scandinavia, the highest number of stonefly species occurs in the northernmost region. This is due to the adaptation of many stonefly species to cold environments (Brittain 1990), and the occurrence of several species that are restricted to the Arctic region. In addition, since the last glaciation one species with a primarily southern distribution, *Protonemura intricata* (Ris, 1902), reached Scandinavia only from the Northeast, and has not yet dispersed south into the peninsula. Only three Norwegian species have not been found in Finnmark, whereas six other species only occur in the northern part of Norway. Finnmark is the Norwegian county with the highest number of stonefly species, namely 32 (Lillehammer 1988, Boumans 2011a).

The stonefly fauna of Norway is well studied so that no new species are to be expected.

However, a number of species are only known from a few observations. The 2010 sampling gave the possibility to collect new data on the rare or undersampled species *Xanthoperla apicalis* (Newman, 1836), *Amphinemura palmeni* (Koponen, 1917) *Nemoura sahlbergi* Morton, 1896, *N. viki* Lillehammer, 1972, *Protonemura intricata* and *Capnia vidua* Klapálek, 1904.

Samples from Finnmark are included in a DNA barcoding library of all Norwegian stonefly species. In order to obtain data on within-species genetic diversity, standard cytochrome oxidase I (COI) sequences have been established from samples from northern, western and southern Norway, as well as from populations in western and central Europe. The COI data can reveal whether widespread species colonised the Scandinavian Peninsula from the South, the Northeast, or both. In addition these data will shed light on the genetic relationships between Palaearctic and Nearctic populations of species with a Holarctic distribution. While the DNA studies are still ongoing, some initial results will be presented here together with the distributional data in relation to environmental parameters.

Methods

Collecting and identification. Stoneflies were collected in Finnmark from mid-June to early September 2010 in the framework of a large-scale survey of the local aquatic insect fauna (Ekrem *et al.* 2012). Most individuals were caught in Malaise traps that were situated along streams and lakes, although many additional collecting sites were added during field trips where stoneflies were taken by sweep-netting, handpicking and beating bushes and tree branches. The collected stoneflies are almost all adults; only a few nymphs were collected by kick-sampling in aquatic habitats. The collecting techniques are described more fully in Ekrem *et al.* (2012), but a description of the sites for the Malaise traps is given in Table 1. Figure 1 shows the location of the Malaise traps and the sites where stoneflies were collected manually.

TABLE 1. Description of the sites for the Malaise traps. From Ekrem *et al.* (2012).

Trap	Description
1	**FinLoc05 – FV**, Alta: Gargia fjellstue, N69.80525 E23.48937, 120m a.s.l. Fast flowing stream; stony bed; in a forest with pine (*Pinus sylvestris*), birch (*Betula pubescens*), willow (*Salix* sp.) and alder (*Alnus incana*).
2	**Finloc08 – FV**, Alta: Storeng, N69.82277 E23.47884, 90m a.s.l. Gargiavannet, lake-like broadening of the Gargiaelva river; wide vegetation zone with sedges (*Carex* spp.) and nearby woodland with birch (*Betula pubescens*), alder (*Alnus incana*). and willow (*Salix* sp.).
3	**Finloc19 – FI**, Kautokeino: Lahpoluoppal, N69.20992 E23.757661, 320m a.s.l. Lake-like bend of the Náhpoljohka River; standing water, soft bottom; dominance of reed (*Phragmites australis*), sedges (*Carex* spp.) and willow (*Salix* sp.) trees. Situated in complex landscape mosaic of lakes, streams and rivers.
4	**Finloc21 – FI**, Kautokeino: Nahpoljohka, N69.21029 E23.76200, 320m a.s.l. Fast flowing river; stony bed; bank zone with stones, sand and patches of vegetation dominated by willow (*Salix* sp.).
5	**Finloc56 – FN**, Porsanger: Rørkulpen, N70.15215 E24.76686, 28m a.s.l. Situated in natural pine (*Pinus sylvestris*) forest of the Stabbursdalen National Park, along river bank with some willow (*Salix* sp.) and alder (*Alnus incana*). River about 10m wide, moderate current and stony bed.
6	**Finloc42 – FN**, Porsanger: Baukop site 1, N70.20469 E24.90605, 26m a.s.l. Small stream running from Vuolit Gealbbotjavri in birch-willow woodland; surrounded by grassland.
7	**Finloc65 – FØ**, Sør-Varanger: Pasvik, Russevann, N69.44497 E29.89904, 60m a.s.l. Lake, c. 4 hectares, 50m deep; mosaic of pine (*Pinus sylvestris*) forest and blanket bog on bank.
8	**Finloc81 – FØ**, Sør-Varanger: Pasvik, Sametijohka near Sameti, N69.40106 E29.71923, 43m a.s.l. Trap in birch-dominated woodland on bank of a stream with variable current and a stony bed.

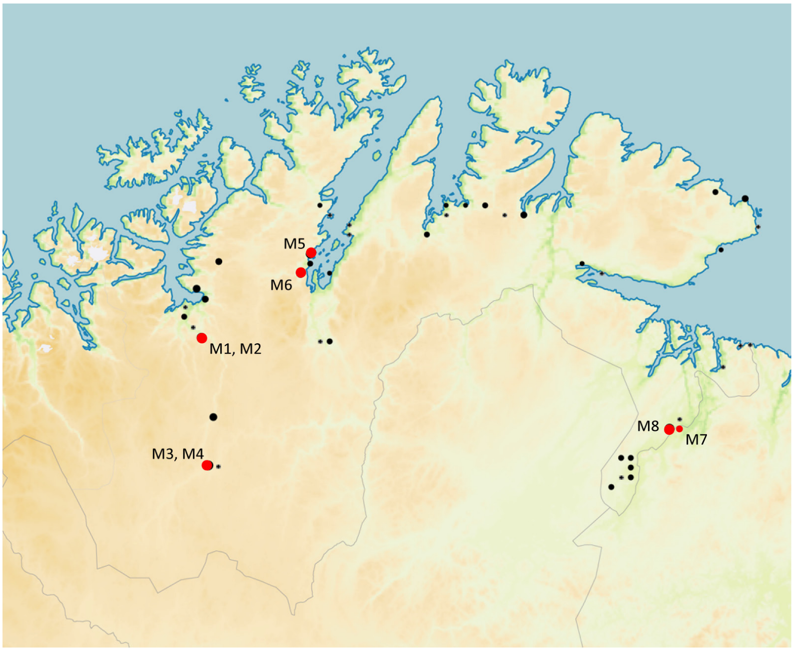

FIGURE 1. Sampling localities of the 2010 Finnmark survey. Red dots represent the Malaise traps M1–M8; the locations of traps M1 and M2 are represented by a single dot and the same for M3 and M4. Black dots represent sites where stoneflies were collected manually. The size of the dots is in proportion to the number of stoneflies taken.

The Malaise traps were in place during the period 11 June to 6 September. They were emptied on average every second week, though in some cases they were emptied after one, three or even four weeks. Insects collected in the traps were sorted at the Department of Natural History, University Museum of Bergen. In some cases such large numbers of one or a few species, often *Leuctra hippopus* Kempny, 1899, occurred in the Malaise trap material, that it was not feasible to identify each specimen. In such cases a subsample was taken and identified.

Stoneflies were collected manually by Torbjørn Ekrem in the period 12 to 20 June, by Torbjørn Ekrem, Steffen Roth and Louis Boumans from 23 July to 1 August, and by Steffen Roth from 1 to 7 September. Identifications are based on Lillehammer (1988), supplemented with descriptions and figures in Tobias (1973), Koese (2008) and Tierno de Figueroa *et al.* (2003).

Statistics. The effect of different biotopes on species composition was explored by clustering analysis of the seven malaise traps that effectively trapped stoneflies (see below). Hierarchical clustering with the between-group average method (also known as UPGMA) was performed in the software package SPSS v. 19. Species composition was used to cluster Malaise traps in two ways: firstly, incidence was coded as binary values (1/0), and the Jaccard index used as distance measure. Secondly, the traps were clustered while taking into account the relative abundance of species, disregarding the fact that these numbers are not exact due to the fact that a subsample of the total catch was identified in some cases. The abundance of each species was calculated as a proportion of the total number of individuals in the trap during the whole collecting period ($P_x = N_{(species\ x)} / (N_{(species\ 1)} + N_{(species\ 2)} +.. + N_{(species\ z)})$. Because the identification of females of the genus *Nemoura* Latreille, 1796 is both time-consuming and less reliable than the identification of males, not all female specimens were identified. For the comparison of the trap sites, the number of each *Nemoura* species was calculated as twice the number of males (Table 2). (The actual number of identified males and females can be calculated from the numbers shown in Table 3.) Subsequently, because the frequency of species was very unevenly distributed in many traps, these proportions were log-transformed using the formula $\ln(100{*}P_x + 1)$. Squared Euclidean distance was used as distance measure.

The nonparametric binomial test was used

TABLE 2. Stoneflies known from Finnmark: Relative abundance in % per species per Malaise trap, including those manually collected at same locality, and number of additional localities where the species have been collected using manual methods. The bottom row gives the number of specimens collected. For the *Nemoura* Latreille, 1796 species, the number of specimens per trap was calculated as twice the number of males. The shaded species have been reported for Finnmark but were not collected in this study.

	Species	M1 Gargia fjellstue	M2 Gargia Storeng	M3 Lahpoluppal	M4 Nahpoljohka	M5 Rørkulpen	M6 Baukop	M8 Sameti	# additional localities	total localities
1	*Arcynopteryx dichroa* (McLachlan, 1872)	0.2	0.4	-	0.1	-	-	-	4	7
2	*Diura bicaudata* (Linnaeus, 1758)	-	-	0.5	2.4	-	-	0.1	1	4
3	*Diura nanseni* (Kempny, 1900)	3.1	1.3	-	1.9	3.5	-	0.3	9	14
4	*Isoperla difformis* (Klapálek, 1909)	-	-	-	-	-	-	-	-	0
5	*Isoperla grammatica* (Poda, 1761)	0.1	-	-	5.3	-	-	1.6	4	7
6	*Isoperla obscura* (Zetterstedt, 1840)	0.1	0.3	0.5	5.1	1.0	-	-	6	11
7	*Dinocras cephalotes* (Curtis, 1827)	-	-	-	-	-	-	-	-	0
8	*Siphonoperla burmeisteri* (Pictec, 1841)	9.5	23.0	-	5.8	1.7	-	0.1	7	12
9	*Xanthoperla apicalis* (Newman, 1836)	-	-	-	-	-	-	-	-	0
10	*Taeniopteryx nebulosa* (Linnaeus, 1758)	0.1	-	-	-	-	-	-	3	4
11	*Brachyptera risi* (Morton, 1896)	-	0.3	-	-	-	-	-	1	2
12	*Amphinemura borealis* (Morton, 1894)	2.0	3.3	13.8	18.1	3.1	-	0.5	6	12
13	*Amphinemura palmeni* (Koponen, 1917)	-	-	-	-	-	-	-	2	2
14	*Amphinemura standfussi* (Ris, 1902)	0.8	-	3.7	0.2	-	42.1	0.1	16	21
15	*Amphinemura sulcicollis* (Stephens, 1835)	2.0	1.2	1.6	6.3	0.3	-	-	6	11
16	*Nemoura arctica* Esben-Petersen, 1910	-	-	-	-	-	-	-	2	2
17	*Nemoura avicularis* Morton, 1894	0.9	10.2	18.0	4.9	0.7	-	3.7	2	8
18	*Nemoura cinerea* (Retzius, 1783)	0.5	7.9	6.3	1.6	4.2	13.2	1.7	10	17
19	*Nemoura flexuosa* Aubert, 1949	8.3	5.5	6.3	-	-	-	0.3	3	7
20	*Nemoura sahlbergi* Morton, 1896	1.4	2.9	4.2	-	-	13.2	-	3	7
21	*Nemoura viki* Lillehammer, 1972	-	-	36.0	-	0.7	1.7	-	2	5
22	*Nemurella pictetii* Klapálek, 1900	0.4	4.4	0.5	-	-	0.8	-	4	8
23	*Protonemura intricata* (Ris, 1902)	3.9	0.7	-	-	-	-	0.1	3	6
24	*Protonemura meyeri* (Pictet, 1841)	0.5	0.4	0.5	0.3	1.0	-	13.8	-	6
25	*Capnia atra* Morton, 1896	0.4	0.6	2.1	8.3	11.2	-	-	12	17
26	*Capnia pygmaea* (Zetterstedt, 1840)	0.1	1.9	-	0.3	26.9	-	-	10	14
27	*Capnia vidua* Klapálek, 1904	-	-	-	-	-	-	-	-	0
28	*Capnopsis schilleri* (Rostock, 1892)	7.1	3.9	2.6	2.8	1.7	-	1.1	-	6
29	*Leuctra digitata* Kempny, 1899	0.6	-	1.1	-	0.7	2.5	0.6	11	16
30	*Leuctra fusca* (Linnaeus, 1758)	9.5	0.9	-	7.2	5.6	-	0.1	12	17
31	*Leuctra hippopus* Kempny, 1899	48.4	30.4	2.1	28.7	30.4	14.0	75.9	16	23
32	*Leuctra nigra* (Olivier, 1811)	0.2	0.4	-	0.7	7.0	12.4	0.1	3	9
	Total specimens	**1278**	**687**	**189**	**1105**	**286**	**121**	**1555**	**789**	
	Number of species	**23**	**20**	**16**	**18**	**16**	**8**	**16**	**26**	

TABLE 3. Sex ratio in collected stonefly species collected manually and in Malaise traps. Deviation from a 1:1 ratio was tested with a binomial test. * P < 0.05 ** P < 0.01. The identification of *Nemoura* Latreille, 1796 females is considered insufficiently reliable for statistical testing. The far right column shows the period each species was collected.

		Traps			Manually collected			
		total indiv	**% female**		**total indiv**	**% female**		**collecting period**
1	*Arcynopteryx dichroa* (McLachlan, 1872)	7	100	*	6	50		VI
2	*Diura bicaudata* (Linnaeus, 1758)	29	59		5	100		VI–mid VII
3	*Diura nanseni* (Kempny, 1900)	74	62	*	46	26	*	VI–early IX
4	*Isoperla grammatica* (Poda, 1761)	74	64	*	23	48		VI–VIII
5	*Isoperla obscura* (Zetterstedt, 1840)	62	24	**	20	50		VI–VII
6	*Siphonoperla burmeisteri* (Pictec, 1841)	337	55		38	58		VI–VIII
7	*Taeniopteryx nebulosa* (Linnaeus, 1758)	1	100		3	0		early VI
8	*Brachyptera risi* (Morton, 1896)	2	50		1	0		VI–early VII
9	*Amphinemura borealis* (Morton, 1894)	272	36	**	31	42		VI–VIII
10	*Amphinemura palmeni* (Koponen, 1917)	0			17	41		30.VII
11	*Amphinemura standfussi* (Ris, 1902)	71	51		84	39		late VII–early IX
12	*Amphinemura sulcicollis* (Stephens, 1835)	103	66	*	26	77	*	VI–VII
13	*Nemoura arctica* Esben-Petersen, 1910	0		nt	2	0	nt	17.VI–24.VII
14	*Nemoura avicularis* Morton, 1894	226	50	nt	8	50	nt	VI–VII
15	*Nemoura cinerea* (Retzius, 1783)	197	64	nt	38	63	nt	VI–VIII
16	*Nemoura flexuosa* Aubert, 1949	190	59	nt	10	40	nt	VI–early VII
17	*Nemoura sahlbergi* Morton, 1896	48	35	nt	7	0	nt	VI–VII
18	*Nemoura viki* Lillehammer, 1972	44	18	nt	10	40	nt	VI–VII
19	*Nemurella pictetii* Klapálek, 1900	36	69	*	11	45		VI–early VIII
20	*Protonemura intricata* (Ris, 1902)	57	53		5	80		late VI–VIII
21	*Protonemura meyeri* (Pictet, 1841)	221	61	*	13	62		VI
22	*Capnia atra* Morton, 1896	130	89	**	79	75	**	VI–VII
23	*Capnia pygmaea* (Zetterstedt, 1840)	88	84	**	48	85	**	VI–VII
24	*Capnopsis schilleri* (Rostock, 1892)	175	45		1	100		VI–VII
25	*Leuctra digitata* Kempny, 1899	25	44		32	50		late VII–early IX
26	*Leuctra fusca* (Linnaeus, 1758)	224	55		39	41		late VII–early IX
27	*Leuctra hippopus* Kempny, 1899	2395	71	**	171	57		VI–VII
28	*Leuctra nigra* (Olivier, 1811)	49	55		15	33		VI–VII
	TOTAL	**5137**			**789**			

in SPSS in order to test if the sex ratio of the trapped and manually collected stoneflies differed significantly from 1:1. This test was not performed for the *Nemoura* species, because not all females had been identified to species level.

DNA barcodes. The COI sequences of *Nemoura* species discussed in this paper were produced at the sequencing facility of the Canadian Centre for DNA Barcoding in Guelph in the framework of the barcoding project 'NorBOL - Freshwater

Insects', and retrieved from the Barcode of Life Data System (BOLD) (Ratnasingham & Hebert, 2007). The only exception is the sequence of *N. viki*, which was produced in Oslo following the methods described in Boumans & Baumann (2012), and subsequently added to the NorBOL - Freshwater Insects data set in BOLD. The NorBOL specimens are all deposited at the Natural History Museum, University of Oslo (NHMO, also known as ZMUN). The Norwegian data set was supplemented with published sequences of *N. arctica* Esben-Petersen, 1910 and unidentified *Nemoura* specimens from Canada, as well as three unpublished sequences of the Nearctic *N. trispinosa* Claassen, 1923 (courtesy Boris Kondratieff, Colorado State University, USA), likewise retrieved from BOLD. Summary specimen data and GenBank accession numbers are given in Appendix 1.

The software package Geneious Pro 5.6.5 (Drummond *et al.* 2012) was used for sequence alignment. Distance and maximum parsimony (MP) analyses were performed in PAUP* version 4.0b10 (Swofford 2003). The distance measure for the neighbour joining (NJ) method in PAUP* was set as calculated according to the Generalised Time Reversible model (GTR) with gamma distributed rates (shape=1.1840) and a proportion of invariant sites (Pinvar=0.6172), based on the evolution model selected for the entire data set according to the Akaike information criterion implemented in MrModelTest 2.2 (Nylander 2004). Heuristic searches were carried out under both optimality criteria (distance and parsimony) with tree bisection-reconnection branch swapping and 100 random addition sequence replicates. Bootstrapping (2000 replicates) was performed to obtain support values for branches.

Bayesian analyses were performed in MrBayes (Ronquist & Huelsenbeck, 2003) version 3.2, at the Bioportal computer facility (http://www.bioportal.uio.no) at the University of Oslo. The COI data were divided into two partitions, viz. a) 1st and 2nd codon position, and b) 3rd codon position. Based on the Akaike criterion in MrModeltest, the GTR+I+G model was selected for the first partition, and the GRT+G for the latter. Two independent analyses were run consisting of four Markov chains that ran for 40×10^6 generations, with sampling every 1000 generations, default priors, and the option "prset ratepr" set as "variable". After discarding the first 10 million generations, remaining trees from both analyses were combined and a 50% majority rule consensus tree was calculated. MrBayes and Tracer v1.5.0 (Drummond & Rambaut, 2007) were used to inspect trace plots and convergence diagnostics (standard deviation of split frequencies < 0.01 , effective sample size > 200) in order to ensure that the Markov chains had reached stationarity and converged on the parameter estimates and tree topology after the burn-in phase that was set at 25%.

Finally, COI haplotype differentiation between clades were calculated in PAUP* as both uncorrected p distance and Kimura two-parameter (K2P) distance in order to facilitate comparison with distances between taxa in other publications.

Results and discussion

28 of the 32 stonefly species on the checklist of Finnmark (Lillehammer 1988; Boumans 2011a) were recorded. In total 5926 specimens were collected, sorted and identified. 789 of these were manually collected, the remainder in the Malaise traps. These trapped hundreds or even over 1000 specimens each, with the exception of trap M7 at southern shore of the lake Russevann, which trapped only two females of *Amphinemura standfussi*. Apparently, few or no stoneflies occur in this small lake, while the distance from the inflow and outflow streams to the trap, 200m and 500m respectively, was too far to catch many stoneflies emerging from these streams.

Table 2 shows the Plecoptera checklist of Finnmark with the percentage of each species in the total catch of Malaise traps 1–6 and 8. Stoneflies collected manually at the same sites were added to the catches of the traps. For this table, the number of *Nemoura* specimens was calculated as twice the number of males, as explained in the Methods section. The percentages are indicative of the faunistic differences between traps sites. However, these numbers are not exact because some very large catches could not be sorted and identified entirely. The second last column of Table 2 shows the number of other localities where the species was taken, including the site of trap M7.

Four species known to occur in Finnmark were not found: *Isoperla difformis* (Klapálek, 1827), *Dinocras cephalotes* (Curtis, 1909), *Xanthoperla apicalis* and *Capnia vidua*. *Amphinemura palmeni* and *Nemoura arctica* were collected manually but not in any of the traps; *Protonemura meyeri* (Pictet, 1841) and *Capnopsis schilleri* (Rostock, 1892) were numerous in some of the traps, but were not collected manually.

Fauna of the Malaise-trap sites. Traps 1–6 and 8 were very well placed for collecting stoneflies. Sixteen to twenty-two species were caught in each of these traps. This reflects high local species diversity, both by Scandinavian and European standards. Ulfstrand (1968: 30) found 11–20 stonefly species at ten sites surveyed in the upstream reaches of the Vindelälven River in Swedish Lapland. Malmqvist (1999), who surveyed 56 sites in northern Sweden in June and September, found at the most 14 species per site. For other regions in Europe 10–20 species have been reported from rhithron sites, and up to 30 in mountainous areas with pronounced endemism (Ulfstrand 1968: 29–30, and references therein). The highest numbers of species at a single site, around thirty, have been recorded in fast flowing streams in the eastern Pyrenees and the Alps between 1000 and 1600 m a.s.l. (pers. com. Gilles Vinçon).

The Malaise trap sites differed in species composition: The spring emerging species *Leuctra hippopus* was dominant in all trap sites except the lake-like river bend, Lahpoluoppal (M3). Disregarding *L. hippopus*, each site was characterised by a different dominant or subdominant species. Figure 2 shows the clustering of Malaise traps based on species composition, taking into account the relative abundance of different species. Clustering based on binomial incidence data (not shown) yielded a similar pattern, but placed M8 Sameti as sister to the cluster [M1+M2][M4+M5].

Elevation can be an important factor determining the stonefly fauna, although indirect. This is primarily a consequence of the reduced tree and bush growth at higher altitudes, as the nymphs of many euholognathan stoneflies feed on terrestrial conditioned leaf litter. Only a few stonefly species occur above the *Salix* vegetation belt in Finnmark (Lillehammer 1974). However, differences in elevation do not explain the differences between the Malaise trap sites. All traps contained significant numbers of species that, according to Lillehammer (1974), are characteristic for the subalpine belt. The traps placed at the highest altitude, M3 and M4 in Kautokeino at 320 m a.s.l., were amidst willow vegetation that was apparently sufficient to support a rich Plecoptera fauna similar to traps M5 and M1 at 28 m and 120 m a.s.l., respectively (Figure 1 and Table 2).

Continentality also influences the stonefly fauna. Generally, more species are found in areas with a continental climate than in coastal areas, even at the Norwegian scale (Lillehammer 1974, 1988: 30). Like elevation, this factor does not explain differences between the trap sites: The species composition of the most continental localities in Kautokeino (M3 and M4) is similar to that of M1 in Alta and M1 on the coast in Porsanger (Figure 1 and Table 2). Lillehammer (1974: 228–229) describes *Leuctra digitata*, *Capnia pygmaea* and *Isoperla obscura* as continental species in Norway. This may be true for the southern and central parts of the country. In Finnmark, however, these three species were collected at many sites near the coast, also during the 2010 survey.

Cluster analysis of the trap sites revealed a high similarity of the sites along the Gargiaelva River in Alta (M 1 and M2), which are embedded in a larger cluster of sites characterised by fast running streams and stony bottoms. *Diura nanseni, Siphonoperla burmeisteri* and *Leuctra fusca* are characteristic species of this cluster. More generally this cluster is characterised by the presence of species belonging to the suborder *Systellognatha* Enderlein, 1909 whose nymphs are partly or wholly predatory (Brittain, 1990). These are differentiated from the broad bend in the river Náhpoljohka at Lahpoluoppal (M3) where the velocity is low, and the small stream in Baukop (M6). The Lahpoluoppal site has a stonefly fauna typical of slowly flowing streams with a preponderance of *Nemoura viki* and high numbers of *N. avicularis* Morton, 1894 and *Amphinemura borealis* (Morton, 1894). Baukop is characterised by the typical small stream species *Leuctra nigra* (Olivier, 1811).

Site M2 at Storeng along Gargiavannet, a lake-like broadening of the river Gargiaelva, looks topographically similar to the bend in the river Náhpoljohka at Lahpoluoppal (M3), yet the stonefly fauna of M2 is typical of river biotopes while the fauna of M3 is characteristic of lakes. Stream velocity may be higher in Gargiavannet, but this was not measured. Sites M1 and M2 are 2 km apart along the Gargiaelva River. Their species composition is almost identical, including the typical lotic stoneflies. However, the lentic aspect of Gargiavannet is reflected in the higher numbers of some Nemouridae, notably *N. avicularis*, *N. cinerea* (Retzius, 1783) and *Nemurella pictetii* Klapálek, 1900, and low numbers of *Leuctra fusca*. Nevertheless, the distinction between lake and river faunas is often less in Arctic and alpine regions owing to low temperatures and wind exposure. This also applies to stoneflies and some species such as *Arcynopteryx dichroa* (McLachlan, 1872), *Diura bicaudata* (Linnaeus, 1758) and *D. nanseni* (Kempny, 1900) that occur mainly in lakes and running waters, respectively, in southern Norway, are found in streams, rivers and lakes in northern Scandinavia (Lillehammer, 1988 : 61–65).

Sex ratio. Table 3 compares the sex ratio of stoneflies collected manually with those caught in Malaise traps. For the *Nemoura* species, numbers of identified females are shown but the sex ratio was not evaluated statistically because not all females of this genus were identified to species level.

Generally more females than males were collected. There are several possible explanations for this: Firstly, artefacts of the collecting technique. It is obvious that in species with sexual dimorphism in flight ability, the shortwinged, non-flying males are less efficiently collected with Malaise traps. This applies to *Arcynopteryx dichroa, Diura bicaudata* and *Isoperla difformis* (which was not collected at all). Incidentally, some males of *D. bicaudata* and nymphs of *D. nanseni* did end up in trap M4, presumably crawling up from vegetation under the tent.

Secondly, the flight period of early emerging species had commenced, and probably peaked, before collecting started in the first half of June (Table 3). The earliest species emerge in mid-May (cf. Tobias & Tobias 1976). Towards the end of

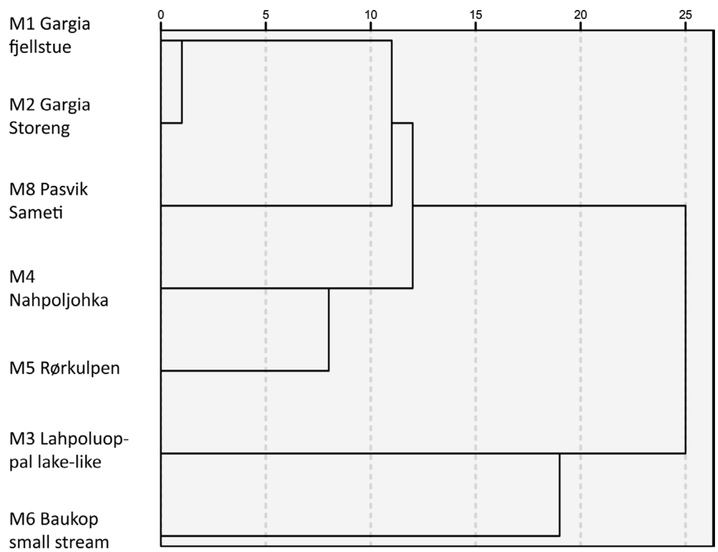

FIGURE 2. Clustering of Malaise traps based on species composition taking into account the relative abundance of each species. Dendrogram using average linkage between groups and squared Euclidian distances rescaled on a scale from 0 to 25.

the flight period females increasingly outnumber males in many common species (Lillehammer 1975, Petersen *et al.* 1999). The preponderance of females in the catch may therefore result from the longer lifetime and/or somewhat later flight period of females. This holds specifically for *Taeniopteryx nebulosa* (Linnaeus, 1785), *Capnia atra* Morton, 1896, *C. pygmaea* (Zetterstedt, 1840) and *Protonemura meyeri*.

Finally, in many species there really are more adult females than males. Petersen *et al.* (1999) established this with emergence traps in the UK for the common species *Leuctra hippopus*, *L. nigra*, *Nemoura cinerea* and *Nemurella pictetii*. Remarkably, more males than females of *I. obscura* (Zetterstedt, 1840) entered the Malaise traps, while the reverse was found for *I. grammatica* (Poda, 1761) in the two traps where it was abundant. This may be an indication that some *I. obscura* females were erroneously identified as *I. grammatica* in trap M4 where they co-occur. However, trap M8 also contained 1.5 times as many females as males of *I. grammatica*. The preponderance of males of *Amphinemura borealis* in trap catches is unexpected. However, it is highly significant and not restricted to particular traps or periods. Insufficient specimens were collected manually to allow for statistical comparison.

Species

This section provides additional comments on some of the stoneflies of the checklist of Finnmark. Collecting data are given below for the rarer species. All specimens are from Malaise traps (leg. Finnmarksprosjektet) unless indicated otherwise, identified by L. Boumans and housed at NHMO. Collection data for all species have been submitted to Artsdatabanken, and will also become available through the GBIF database.

Nomenclature. Four nomenclatural corrections should be made to the checklist of Norwegian stoneflies (Lillehammer 1988, Boumans 2011b, a) and to the online checklist Artsnavnebasen (artsdatabanken.no). **1)** In her review of the genus *Arcynopteryx* Klapálek, Teslenko (2012) pointed out that *A. dichroa* (McLachlan, 1872) is the correct name for the widespread Holarctic species that has been commonly referred to as *A. compacta*. **2)** The authority for *Xanthoperla apicalis* (Newman, 1836) should be written between parentheses. The species was originally described in the genus *Chloroperla*. **3)** Some literature sources (Lillehammer 1988; Fochetti and Tierno de Figueroa 2004) state the publication year of *A. palmeni* as 1916. Volume 44 of the journal Acta Societatis pro fauna et flora Fennica was published in eight issues from 1916 to 1919. The description of *A. palmeni* appeared in issue 3 dated 1917. **4)** The publication year of *Amphinemura sulcicollis* (Stephens, 1835) is stated as 1836 in some literature sources (Kimmins 1970; Lillehammer 1988: 43; Tierno de Figueroa *et al.* 2003: 176, 385; Fochetti and Tierno de Figueroa 2004). ‘Illustrations of British Entomology’ was published in eleven volumes from 1828 to 1835 and a supplement published in 1846. The description of *A. sulcicolis* (as *Nemoura sulcicollis*) appeared on page 143 of volume 10 dated 1835.

Isoperla difformis (Klapálek, 1909)

Old collection material checked. **FI**, Kautokeino: Aiddejavrre, elv [=Áidejávri], 28.VI.1972, leg. Lillehammer, collecting event label P2814: 31♂♂28♀♀, 4 skins.

Remarks. *Isoperla* females are identified by the shape of the subgenital plate, which is rectangular in *I. difformis*, rounded in *I. grammatica* and pointed in *I. obscura* (Lillehammer 1988: 51–52, 54). In some individuals, however, this character is difficult to judge. *Isoperla difformis* is the only Scandinavian species in which the males are shortwinged. In trap M4 Nahpoljohka some female *Isoperla* specimens were caught that are provisionally identified as either *I. grammatica* or *I. difformis*. Since no males of *I. difformis* were collected during the 2010 survey, neither in this trap, nor at any other locality, no new records for this species can be added. It is less common than *I. grammatica* and *I. obscura*. The online database Artskart (artskart.artsdatabanken.no) includes a few older records from Finnmark. Lillehammer (1974) collected *I. difformis* at four localities in Kautokeino but did not find it in Alta or Sør-Varanger. However, Tobias (1974) found small numbers in June in one stream in Sør-Varanger in the 1970s. This stream, Emanuelbekken, was also sampled in June and July 2010 but *I. difformis* was not found again. The specimens housed in the alcohol collection of the NHMO stem from a single collecting event and have been checked.

***Dinocras cephalotes* (Curtis, 1827)**

Remarks. This species was not collected during the 2010 survey. The Artskart database includes twenty records from Alta and Porsanger, all from the period 1979–1985. *Dinocras cephalotes* only occurs sparsely in the sub-alpine western and northern parts of Finnmark (Lillehammer 1974, 1987; 1988: 153). The lotic trap localities in Alta (M1 and M2) may constitute suitable biotopes for *D. cephalotes*, and possibly also M5 in Porsanger. Being the largest Scandinavian stonefly, it is hard to overlook. However, it is a stenothermal species whose eggs require a water temperature of at least 12°C before development can start (Lillehammer 1987; 1988: 72; Sand and Brittain 2001). It has a multivoltine life cycle, up to 5–6 years (Sand and Brittain 2001). The temperature requirements and the long life cycle may mean that adults of *D. cephalotes* are more common in some years than in others.

***Xanthoperla apicalis* (Newman, 1836)**

Remarks. This species was not collected during the 2010 survey. Tromsø University Museum (Univeristy of Tromsø) holds some specimens from Finnmark from 1908 and 1924 that need to be checked. It was not found during the faunistic surveys held in Finnmark in the 1970s (Lillehammer 1974; Tobias 1974; Tobias and Tobias 1976). Being restricted to larger rivers, *X. apicalis* is a truly rare species in Norway and elsewhere in Europe, cf. Boumans (2011a).

***Taeniopteryx nebulosa* (Linnaeus, 1758)**

Remarks. This species is common and widespread throughout Norway. Only four females were taken because the flight period was almost over when collecting started.

***Brachyptera risi* (Morton, 1896)**

Material. FV, Alta: Gargiaelva, ved Storeng, 90m a.s.l. (M2), N 69.8227° E 23.4788°, 26.VI–10.VII.2010, 1♂1♀; **FN**, Tana: Vestertana, Kjørebekken, 6m a.s.l., N 70.4258° E 27.8745°, 17.VI.2010, 1♀, leg. T. Ekrem.

Remarks. Only three specimens were collected. It is reported from the fjord and coastal areas of Finnmark (Lillehammer 1974), but it does not seem to be common in northernmost Scandinavia (cf. Tobias 1974; Tobias and Tobias 1976; Malmqvist 1999). Artskart has only fourteen additional records from the county.

***Amphinemura palmeni* (Koponen, 1917)**

Material. FØ, Sør-Varanger: Nordvest-bukta: Emanuelbekken, 62m a. s. l.,N 69.3035° E 29.2632°, 30.VII.2010, 9♂♂6♀♀; Sør-Varanger: Ellenelva, 67m a.s.l., N 69.2132° E 29.1535°, 30.VII.2010, 1♂1♀. All leg. L. Boumans, S. Roth & T. Ekrem, det. L. Boumans.

Remarks. There has been confusion about the validity and identity of this taxon. It has been confused with *A. standfussi*, which occurs at the same localities and also flies in late summer. The collection of fresh specimens in Sør-Varanger allowed clarification of the taxonomic issues. *Amphinemura palmeni* is in fact a valid, Holarctic species, and *A. linda* (Ricker, 1952) and *A. norvegica* Tobias, 1973 are junior synonyms (Boumans & Baumann 2012).

In the Palaearctic, *A. palmeni* is known only from northernmost Finland, Norway and the Kola Peninsula (Koponen 1917; Lillehammer 1988; Boumans & Baumann 2012). There are very few records, and the Norwegian Red List (Kjærstad *et al.* 2010) lists it as vulnerable (VU). So far all Norwegian records are from Sør-Varanger (Tobias 1973, 1974). It has not yet been reported from Sweden, but can probably be found in northernmost Lappland as it has been found in Finland 2 km from the Swedish border (Boumans & Baumann 2012). The new data confirm that *A. palmeni* is rare compared to the other three Fennoscandian *Amphinemura* species. However, re-inspection of *A. standfussi* specimens from northern Fennoscandia may yield additional records (cf. Meinander 1975). The descriptions below and Figures 3–10 are meant to facilitate the distinction between *A. palmeni* and *A. standfussi*. The following two paragraphs are repeated from

Boumans & Baumann (2012), where more illustrations are provided.

In the male, the organisation and number of spines on the median lobe of the paraproct provide good diagnostic characters: *A. standfussi* has a field of 8–14 smaller ventrally pointing spines on the central, posterior part of the lobe, and a second group of 3–4 outward pointing spines on the apex (i.e. dorsal part). See Figures 3–4; cf. also Figure 6 in Tobias (1973) and Figure 74D in Tierno de Figueroa *et al.* (2003: 175). The median lobe of *A. palmeni* bears on the central part 2–5 ventrally pointing spines that are larger than in *A. standfussi*, in addition to 3–4 outward pointing spines at the apex. See Figure 5 and Figure 5 in Tobias (1973). Secondly, the outer lobe of the paraproct is C-shaped in posterior view in *A. standfussi* and L-shaped in *A. palmeni* (Figures 3 and 5; cf. Figures 5–6 in Tobias 1973). This character is useful under lower magnification, but can be misinterpreted if not viewed at the right angle. A third character is the shape of the epiproct in lateral view: the epiproct of *A. standfussi* is knife-shaped (Figure 6), whereas it has a pre-distal dorsal hump in *A. palmeni* (Figure 8). See also Tobias (1973) Figures 4–5 and Figures 144–145 in Lillehammer (1988: 93). However, this is a variable character because the hump is partly caused by a patch of hairs that is sometimes bulged upward and sometimes not. Moreover, some *A. standfussi* individuals also have a (less pronounced) dorsal bulge (Figure 7), so that this character, if used on its own, can be misleading.
The females of *A. standfussi* and *A. palmeni* are distinguished by the different shapes of the subgenital plate. *Amphinemura standfussi* has a pair of lobe-shaped vaginal lobes, which are unpigmented and unsclerotised. To both sides of this pair is a smaller, usually sclerotised lobe. In *A. palmeni*, the vaginal lobes are fused with the neighbouring lobes, forming a single pair of broad, square pigmented and sclerotised lobes. In addition, the posterior edge of the 8th sternite bears a dark sclerotised, medially interrupted ridge. In *A. standfussi* this ridge is not sclerotised and therefore not clearly distinguishable. See Figures 9 and 10, and Figure 7 in Tobias (1973).

Nemoura Latreille, 1796 species

Table 4 compares the records of the *Nemoura* species in the 2010 survey with collecting data from Finnmark previously present in the Artskart database. Artskart records do not correspond exactly to either specimens or localities; two records may refer to collecting events differing only in the date, or even to different specimens collected at the same event. Nonetheless, the number of records gives an impression of the relative commonness of different species. The historical data suggest that *N. arctica* was among the commonest *Nemoura* species in Finnmark, while it was the least common in the 2010 survey. The reverse is true for *N. viki* and *N. sahlbergi*.

Nemoura arctica Esben-Petersen, 1910

Material. FN, Lebesby: Bukt ved Garnvika, rock pools, N 70.4228° E 26.7369°, 14m a.s.l., 17.VI.2010, 1♂, leg. T. Ekrem; **FI**, Kautekeino: Láhpojávri lake shore, N 69.2441° E 23.7924°, 36m a.s.l., 24.VII.2010, 1♂, leg. Boumans, Ekrem & Roth.

Remarks. This species was collected only twice, once near rock pools on the coast, and once on a sandy lake shore. Neither locality represents a typical biotope for stoneflies. Apart from an *Amphinemura sulcicollis* female on the sandy lake shore, no other stoneflies were found there.

Based on the historical records (Table 4) and Lillehammer's (1974, 1985; 1988: 114) faunistic descriptions, *N. arctica* was expected to be rather common in Finnmark, especially in the Kautokeino area. Tobias (1974) reports it as an abundant species in the river Pasvikelva in Sør-Varanger. It may, however, not occur on the Varanger Peninsula (Tobias & Tobias 1976). Lillehammer (1974: 235) notes "*The species occurs in small and large streams, in lakes and outlets, both in places with stable stone substrata and places with much fine sand and an unstable bottom. At higher altitudes (Middle-Alpine belt) the species may be the sole plecopteran species and in such localities can be very numerous.*" It is not clear why so few specimens have been collected in 2010. Possibly the higher altitudes (600–700m a.s.l.) in Kautokeino were insufficiently sampled. The most recent records

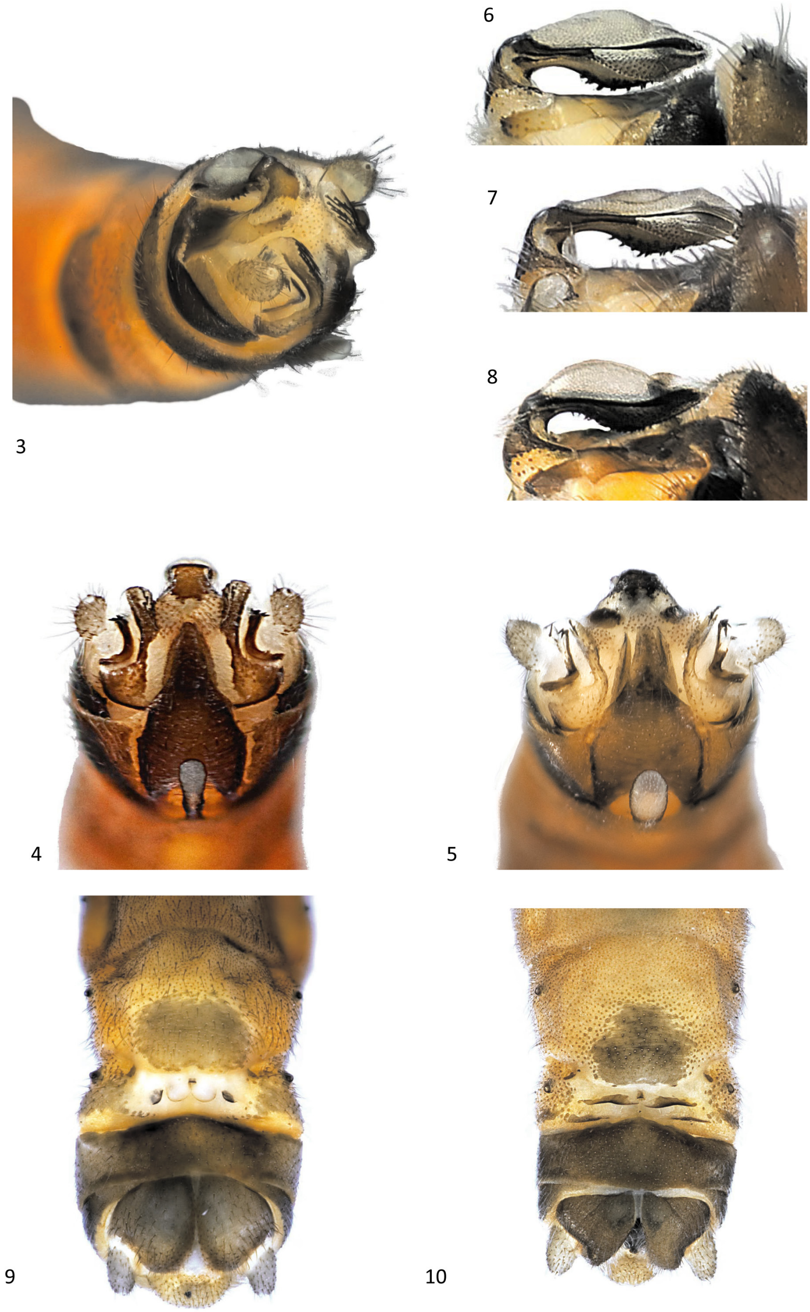

FIGURE 3–10. 3. *Amphinemura standfussi* (Ris, 1902), from Sør-Varanger, postero-lateral view. **4.** *Amphinemura standfussi* (Ris, 1902), Idem, male terminalia, posterior view. **5.** *Amphinemura palmeni* (Koponen, 1917) from Dunnings Spring, Iowa, USA, male terminalia, posterior view. **6.** Epiproct, lateral, *Amphinemura standfussi* (Ris, 1902) from Sør-Varanger. **7.** Idem, *Amphinemura standfussi* (Ris, 1902) from Skibotn, Troms Norway. **8.** Idem, *Amphinemura palmeni* (Koponen, 1917) from Dunnings Spring, Iowa USA. **9.** *Amphinemura standfussi* (Koponen, 1917) from Sør-Varanger, female abdomen, ventral. **10.** *Amphinemura palmeni* (Koponen, 1917) from Sør-Varanger, female abdomen, ventral. Photos: Karsten Sund.

TABLE 4. *Nemoura* Latreille, 1796 species in Finnmark: number of specimens and localities in the 2010 survey and number of previous records with their predominant time period in the Artskart database.

	2010 survey		Artskart database	
	Specimens	Localities	Records	Predominant period
Nemoura arctica Esben-Petersen, 1910	2	2	26	1972–1984
Nemoura avicularis Morton, 1894	234	8	62	1966–1989
Nemoura cinerea (Retzius, 1783)	235	17	130	1924, 1966–1989
Nemoura flexuosa Aubert, 1949	200	7	15	1966–1969, 1984
Nemoura sahlbergi Morton, 1896	55	7	5	1968–1979
Nemoura viki Lillehammer, 1972	54	5	1	1972

in Artskart date from 1984 (Alta in Finnmark) and 2004 (Troms county, various localities in Nordreisa and Harstad municipalities). It will be worthwhile to search specifically for *N. arctica* in order to establish whether it has declined in northern Norway since the late 1960s and early 1970s.

Nemoura sahlbergi **Morton, 1896**

Material. FV, Alta: Gargiaelva, ved Storeng (M2), 90m a.s.l., N 69.8227° E 23.4788°, 11–26. VI.2010, 3♂♂8♀♀; 26.VI–10.VII.2010, 7♂♂; Alta, Gargiaelven, ved Gargia Fjellstue (M1), 120m a.s.l., N 69.8052° E 23.4893°, 11–26. VI.2010, 1♂; 26.VI–10.VII.2010, 8♂♂1♂; **FI**, Kautekeino: Lahpoluoppal, ved innsjø (M3), 323m a.s.l., N 69.2099° E 23.7576°, 24.VII–5.VIII.2010, 3♂♂; 25.VI–9.VII.2010, 1♂; **FN**, Porsanger: Baukop, bekk fra Vuolit Gealbotjavri (M6), 24m a.s.l., N 70.2046° E 24.9060°, 15.VI–2.VII.2010, 4♂♂5♀♀; 17–26. VII.2010, 4♂♂2♀♀; 26.VII–25.VIII.2010, 1♀; Skoganvarre, Øvrevatn, 76m a.s.l., N 69.8439° E 25.0760°, 27.VII.2010, 1♂ leg. Boumans, Ekrem, Roth; Gaggavannet, 106m a.s.l., N 69.8237° E 25.2009°, 16.VI.2010, 2♂♂. leg. T. Ekrem; **FØ**, Sør-Varanger, Mikkelstad, bekk, 83m a.s.l., N 69.4112° E 29.8066°, 19.VI.2010, 4♂♂ leg. T. Ekrem.

Remarks. Literature records show that this was a common species in Finnmark (Lillehammer 1974; Tobias 1974; Tobias & Tobias 1976). However, until recently there were very few georeferenced records (Table 4). *Nemoura sahlbergi* was found both in larger, fast running streams and in small streams like the site of trap M4, Baukop, where it was one of the dominant species (Table 2). It was also collected at lake shores (Øvrevatn, Gaggavannet). DNA barcoding results indicate that it also occurs in North America (see below).

Nemoura viki **Lillehammer, 1972**

Material. FI, Kautokeino: Lahpoluoppal, ved innsjø, 323m a.s.l. (M3), N 69.2099° E 23.7576° 25.VI–9.VII.2010, 22♂♂2♀♀; 9–23.VII.2010, 3♂♂1♀; 24.VII–5.VIII.2010, 9♂♂2♀♀; **FN**, Porsanger: Rørkulpen, 28m a.s.l. (M5), N 70.1521° E 24.7668° 17–26.VII.2010, 1♂ leg. T. Ekrem; Baukop, bekk fra Vuolit Gealbotjavri 26m a.s.l. (M4), N 70.2046° E 24.9060°, 2–17. VII.2010, 1♀; 26.VII–24.VIII.2010, 1♂2♀♀; Gaggavann, myr 106m a.s.l., N 69.8237° E 25.2009° 16.VI.2010, 5♂♂2♀♀, leg. T. Ekrem; Lebesby: Eastorjavri, innsjø ved utløp, 250m a.s.l., N 70.4427° E 27.3482°, 28.VII.2010, 2♀♀, leg. Boumans, Ekrem, Roth; **FØ**, Sør-Varanger: Vann sør for 96-Høyden (location of M7), 149m a.s.l., N 69.4449° E 29.8990°, 20.VII.2010, 1♂ leg. T. Ekrem;

Remarks. Historical records show this species was common in Kautokeino and rather rare in Sør-Varanger, while it was not found in Alta or on the Varanger Peninsula (Lillehammer 1974; Tobias 1974; Tobias & Tobias 1976). The 2010 survey revealed many new localities for this species (Table 4). Unlike *N. sahlbergi*, it was only found in small streams, streams with slowly flowing water, and along lake shores. This concurs with the observations of Lillehammer (1974) and

Malmqvist (1999). It constituted 36% of the collected material of trap M3, the lake-like bend in the river Lahpoluoppal (Table 3).

Nemoura viki is an intriguing species because it is only known from a relatively small geographic area in the north of Fennoscandia (Meinander 1975, Lillehammer 1988, Malmqvist 1999), while Arctic species typically have a wide distribution (Downes 1962). A photograph of the epiproct is given in Figure 11 as to facilitate its identification under a binocular microscope. A picture of a slide preparation from the NHMO collection has been published in Boumans (2011b).

Lillehammer (1972a) conjectured that *N. viki* is closely related to the other Arctic species *N. artica*, *N. sahlbergi* and the Nearctic *N. trispinosa*. The male epiprocts of *N. arctica* and *N. viki* certainly look very similar (Boumans 2011b). However, no phylogenetic analysis of the genus has been published so far. COI sequences lend support to the hypothesis that *N. artica*, *N. sahlbergi* and *N. trispinosa* are relatively closely related, but suggest that N. *viki* is more closely related to *N. avicularis* (Figure 12).

FIGURE 11. *Nemoura viki* Lillehammer, 1972 male from Sør-Varanger, epiproct dorsal view. Photo: Karsten Sund.

Protonemura intricata **(Ris, 1902)**

Material. FV, Alta: Gargiaelva, ved Storeng, 90m a.s.l. (M1), N 69.8227° E 23.4788°, 10–23. VII.2010, 2♂♂2♀♀; 7–24.VIII.2010, 1♀ T. Ekrem; Gargiaelven, ved Gargia Fjellstue (M1), 120m a.s.l., N 69.8052° E 23.4893°, 26.VI–10. VII.2010, 19♂♂2♀♀; 10–23.VII.2010, 1♂4♀♀; 23.VII–6.VIII.2010, 3♂♂17♀♀; 23.VII.2010, 1♀ leg. Boumans, Ekrem, Roth; 7–24.VIII.2010, 1♂3♀♀; **FN**, Lebesby: Kunes, Austerelva, 10m a.s.l., N 70.3436° E 26.5192° 28.VII.2010, 1♂ leg. Boumans, Ekrem, Roth; Nesseby: Nyborg, bekk, 6m a.s.l., N 70.1775° E 28.6105° 28.VII.2010, 2♀♀ leg. Boumans, Ekrem, Roth; **FØ**, Sør-Varanger: Sametijohka, ved Sameti, 43m a.s.l. (M8), N 69.4010° E 29.7192°, 24.VI–20.VII.2010, 1♂1♀; Nordvest-bukta, Emanmuelbekken, 62m a.s.l., N 69.3035° E 29.2632°, 30.VII.2010, 1♀ leg. Boumans, Ekrem, Roth. (Part of these data was published previously in Boumans 2011a, 2011b.)

Remarks. This species is widespread in Europe (Illies 1978, Fochetti & Tierno de Figueroa 2004), but in Scandinavia it is restricted to the northernmost parts as it reached the peninsula only from the northeast (Lillehammer 1988: 125). Although it is listed as near threatened on the Norwegian Red List (Kjærstad *et al.* 2010), it was one of the commoner species in the present study (Table 2). It has only been found in coastal areas and in the Pasvik valley (Lillehammer 1974). Many specimens were collected in trap M1 along Gargiaelva River in Alta. The time series of this trap show the preponderance of males at the beginning and of females at the end of the flight period (within the trapping period 26 June–24 August). At this locality *P. intricata* co-occurs with the spring emerging species *P. meyeri*, but the flight periods were neatly distinct: the latter was only trapped between 11 and 26 June.

There are only few historical records from Norway. Lillehammer (1974) found only two specimens during his investigations in the 1960s; Tobias and Tobias found the species in one out of seventeen sampled localities Sør-Varanger (Tobias 1974), but not on the Varanger Peninsula (Tobias & Tobias 1976). However, the seven additional records in the Artskart database are from the Varanger Peninsula (Saltveit & Brabrand 1990), and the new locality in Nesseby is on the eastern neck of the peninsula. This suggests that *P. intricata* has become more widespread in Finnmark since the 1960s.

Protonemura meyeri **(Pictet, 1841)**

Remarks. This ubiquitous species was undersampled due to its early flight period. It was the subdominant species at the site of Malaise trap M8 Sameti (Table 2).

Capnia vidua **Klapálek, 1904**

Remarks. This stonefly has a scattered patchy distribution in the western Palaearctic, with several described subspecies of uncertain taxonomic status (Lillehammer 1972b,, Illies 1978, Graf & Wenzierl 2003). In Scandinavia it only occurs in the North, where it is rather rare. Lillehammer (1974) found it in Kautokeino, but not in Alta or Sør-Varanger. Tobias (1974) found a few specimens at one site in Sør-Varanger, but not on the Varanger Peninsula (Tobias & Tobias 1976). It occurs in small streams with unstable substrata (Lillehammer 1974, Malmqvist 1999).

It was not collected in the 2010 survey, possibly because the collecting effort concentrated on larger streams and lakes. Artskart contains ten records from the counties of Troms and Finnmark, where adult *C. vidua* have been collected in late June.

Leuctra digitata **Kempny, 1899 and *L. fusca*** **(Linnaeus, 1758)**

Remarks. These autumn emerging stoneflies co-occur in some localities, but *L. fusca* appears to be more closely associated with the larger, moderately or fast running streams (M1, M4 and M5), and *L. digitata* with small streams (Baukop, M6) and slowly running water as in the lake-like river bend of Lahpoluoppall (M3), see Table 2. This observation concurs with Malmqvist's (1999) findings on the relationship between stream width and species composition.

Leuctra hippopus **Kempny, 1899 and *L. nigra*** **(Olivier, 1811)**

Remarks. *Leuctra hippopus* and *L. nigra* are common spring emerging stoneflies co-occurring in many localities. However, *L. hippopus* was considerably more abundant in larger streams (trap localities M1, M2, M4 and M8, see Table 2). *Leuctra nigra* is known as a typical inhabitant of small streams (Lillehammer 1988: 149, Malmqvist 1999). This is confirmed by its abundance in the small stream in Baukop (M6), where both species were equally abundant. The slow running stream Rørkulpen (M5) had an intermediate position with four times as many *L. hippopus* as *L. nigra*.

DNA Barcoding

DNA barcoding of Norwegian stoneflies is currently ongoing. COI sequences have been produced for about half of the 35 Norwegian stonefly species, sampled from both southern and northern Norway. Samples from central, eastern and southern Europe have also been added for comparison. Barcoding yields interesting data on the colonisation of the Scandinavian Peninsula and Holarctic relationships. Some initial results are presented here.

Figure 12 shows a phylogenetic tree of the barcode sequences for the Norwegian *Nemoura* species, supplemented with hypothesised close relatives from North America. Note that none of the deeper nodes has statistical support, and that neither the taxon sampling nor the choice of genetic markers is suitable for phylogenetic studies at the genus level. The tree illustrates results of DNA barcoding at the level of species and closely related species groups.

Mitochondrial gene trees indicate by which dispersal routes stoneflies arrived in Scandinavia after the end of the last glacial period (10,000 years BP) from the South, the Northeast, or both (Lillehammer 1988: 25–27). Some widespread stonefly species are represented by a single haploclade in both southern and northern Norway. Examples are *Amphinemura borealis* and *A. sulcicollis* (Boumans & Baumann 2012), as well as *Nemoura cinerea* (Figure 12). Sequence data

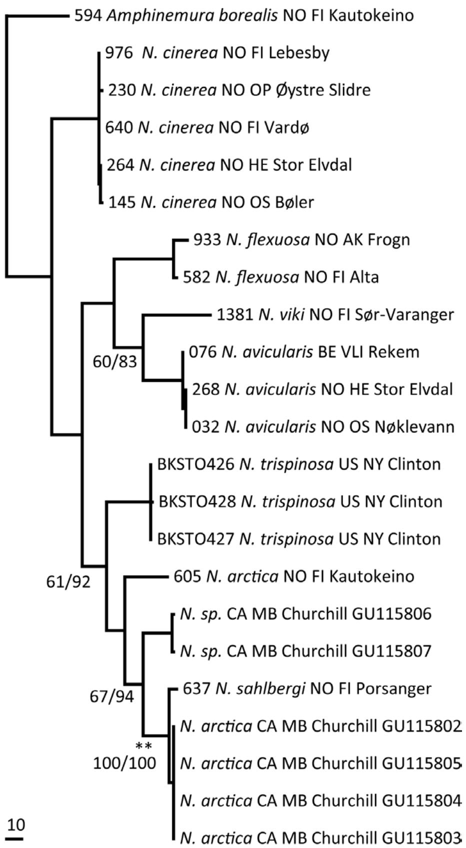

FIGURE 12. Barcoding sequences of the Norwegian *Nemoura* Latreille, 1796 species together with North American taxa that are hypothesised to be close relatives of the Arctic species, *N. arctica* Esben-Petersen, 1910, *N. sahlbergi* Morton, 1896 and *N. viki* Lillehammer, 1972. Neighbour joining tree with *Amphinemura borealis* (Morton, 1894) designated as outgroup species, based on 654 bp fragment of COI. Support values: *, ** indicate Bayesian posterior probability > 0.95 and > 0.99 respectively; MP and NJ bootstrap percentages are shown in this order separated by a slash. The monophyly of sequences attributed to the same species has maximal statistical support in all three analyses (not shown in the graph).

from other European populations are needed to infer the most likely dispersal route. On the other hand, *A. standfussi* has two distinct haploclades in Finnmark and in southern Norway, which differ by 2.8% uncorrected p distance (K2P 2.8). The southern haploclade is similar to haploclades found in the Netherlands and Germany (Boumans & Baumann 2012), whereas the haploclade from Finnmark also occurs in central Finland (unpublished data Jari Ilmonen). These data show that *A. standfussi* colonised the Scandinavian Peninsula from the South as well as the Northeast. The same pattern can be found in some of the other widespread Scandinavian stoneflies. *Nemoura flexuosa* may be a similar case (Figure 12), but more data are needed before a conclusion can be drawn. In cases of distinct southern and northern Scandinavian lineages, the question arises where the two meet and if they interbreed.

The COI sequences are also a useful tool to explore phylogenetic relationships with closely related Nearctic taxa. This is particularly useful for Arctic species, as many of these have a Holarctic distribution. The comparison of Fennoscandian and Nearctic stoneflies is greatly facilitated by DNA barcoding of aquatic insects at several institutions in the US and Canada, and in particular the large-scale inventory of the freshwater fauna of Churchill, Manitoba (Zhou *et al.* 2009, Zhou *et al.* 2010). DNA barcodes helped to identify *Amphinemura palmeni* as a Holarctic species, something that had been suspected on morphological grounds (Boumans & Baumann 2012).

Another example of Holarctic relationships was found in the genus *Nemoura*. *Nemoura arctica* is known to occur on both continents (Kondratieff & Baumann 2004, and references therein). However, the published North American barcode sequences labelled as *N. arctica* cluster with Scandinavian *N. sahlbergi* rather than *N. arctica* (Figure 12). The Canadian sequences labelled as *N. arctica* and the Scandinavian *N. sahlbergi* differ by 1.2% (K2P 1.2), which is less than the difference between Norwegian *N. flexuosa* from Akershus and Finnmark (1.7% or K2P 1,7). This indicates that *N. sahlbergi* is another Holarctic species, as has been suggested by Lillehammer (1988: 118), and that the Canadian specimens labelled as *N. arctica* are misidentified. *Nemoura sahlbergi* resembles the Nearctic *N. rickeri* Jewett 1971, and the latter name may be a junior synonym (Jewett 1971, Lillehammer 1986). However, it is also possible that the unidentified specimens with COI accession numbers GU115806–GU115807 belong to *N. rickeri* (cf. Figure 12). Morphological inspection of the Canadian voucher specimens is required in order to establish this. In July 2012 the BOLD database contained no sequences labelled as *N. rickeri*, nor sequences that cluster with the Scandinavian *N. arctica*.

Conclusions

Stoneflies are relatively well-studied in Norway. With 32 recorded species, Finnmark is the county with the highest species diversity. 28 of these were found during the 2010 survey (Ekrem *et al.* 2012). Sampling with Malaise traps showed that streams in Finnmark are remarkably species-rich by both Scandinavian and even European standards. Clustering trap sites by the incidence and abundance of stonefly species suggests three main habitat types for northern Scandinavian stoneflies a) streams with fast or moderately fast running water, b) slow running waters and c) very small streams. (Although the latter two categories contained only one trap each.) These observations confirm earlier findings on individual species' habitat preferences (Brinck 1949, Lillehammer 1974, 1988).

New records have been added for five rare or lesser known species. Of these, *Nemoura sahlbergi*, *N. viki*, and *Protonemura intricata* seem to be rather common in Finnmark, while *Amphinemura palmeni* and *N. arctica* appear to be rare. For a more complete and updated overview of the occurrence of stonefly species in Norway, further collecting effort should focus on documenting the distribution of the rare species, *Xanthoperla apicalis*, *A. palmeni* and *C. vidua*. Additional data on the occurrence of *N. arctica* should establish whether its distribution and abundance have declined since the 1970s.

DNA barcoding efforts are ongoing. Initial results clearly show that this is a helpful tool for detecting likely dispersal routes of stoneflies into the Scandinavian Peninsula, and for identifying closely related and potentially conspecific taxa in the Nearctic.

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APPENDIX 1. Collecting data and GenBank accession numbers for DNA barcode sequences (COI) of *Nemoura* species and outgroup *Amphinemura borealis*. BIOUG = Biodiversity Institute of Ontario, NHMO = Natural History Museum, University of Oslo.

Taxon	Country	State/county	Locality	Date	Leg.	Det.	Coll.	Field ID	GB accession
A. borealis	Norway	Finnmark	Kautekeino	24-Jul-2010	Boumans, Ekrem, Roth	L. Boumans	NHMO	594	JX495660
N. arctica	Norway	Finnmark	Kautekeino	24-Jul-2010	Boumans, Ekrem, Roth	L. Boumans	NHMO	605	JX905851
N. avicularis	Norway	Hedmark	Stor-Elvdal	30-Jun-2010	Boumans	L. Boumans	NHMO	268	JX905860
N. avicularis	Norway	Oslo	Nøklevann	09-May-2010	Boumans	L. Boumans	NHMO	32	JX905857
N. avicularis	Belgium	Limburg	Rekem	18-Mar-2010	Koese & Boumans	B. Koese	NHMO	76	JX905858
N. cinerea	Norway	Hedmark	Stor-Elvdal	30-Jun-2010	Boumans	L. Boumans	NHMO	264	JX905863
N. cinerea	Norway	Finnmark	Lebesby	28-Jul-2010	Boumans, Ekrem, Roth	L. Boumans	NHMO	976	JX905859
N. cinerea	Norway	Oslo	Bøler	15-Jun-2010	Boumans	L. Boumans	NHMO	145	JX495661
N. cinerea	Norway	Oppland	Fisketjernknausen	01-Jul-2010	Boumans	L. Boumans	NHMO	230	JX905854
N. cinerea	Norway	Finnmark	Vardø	29-Jul-2010	Boumans, Ekrem, Roth	L. Boumans	NHMO	640	JX905850
N. flexuosa	Norway	Finnmark	Alta	23-Jul-2010	Boumans, Ekrem, Roth	L. Boumans	NHMO	582	JX905856
N. flexuosa	Norway	Akershus	Frogn	10-Apr-2011	Boumans	L. Boumans	NHMO	933	JX905853
N. sahlbergi	Norway	Finnmark	Porsanger	27-Jul-2010	Boumans, Ekrem, Roth	L. Boumans	NHMO	637	JX905861
N. trispinosa	United States	New York	Clinton County	17-May-2010	Myers	B. Kondratieff	BIOUG		JX905855
N. trispinosa	United States	New York	Clinton County	17-May-2010	Myers	B. Kondratieff	BIOUG		JX905852
N. trispinosa	United States	New York	Clinton County	17-May-2010	Myers	B. Kondratieff	BIOUG		JX905862
N. viki	Norway	Finnmark	Sør-Varanger	20-Jul-2010	Ekrem	L. Boumans	NHMO	1381	JX905849