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Exploring water mites (Hydrachnidia) in calcareous freshwater habitats of Norway

REINHARD GERECKE, GAUTE KJÆRSTAD, TORBJØRN EKREM & ELISABETH STUR

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The water mite fauna inhabiting calcareous water bodies in Southeastern, Central, and Northern Norway was surveyed through the collection of 4334 specimens across 110 localities. Morphological identification combined with DNA barcoding revealed a total of 144 species, 132 of which were assigned Linnean names. Analysis of DNA barcodes uncovered 11 previously unrecorded taxa, some of which may represent species new to science. These lineages warrant further study to clarify their taxonomic status and ecological relationships. The study also explores a potential affinity of water mite assemblages for habitats with elevated calcium concentrations, with particular attention to the 19 species, 14 of them formally named, documented here as new records for Norway.

Key words: Hydrachnidia, water mites, habitat preference, calcareous waters, DNA barcoding, Norway.

Reinhard Gerecke, University of Tübingen, Faculty of Science, Department of Evolution and Ecology, DE-72074 Tübingen, Germany and Arachnologie, Senckenberg Forschungsinstitut, Mertonstr. 17-21, DE-60325 Frankfurt, Germany. E-mail: reinhard.gerecke@uni-tuebingen.de

Gaute Kjærstad, Department of Natural History, NTNU University Museum, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway. E-mail: gaute.kjarstad@ntnu.no

Torbjørn Ekrem, Department of Natural History, NTNU University Museum, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway. E-mail: torbjorn.ekrem@ntnu.no

Elisabeth Stur, Department of Natural History, NTNU University Museum, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway. E-mail: elisabeth.stur@ntnu.no

Introduction

Water mites are a diverse, polyphyletic group of arachnids, including representatives of various clades of mites. Most of them have terrestrial ancestors and developed secondary adaptations to submerged life (Gerecke & Di Sabatino 2008). This study focusses on true water mites (Hydrachnidia), of which at present approximately 7500 species within 485 genera are recognized worldwide (Smit 2020). The true number is likely much higher, since many geographical regions and habitats have not been surveyed yet, and DNA-based research has demonstrated that numerous traditionally accepted species are, in fact, species aggregates (e.g. Pešić et al. 2022, Tyukosova et al. 2022).

Comprehensive studies of Norwegian water mites began in the late 19th century with the activity of Sig Thor (1856 –1936). Following two incomplete national species catalogues (Mehl 1979, 1996), Gerecke et al. (2022) presented an updated record list, merging a critical review of all published data with then new unpublished

results, mostly deriving from a survey focusing on the fauna of southern Norway. This checklist included 187 species of which 46 previously were unrecorded.

Despite extensive faunistic and ecological documentation of the water mite faunas of Central and Northern European inland waters (e.g., Sweden: Lundblad 1968, The Netherlands: Smit 2018; Germany: a compilation given in Stevens & Gerecke 2023), there has been minimal focus on differences in water mite communities of water bodies with low versus high calcium levels. Schwoerbel (1959) dedicated a chapter to this topic in his research on the water mite fauna of the Black Forest, Southern Germany, and adjacent areas, based on the literature available at that time and data from his own work. He classified stream-dwelling water mites of his study region into five categories: 1. calciophobic; 2. distributed preferably on siliceous bedrock; 3. indifferent; 4. distributed preferably on calcareous bedrock; 5. restricted to calcareous streams. This matter has not been directly addressed since then, but new faunistic data from other areas of central Europe were often in contradiction to his ordination (e.g. Lundblad 1968, Lichtenwöhrer et al. 2019). Additional issues with his data arise due to recent developments in taxonomy, leaving the identity of some of his examined specimens and species uncertain.

Calcareous water bodies are known to harbor species-rich and characteristic invertebrate communities (e.g. Ekrem et al. 2010, Cantonati et al. 2016, Polášková et al. 2017, Pozojević & Pešić 2022). Unlike many other regions of Europe, Fennoscandia is predominantly characterized by siliceous bedrock where areas with limestone sediments, resulting in elevated calcium concentrations in the draining waters, are island-like scattered. There has been a significant reduction in the surface area of calcareous small water bodies over the past few decades (Dervo et al. 2018). Therefore, ponds, puddles and small lakes (< 5 km^2) as well as calcareous bogs and fens with highly elevated calcium levels (> 20 mg Ca/l), are listed as vulnerable in the Norwegian Red List of Ecosystem Types (Dervo et al. 2018). Calcareous lakes are due to their unique fauna and flora among the specifically selected nature types prioritized for conservation following the Norwegian Nature Diversity Act (Naturmangfoldloven 2009). Despite the threats facing these habitat types, their aquatic fauna remains insufficiently documented (Polášková et al. 2017).

This study is part of the Norwegian Taxonomy Initiative project "Water mites and non-biting midges in calcareous water bodies" (Artsprosjektet 2022). It builds upon the water mite inventory by Gerecke et al. (2022), and focuses on freshwater habitats with documented calcium levels above 20 mg/l. The aim is to increase the knowledge of water mite species associated with calcareous water bodies and provide quality assured inventories for such habitats in Norway.

Material and methods

In 2022 and 2023 fieldwork was conducted in various types of calcareous lotic and lentic waters in the southeastern, central and northern parts of Norway (Figure 1). The targeted localities were selected from maps indicating calcareous bed rock (Norges Geologiske Undersøkelse 2021) and from publications on calcareous lakes with Ca-values of at least 20 mg/l (e.g. Langangen 2011, Mjelde 2016). Calcium concentrations were determined in situ by a titrimetric test using a Merck KGaA 1.11110.0001 MQuant® analyzing kit, and pH and specific conductance (K_{25}) was measured with a WTW pH/Conductivity Measuring Instrument (Avantor 2025). Water mites were collected from different limnic microhabitats (i.e. water vegetation, stones, gravel, sand, clay, water column) using a net with mesh size of 250 µm. Living specimens were individually picked in the field, transferred to tubes with 96% ethanol, and then immediately stored in cool bags/refrigerators until identification in the lab.

For morphological investigation, gnathosoma, palps and selected legs were often detached and investigated under a Leitz Laborlux K microscope. In general, idiosoma and detached parts were slide mounted in Hoyers fluid or in glycerine jelly. In some instances, idiosoma and detached

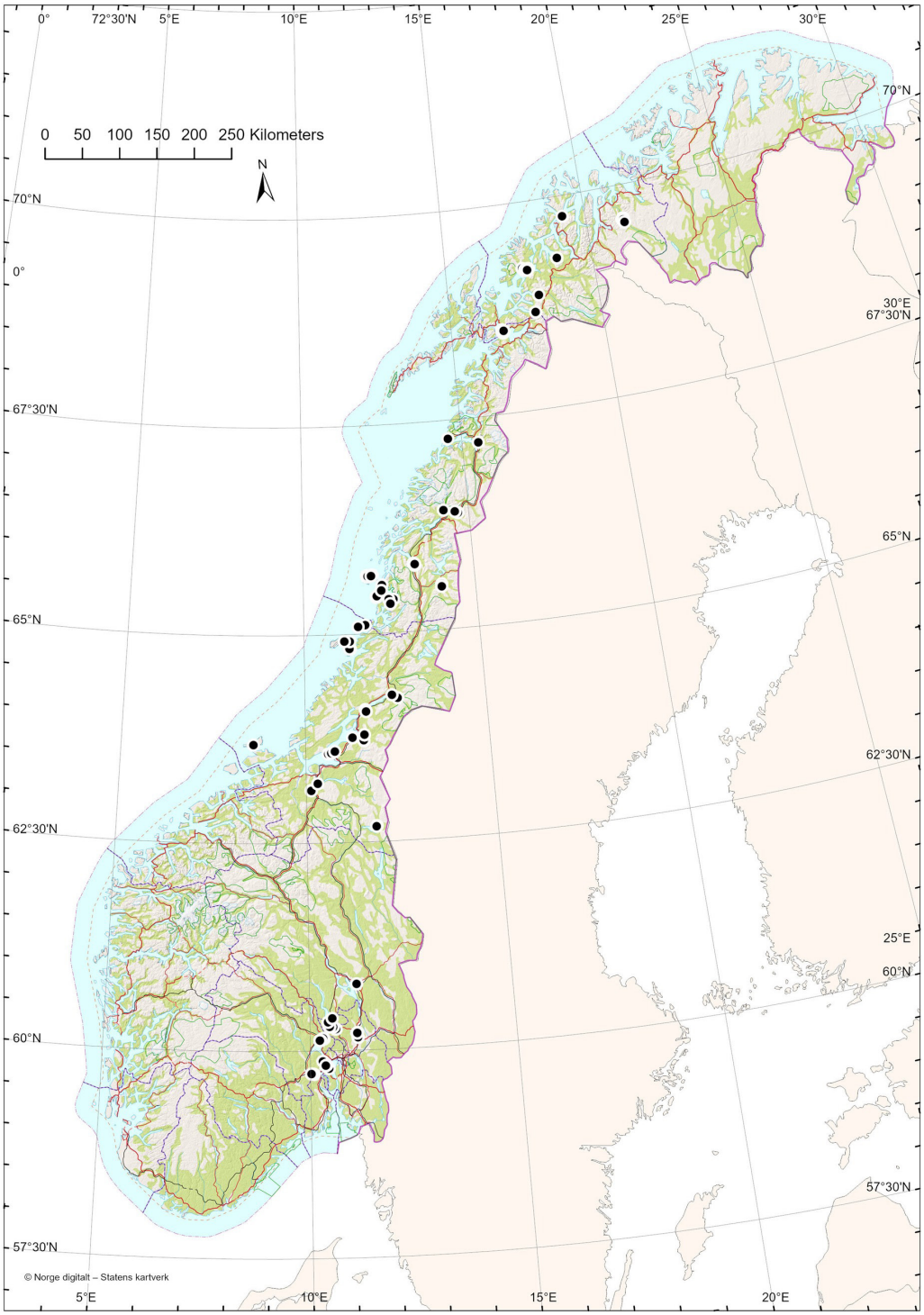

FIGURE 1. Collection sites for water mites in 2022 and 2023.

appendages were returned to 80% ethanol to be further preserved, with a remark about dissected parts on a label.

Morphological identification was based on the latest literature (Davids et al. 2007, Di Sabatino et al. 2010, Gerecke et al. 2016, Tyukosova et al. 2022) and original descriptions. A total of 392 specimens comprising 93 species were selected for DNA barcoding. The specimens were selected with the goal to obtain a fair representation of all species within their recorded distribution range. DNA was extracted from either dissected tissue (legs) or whole specimen using standard protocols for animal tissue at the Canadian Centre for DNA Barcoding (CCDB) at the University of Guelph. PCR and bidirectional Sanger sequencing were performed with the primer cocktail LepFolF and LepFolR (Hernández-Triana et al. 2014) using established protocols at CCDB. The sequences were edited and uploaded to the Barcode of Life Data Systems (BOLD). All barcode data and metadata are publicly available in the dataset "DS-CMMHY Water mites in calcareous water bodies" (Stur et al. 2025), dx.doi.org/10.5883/DS-CMMHY. All material is deposited in the scientific collections of the Museum of the Norwegian University of Science and Technology (Collection numbers: NTNU-VM 228713 – 229200 and 290629 – 291402). BOLD v4 was used to register geographical distribution of Barcode Index Numbers (BINs, Ratnasingham & Hebert 2013) as this version also displays private records.

When characterizing habitat preferences of water mites, we use the following terms:

Crenobiont: Species completing its life cycle exclusively in springs.

Crenophilous: Species with a preference for springs, but able to complete its life cycle also in other habitat types.

Crenoxenic: Species cannot complete their life cycle in springs, casually appearing in the community of a spring habitat.

Helocrene: Ground water-fed wetland, water diffusely poring to the surface through layers of fine sediment and detritus.

Lenitobiont: Living in stagnant waters.

Limnocrene: Spring fed by ground water that emerges into a pool of standing water.

Rheocrene: Spring fed by ground water immediately forming a small stream at the point of its emergence.

Rhithrobiont: Living in running waters.

Hyporheic: Habitats in the saturated portions of streambeds and banks, containing underground water flowing parallel to the stream that is to various degree in continuous exchange with the surface flow.

Quagfen: ground water fed fen with floating vegetation mats.

Results and discussion

A total of 4334 mite specimens were collected and assigned to 146 species of which 19 (14 with Linnean names and 5 with interim names) are recorded in Norway for the first time (Table 1). Of the 392 specimens selected for DNA barcoding, partial COI-sequences were successfully generated for 313 (~80% success). The barcodes obtained were assigned to 117 Barcode Index Numbers (BINs) in BOLD and mostly grouped by their assigned taxonomy based on morphology. Taking in account the exclusion of *Lebertia pusilla* from the list (in Gerecke et al. 2022 erroneously for *L. brigantina*) and the addition of *Ocybrachypoda celeripes* (see below, Aturidae), the number of water mite species recorded from Norwegian inland waters now totals 209, including three species of Halacaridae.

The various species were recorded at localities with different calcium concentrations (Table 2). Although there are indications that some taxa prefer calcareous waters, calcium concentration does not appear to be the limiting factor for presence of most water mite species (see below, discussion).

The taxonomic treatment below follows the traditional systematic order (e.g., Davids et al. 2007, Di Sabatino et al. 2010, Gerecke et al. 2016), while Table 2 lists all species alphabetically.

TABLE 1. Water mites new to Norway.

Species	Material
Arrenurus biscissus Lebert, 1879	**AK**, Asker: Finnsrudvannet, 59.83030°N 10.38718°E, 7.VI.2022, 1♂8♀♀, kick sample, leg. R. Gerecke & G. Kjærstad, coll. NTNU-VM 228767–228770.
Arrenurus inexploratus K. Viets, 1930	**AK**, Asker: Gjellumvannet, 59.78780°N 10.44326°E, 7.VI.2022, 1♂1♀, z-sweep, leg. R. Gerecke & G. Kjærstad, coll. NTNU-VM 228844 & 228845.
Arrenurus securiformis Piersig, 1895	**STI**, Melhus: Damtjønna, 63.13483°N 10.13358°E, 30.V.2022, 1♀, z-sweep, leg. R. Gerecke & G. Kjærstad, coll. NTNU-VM 228902. Skjersjøen, 63.13922°N 10.13143°E, 30.V.2022, 2♀♀, 15.VI.2022, 2♀♀, kick sample, leg. R. Gerecke & G. Kjærstad, NTNU-VM 228896 & 228897. Skjersjøen, 63.13717°N 10.12740°E, 30.V.2022, 2♀♀, z-sweep, 15.VI.2022, 3♀♀, z-sweep, leg. R. Gerecke & G. Kjærstad, coll. NTNU-VM 228898-228900. Skjersjøbekken, 63.13697°N 10.12637°E, 15.VI.2022, 2♀♀, kick sample, leg. R. Gerecke & G. Kjærstad, coll. NTNU-VM 228901.
Arrenurus sinuator (Müller, 1776)	**OS**, Lunner, Kalvsjøtjernet, 60.28771°N 10.56247°E, 8.VI.2022, 2♀♀, z-sweep, leg. R. Gerecke & G. Kjærstad, coll. NTNU-VM 228903 & 228904.
Arrenurus subarcticus Lundblad, 1917	**NNØ**, Evenes: Nautåvatnet, 68.49489°N 16.70889°E, 12.VII.2023, 1♂, z-sweep, leg. G. Kjærstad, coll. NTNU-VM 228935. **NSI**, Saltdal: Grytvikvatnet, 67.19865°N 15.50381°E, 13.VII.2023, 1♀, z-sweep, leg. G. Kjærstad, coll. NTNU-VM 228936. **NTI**, Snåsa: Lake in Muusdalen, 64.21476°N 12.56210°E, 10.VIII.2022, 1♀, z-sweep, leg. G. Kjærstad & K. Hårsaker, coll. NTNU-VM 228933. **STI**, Melhus: Skjersjøen, 63.13717°N 10.12740°E, 11.VII. 2022, 1♀, z-sweep, leg. G. Kjærstad, coll. NTNU-VM 228932. **TRY**, Senja: Litjevatnet, 69.18022°N 17.75123°E, 10.VII.2023, 1♀, kick sample, leg. G. Kjærstad, coll. NTNU-VM 228934.
Atractides lacustris (Lundblad, 1925)	**AK**, Viken: Ullensaker, Nordbytjern landskapsvernområde, Nordbytjernet, 60.15587°N 11.15848°E, 5.VI. 2022, 1♀, z-sweep, leg. R. Gerecke & G. Kjærstad, coll. NTNU-VM 228949.
Forelia variegator (Koch, 1837)	**BØ**, Drammen: Hagatjern, 59.72546°N 10.05901°E, 4.VI. 2022, 2♂12♀♀, kick sample, leg. R. Gerecke & G. Kjærstad, coll. NTNU-VM 229057–229059.
Lebertia brigantina K. Viets, 1933	**AK**, Asker: Verkenselva, 59.80491°N 10.39871°E, 7.VI.2022, 7♂♂3♀♀, kick sample, leg. R. Gerecke & G. Kjærstad, coll. NTNU-VM 229193. **BØ**, Drammen: Hagatjern, 59.72546°N 10.05901°E, 4.VI. 2022, 2♀♀, kick sample, leg. R. Gerecke & G. Kjærstad, coll. NTNU-VM 229191 & 229192. **TRY**, Senja: Langvatnet, 69.18924°N 17.76215°E, 9.VII.2022, 1♂, kick sample, leg. G. Kjærstad, coll. NTNU-VM 229194.
Lebertia holsatica K. Viets, 1920	**STI**, Melhus: Spring near Damtjønna, 63.13480°N 10.13281°E, 30.V.2022, 1♀, kick sample, leg. R. Gerecke & G. Kjærstad, coll. NTNU-VM 290642.
Oxus angustipositus K. Viets, 1908	**STI**, Melhus: Gammelelva, 63.21726°N 10.30783°E, 22.VIII.2022, 1♀1♂, z-sweep, leg. G. Kjærstad & E. Stur, coll. NTNU-VM 290946 & 290947. **NNØ**, Evenes: Nautåvatnet, 68.49489°N 16.70889°E, 12.VII.2023, 3 adults, z-sweep, leg. G. Kjærstad, coll. NTNU-VM 290945 & 290948.
Parathyas inepta (Lundblad, 1925)	**NSI**, Rana: Mårtjønna, 66.38199°N 14.67687°E, 15.VII.2023, 1♀, kick sample, leg. G. Kjærstad & K. Hårsaker, coll. NTNU-VM 291012.

TABLE 1. *continued*

Species	Material
Piona lacustricola K. Viets, 1949	**NTI**, Frosta: Beitemarksdammen, 63.58126°N 10.68967°E, 8.VIII.2022, 1♂, z-sweep, leg. G. Kjærstad & K. Hårsaker, coll. NTNU-VM 291064. **NSY**, Brønnøy: Hallarauntjønna, 65.40398°N 12.46316°E, 16.VII.2023, 4♀♀, z-sweep, leg. G. Kjærstad & K. Hårsaker, coll. NTNU-VM 291081. Vega: Olhåksådammen, 65.69632°N 11.88880°E, 17.VII.2023, 2♀♀, z-sweep, leg. G. Kjærstad & K. Hårsaker, coll. NTNU-VM 291065 & 291066.
Piona punctata (Neuman, 1875)	**AK**, Asker: Gjellumvannet, 59.78780°N 10.44326°E, 7.VI.2022, 7♀ 1 deutonymph, z-sweep, leg. R. Gerecke & G. Kjærstad, coll. NTNU-VM 291074. Finnsrudvannet, 59.83030°N 10.38718°E, 7.VI.2022, 6♀♀, kick sample, leg. R. Gerecke & G. Kjærstad, coll. NTNU-VM 291075. Padderudvannet, 59.82215°N 10.36345°E, 7.VII.2022, 5♀♀, z-sweep, leg. R. Gerecke & G. Kjærstad, coll. NTNU-VM 291052, 291053, 291060. Ullensaker: Nordbytjernet, 60.15587°N 11.15848°E, 5.VI.2022, 1♀, z-sweep, leg. R. Gerecke & G. Kjærstad, coll. NTNU-VM 291050. Ullensaker: Hersjøen, 60.21444°N 11.15219°E, 6.VI.2022, 6♀♀, kick sample, leg. R. Gerecke & G. Kjærstad, coll. NTNU-VM 291072. **BØ**, Drammen: Hagatjern, 59.72546°N 10.05901°E, 4.VI.2022, 1♀1♂, kick sample, leg. R. Gerecke & G. Kjærstad, coll. NTNU-VM 291049. Ringerike: Juveren, 60.12605°N 10.25533°E, 6.VI.2022, 1♂, kick sample, leg. R. Gerecke & G. Kjærstad, coll. NTNU-VM 291051. **NNØ**, Evenes: Nautåvatnet, 68.49489°N 16.70889°E, 12.VII.2023, 2♀♀, z-sweep, leg. G. Kjærstad, coll. NTNU-VM 291079. **NSY**, Brønnøy: Aunvatnet, 65.40108°N 12.60014°E, 16.VII.2023, 1♀, z-sweep, leg. G. Kjærstad & K. Hårsaker, coll. NTNU-VM 291080. Brønnøy: Tilremsvatnet, 65.51337°N 12.26493°E, 18.VII.2023, 1♀, z-sweep, leg. G. Kjærstad & K. Hårsaker, coll. NTNU-VM 291082. Vega: Olhåksådammen, 65.69632°N 11,88880°E, 17.VII.2023, 7♀♀, z-sweep, leg. G. Kjærstad & K. Hårsaker, coll. NTNU-VM 291067. **NTY**, Nærøysund: Staverengvatnet, 64.82625°N 11.30524°E, 11.VIII.2022, 1♀, z-sweep, leg. G. Kjærstad & K. Hårsaker, coll. NTNU-VM 291069. **OS**, Lunner: Galtedalstjerna, 60.28883°N 10.47007°E, 9.VI.2022, 19♀♀2♂♂, z-sweep, leg. R. Gerecke & G. Kjærstad, coll. NTNU-VM 291054, 291055-291057, 291214. Lunner: Kalvsjøtjernet, 60.28771°N 10.56247°E, 8.VI.2022, 4♀♀, z-sweep, leg. R. Gerecke & G. Kjærstad, coll. NTNU-VM 291076. Lunner: Markatjernet, 60.29092°N 10.47990°E, 9.VI.2022, 13♀♀1♂, z-sweep, leg. R. Gerecke & G. Kjærstad, coll. NTNU-VM 291058, 291061, 291062. Gran: Jarenvannet, 60.39123°N 10.54420°E, 9.VI.2022, 2♀♀, z-sweep, leg. R. Gerecke & G. Kjærstad, coll. NTNU-VM 291059, 291063. **STY**, Frøya: Kavldalen, pond north, 63.68941°N 8.58363°E, 29.VI.2022, 2♀♀, kick sample, leg. G. Kjærstad, coll. NTNU-VM 291077. Frøya: Kavldalen, pond south, 63.68849°N 8.58485°E, 29.VI.2022, 6♀♀, z-sweep, leg. G. Kjærstad, coll. NTNU-VM 291078.
Unionicola figuralis (Koch, 1836)	**STI**, Melhus: Gammelelva, 63.21726°N 10.30783°E, 22.VIII.2022, 3♂♂, z-sweep, leg. G. Kjærstad & E. Stur, coll. NTNU-VM 291382-291384.

TABLE 2. Water mite taxa (Hydrachnidia and Halacaridae) recorded in the project, with environmental variables; Ca = calcium, Cond. = conductivity, pH, Elev. = elevation; n loc = number of localities where each taxon was recorded. The number of localities where calcium, conductivity and pH was measured is given in square brackets. Literature with records of water mites from habitats with low calcium concentration are given in the column "Ca-poor habitat" 1) Gerecke et al. (2022), 2) Gerecke et al. (2016), 3) Davids et al. (2007), 4) Lundblad (1968), 5) Schwoerbel (1959), 6) Schwoerbel (1956), 7) Van Haaren & Tempelman (2009).

Taxon	Ca (mg/l) Mean (range)		Cond. (µS/cm) Mean (range)		pH (range)		Elev. (m.a.s.l) Mean (range)	n loc	Ca-poor habitat
Arrenurus albator	51 (24-100)	[13]	314 (157-409)	[13]	(6.2-8.5)	[10]	130 (1-359)	14	1
Arrenurus bicuspidator	59 (32-82)	[8]	322 (256-391)	[8]	(7.5-8.5)	[8]	196 (63-359)	8	4
Arrenurus biscissus	54	[1]	342	[1]	7.5	[1]	176	1	
Arrenurus bruzelii	63 (40-100)	[3]	392 (204-594)	[3]	(7.6-8)	[3]	133 (29-189)	3	1
Arrenurus buccinator	44 (22-142)	[11]	256 (111-741)	[11]	(5.3-8)	[6]	99 (2-418)	11	1,2
Arrenurus compactus	39 (34-45)	[3]	215 (183-292)	[3]	(7.3-7.9)	[3]	238 (3-338)	3	1,4
Arrenurus crassicaudatus	65 (50-82)	[3]	431 (308-594)	[3]	(7.5-7.9)	[3]	173 (159-189)	3	1
Arrenurus forpicatus	44 (22-80)	[10]	242 (111-339)	[10]	(5.3-8.5)	[10]	85 (3-234)	10	1,2
Arrenurus globator	52 (22-158)	[28]	304 (111-675)	[28]	(5.3-8.5)	[22]	109 (1-472)	28	1,2
Arrenurus inexploratus	32	[1]	219	[1]	7.7	[1]	97	1	2
Arrenurus kjerrmanni	39 (24-55)	[10]	198 (132-378)	[10]	(5.4-8.5)	[8]	132 (1-338)	10	1,4
Arrenurus leuckarti	(44-58)	[2]	(190-289)	[2]	(7.8-8)	[2]	(255-455)	2	1,2
Arrenurus mediorotundatus	100	[1]	377	[1]	(8-8)	[1]	181	1	1,2
Arrenurus membranator	38 (28-52)	[6]	256 (118-387)	[6]	7.2	[1]	111 (1-472)	6	
Arrenurus neumani	45 (20-82)	[16]	252 (88-594)	[16]	(6.7-8.1)	[14]	167 (3-356)	16	1,4
Arrenurus pustulator	44	[1]	208	[1]	-	-	19	1	2
Arrenurus securiformis	40 (34-44)	[3]	201 (183-212)	[3]	(7.4-7.9)	[3]	276 (255-338)	3	
Arrenurus sinuator	50	[1]	256	[1]	8	[1]	359	1	
Arrenurus stecki	(64-100)	[2]	(308-377)	[2]	(7.9-8)	[2]	(159-181)	2	2
Arrenurus stjordalensis	(36-40)	[2]	(147-187)	[2]	-	-	(3-246)	2	1,4
Arrenurus subarcticus	40 (30-45)	[5]	182 (147-212)	[5]	(7.1-8)	[2]	216 (17-423)	5	4
Arrenurus tricuspidator	52 (48-58)	[3]	291 (256-328)	[3]	(7.8-8)	[3]	334 (188-455)	3	4
Arrenurus truncatellus	61 (32-100)	[3]	397 (219-594)	[3]	(7.6-8)	[3]	156 (97-189)	3	4
Arrenurus zachariae	(26-70)	[2]	(209-355)	[2]	(7.3-7.8)	[2]	(25-255)	2	1
Atractides lacustris	48	[1]	328	[1]	7.8	[1]	188	1	
Atractides nodipalpis	34 (18-58)	[6]	198 (71-428)	[6]	(7.3-7.8)	[3]	131 (20-226)	6	1
Atractides ovalis	65 (48-100)	[11]	351 (256-439)	[11]	(7.5-8)	[11]	220 (159-359)	11	1
Atractides tener	50 (26-96)	[6]	271 (110-434)	[6]	(7-7.8)	[5]	184 (19-473)	6	1

TABLE 2. *continued*

Taxon	Ca (mg/l) Mean (range)		Cond. (µS/cm) Mean (range)		pH (range)		Elev. (m.a.s.l) Mean (range)	n loc	Ca-poor habitat
Aturus scaber	(36-58)	[2]	331 (234-428)	[2]	(7.5-7.8)	[2]	(148-226)	2	1
Brachypoda versicolor	43 (25-82)	[17]	232 (125-409)	[17]	(5.4-7.8)	[8]	135 (2-313)	17	1
Eylais infundibulifera	45 (32-58)	[2]	(289-323)	[2]	(7.8-8.5)	[2]	(63-455)	2	1
Eylais koenikei	32	[1]	219	[1]	7.7	[1]	97	1	1
Forelia liliacea	38 (20-55)	[21]	230 (88-350)	[21]	(5.4-7.5)	[6]	41 (1-234)	21	1
Forelia longipalpis	35 (20-48)	[3]	201 (88-328)	[3]	7.8	[1]	65 (3-188)	3	
Forelia variegator	26	[1]	209	[1]	7.8	[1]	255	1	
Huitfeldtia rectipes	39 (36-45)	[3]	273 (212-350)	[3]	-	-	49 (3-138)	3	4
Hydrachna conjecta	36	[1]	247	[1]	-	-	10	1	
Hydrachna cruenta	-	-	-	-	-	-	-	1	
Hydrachna geographica	82	[1]	391	[1]	7.5	[1]	(171-247)	2	
Hydrachna globosa	85 (32-158)	[3]	476 (323-675)	[3]	(7.7-8.5)	[3]	138 (63-186)	3	1
Hydrochoreutes krameri	44 (20-80)	[9]	249 (88-431)	[9]	(6.6-8)	[5]	55 (2-186)	9	1
Hydrodroma despiciens	50 (20-158)	[37]	275 (111-675)	[37]	(5.3-8.7)	[28]	151 (1-423)	38	1
Hydrodroma pilosa	55 (32-82)	[9]	336 (219-439)	[9]	(7.5-8.5)	[9]	188 (63-313)	9	1
Hygrobates calliger	(18-36)	[2]	(71-234)	[2]	(7.3-7.5)	[2]	(120-148)	2	1
Hygrobates fluviatilis	33 (18-44)	[8]	213 (71-394)	[8]	(7.3-8.7)	[3]	74 (2-170)	8	1
Hygrobates foreli	39 (22-64)	[10]	200 (113-394)	[10]	(5.4-7.7)	[5]	131 (17-425)	10	1
Hygrobates longiporus	(26-66)	[2]	(209-431)	[2]	(7.8-8)	[2]	(186-255)	2	1
Hygrobates norvegicus	56 (26-96)	[8]	261 (110-434)	[8]	(6.4-7.8)	[8]	376 (25-781)	9	1
Hygrobates prosiliens	40 (22-64)	[14]	231 (113-439)	[14]	(5.4-8.1)	[8]	116 (5-313)	14	1
Hygrobates setosus	(20-58)	[2]	(173-428)	[2]	(7.8-8.7)	[2]	(21-226)	2	1
Hygrobates trigonicus	36	[1]	187	[1]	-	-	3	1	
Kongsbergia materna	(18-58)	[2]	(71-428)	[2]	(7.3-7.8)	[2]	(120-226)	2	
Lebertia brevipora	(25-36)	[2]	(155-257)	[2]	6	[1]	(6-24)	2	
Lebertia brigantina	36 (26-46)	[3]	212 (193-234)	[3]	(7.5-7.8)	[2]	186 (148-255)	3	
Lebertia contracta	(42-46)	[2]	(247-253)	[2]	(6.6-6.6)	[2]	(4-16)	2	
Lebertia fimbriata	43 (25-58)	[5]	232 (125-428)	[5]	(7.5-7.8)	[3]	119 (30-226)	5	1
Lebertia gibbosa	(22-36)	[2]	(153-174)	[2]	5.4	[1]	(17-418)	2	1
Lebertia glabra	24	[1]	88	[1]	7.1	[1]	103	1	
Lebertia holsatica	42	[1]	196	[1]	6.5	[1]	340	1	
Lebertia inaequalis	44 (36-64)	[8]	240 (149-394)	[8]	5.4	[1]	88 (2-234)	8	1

TABLE 2. *continued*

Taxon	Ca (mg/l) Mean (range)		Cond. (µS/cm) Mean (range)		pH (range)		Elev. (m.a.s.l) Mean (range)	n loc	Ca-poor habitat
Lebertia insignis	26 (18-30)	[4]	129 (71-153)	[4]	7.3	[1]	120 (19-171)	4	1
Lebertia litoralis	39 (22-50)	[8]	205 (147-338)	[7]	(7.5-8)	[3]	255 (138-418)	8	
Lebertia obscura	39 (28-48)	[7]	188 (118-247)	[7]	(5.4-7.4)	[3]	112 (8-218)	8	1
Lebertia porosa aggr. sp. A	36 (28-64)	[8]	204 (118-394)	[8]	7.2	[1]	81 (4-172)	8	
Lebertia porosa aggr. sp. E	28	[1]	118	[1]	-	-	46	1	
Lebertia sefvei	35 (24-42)	[3]	158 (88-196)	[3]	(6.4-7.1)	[3]	399 (103-753)	3	1
Lebertia stigmatifera	46 (22-96)	[9]	207 (88-434)	[9]	(6.4-7.8)	[7]	287 (30-781)	9	1
Limnesia connata	50	[1]	337	[1]	7.8	[1]	313	1	1,4,6,7
Limnesia curvipalpis	39 (30-48)	[6]	261 (167-378)	[6]	(7-8.5)	[6]	55 (1-196)	6	1
Limnesia fulgida	(50-54)	[2]	468 (342-594)	[2]	(7.5-7.6)	[2]	(176-189)	2	1, 4
Limnesia koenikei	40 (30-48)	[21]	235 (142-378)	[21]	(5.4-8.5)	[5]	58 (1-234)	21	1
Limnesia maculata	47 (20-100)	[29]	279 (88-594)	[29]	(5.4-8.5)	[17]	121 (1-359)	29	1
Limnesia undulata	58 (26-80)	[4]	354 (209-439)	[4]	(7.6-8)	[4]	203 (172-255)	4	1
Limnesia undulatoides	38 (22-50)	[9]	284 (193-353)	[9]	(7-8)	[2]	43 (1-359)	9	1
Limnochares aquatica	52 (28-100)	[24]	288 (132-594)	[25]	(6.6-8.5)	[22]	160 (3-356)	25	1,3
Ljania bipapillata	57 (18-96)	[3]	311 (71-434)	[3]	(7.3-7.8)	[3]	185 (120-226)	3	1
Mesobates forcipatus	38 (28-44)	[3]	245 (153-394)	[3]	-	-	43 (19-88)	3	1
Midea orbiculata	68 (32-100)	[4]	345 (290-391)	[4]	(7.5-8.5)	[4]	178 (63-296)	4	1
Mideopsis crassipes	(44-64)	[2]	(308-394)	[2]	7.9	[1]	(21-159)	2	1
Mideopsis orbicularis	50 (26-82)	[16]	290 (156-431)	[16]	(5.4-8)	[11]	131 (2-359)	16	1
Mideopsis roztoczensis	34 (18-48)	[3]	211 (71-328)	[3]	(7.3-7.8)	[3]	152 (120-188)	3	1
Mixobates processifer	(42-44)	[2]	(187-339)	[2]	-	-	(2-88)	2	1
Neumania callosa	22	[1]	153	[1]	-	-	418	1	2
Neumania limosa	73 (26-158)	[11]	362 (209-675)	[11]	(7.5-8)	[11]	211 (158-359)	11	1
Neumania spinipes	39 (22-50)	[6]	289 (111-594)	[6]	(5.3-7.6)	[3]	84 (2-189)	6	1
Neumania vernalis	49 (48-50)	[3]	420 (328-594)	[3]	(7.6-7.8)	[3]	230 (189-313)	3	1
Oxus angustipositus	(30-42)	[2]	(156-247)	[2]	6.6	[1]	(16-17)	2	
Oxus carpenteri	39 (20-62)	[18]	217 (88-439)	[18]	(5.4-8)	[7]	136 (1-472)	18	1
Oxus longisetus	40 (24-54)	[5]	270 (157-342)	[5]	(6.2-8.5)	[4]	175 (63-356)	5	1
Oxus musculus	41 (32-48)	[4]	308 (266-353)	[4]	(7.5-8.5)	[2]	18 (2-63)	4	1

TABLE 2. *continued*

Taxon	Ca (mg/l) Mean (range)		Cond. (µS/cm) Mean (range)		pH (range)		Elev. (m.a.s.l) Mean (range)	n loc	Ca-poor habitat
Oxus ovalis	43 (30-55)	[9]	260 (174-378)	[9]	(5.4-8.5)	[7]	65 (1-356)	9	1
Oxus setosus	28	[1]	118	[1]	-	-	46	1	
Oxus strigatus	44 (26-66)	[5]	292 (155-431)	[5]	(7.5-8)	[4]	175 (2-255)	5	1
Panisus michaeli	46 (36-70)	[5]	257 (173-355)	[5]	(6.4-7.3)	[5]	551 (25-781)	5	
Parathyas dirempta	32	[1]	219	[1]	7.7	[1]	97	1	
Parathyas inepta	40	[1]	188	[1]	-	-	218	1	
Parathyas pachystoma	32	[1]	219	[1]	7.7	[1]	97	1	
Parathyas thoracata	32	[1]	219	[1]	7.7	[1]	97	1	
Piona alpicola	(25-36)	[2]	(155-257)	[2]	6	[1]	15	2	1
Piona carnea	52 (40-70)	[5]	263 (190-439)	[5]	(7.1-8)	[5]	273 (200-423)	5	
Piona carnea aggr. sp. 1	48 (25-83)	[3]	259 (155-364)	[3]	(6-6.8)	[2]	22 (6-35)	3	
Piona coccinea	45 (25-66)	[4]	282 (127-431)	[4]	(5.9-8)	[3]	98 (5-186)	4	1
Piona coccinoides	(42-45)	[2]	(247-292)	[2]	(6.6-7.5)	[2]	(3-16)	2	1
Piona conglobata	58 (44-80)	[4]	229 (198-387)	[4]	(6.7-8.5)	[3]	45 (1-172)	4	
Piona discrepans	39 (35-45)	[4]	192 (174-212)	[4]	(5.4-8.1)	[3]	92 (17-170)	4	1
Piona lacustricola	33 (22-48)	[3]	199 (111-353)	[3]	5.3	[1]	45 (6-105)	3	1
Piona laminata aggr. sp. 1	60 (42-142)	[7]	362 (190-741)	[7]	(7.1-8)	[6]	245 (41-423)	7	1
Piona laminata aggr. sp. 2	48	[1]	328	[1]	7.8	[1]	188	1	
Piona laminata aggr. sp. 3	32 (25-38)	[4]	174 (125-223)	[3]	(7.5)	[1]	83 (4-231)	4	
Piona longipalpis	45 (25-66)	[9]	273 (142-439)	[9]	(6-8.1)	[7]	102 (6-200)	9	1,4
Piona neumani	51 (48-54)	[3]	268 (205-342)	[3]	(7.5-8)	[2]	241 (176-359)	3	1
Piona paucipora	37 (30-45)	[6]	202 (142-350)	[6]	5.4	[1]	96 (3-246)	6	1
Piona punctata	43 (20-66)	[18]	224 (88-439)	[18]	(6.7-8.7)	[13]	132 (5-359)	18	1
Piona pusilla	47 (40-52)	[4]	303 (256-387)	[3]	8	[1]	90 (0-359)	4	1
Piona pusilla aggr. sp. 1	45 (30-56)	[8]	276 (205-353)	[8]	(6.6-7.9)	[6]	160 (4-356)	8	1
Piona pusilla aggr. sp. 4	(64-82)	[2]	350 (308-391)	[2]	(7.5-7.9)	[2]	(159-171)	2	
Piona rotundoides	41 (30-66)	[15]	244 (156-431)	[15]	(5.4-8)	[3]	73 (2-234)	15	1
Piona stjordalensis	40 (30-48)	[6]	284 (227-353)	[6]	(6.6-7.5)	[2]	6 (2-16)	6	4
Piona variabilis	57 (36-82)	[10]	337 (178-594)	[10]	(7.5-8)	[8]	192 (5-359)	10	1
Pionacercus leuckarti	41 (30-55)	[8]	190 (142-266)	[8]	6.7	[1]	96 (2-187)	8	4
Pionacercus norvegicus	42	[1]	227	[1]	7	[1]	430	1	1

TABLE 2. *continued*

Taxon	Ca (mg/l) Mean (range)		Cond. (µS/cm) Mean (range)		pH (range)		Elev. (m.a.s.l) Mean (range)	n loc	Ca-poor habitat
Pionacercus uncinatus	28 (20-36)	[4]	158 (88-239)	[4]	5.4	[1]	12 (2-23)	4	1
Pionopsis lutescens s.l.	51 (24-83)	[12]	296 (157-594)	[12]	(6.2-8.1)	[11]	138 (3-359)	12	
Porolohmanella violacea	22	[1]	111	[1]	5.3	[1]	105 (105-105)	1	1
Sperchon brevirostris	36 (18-58)	[5]	166 (71-269)	[5]	(7.3-7.7)	[2]	72 (20-120)	5	1
Sperchon clupeifer	(18-36)	[2]	(71-234)	[2]	(7.3-7.5)	[2]	(120-148)	2	1
Sperchon glandulosus aggr. sp. 1	18	[1]	71	[1]	7.3	[1]	120	1	
Sperchon glandulosus aggr. sp. 2	35 (24-44)	[4]	205 (88-394)	[4]	7.1	[1]	96 (21-170)	4	
Sperchon papillosus	28	[1]	153	[1]	-	-	20	1	
Sperchon squamosus	44 (26-66)	[3]	255 (110-431)	[3]	(7-8)	[3]	361 (186-473)	3	1
Sperchonopsis verrucosa aggr. sp. 1	58	[1]	428	[1]	7.8	[1]	226	1	
Sperchonopsis verrucosa aggr. sp. 2	58	[1]	428	[1]	7.8	[1]	226	1	
Teutonia cometes	38 (26-48)	[10]	197 (142-339)	[10]	(5.4-7.8)	[3]	129 (2-255)	10	1
Thyasides dentatus	-	-	-	-	-	-	-	1	
Tiphys bullatus	48	[1]	167	[1]	7	[1]	196	1	
Tiphys latipes	35 (32-36)	[3]	196 (174-219)	[3]	(5.4-7.7)	[3]	195 (17-472)	3	4
Tiphys scaurus	40	[1]	178	[1]	-	-	146	1	1,4
Tiphys torris	44 (40-46)	[6]	258 (193-378)	[6]	(6.6-8.5)	[3]	122 (1-430)	6	1
Torrenticola amplexa	37 (18-58)	[5]	256 (71-428)	[5]	(7.3-7.8)	[3]	107 (19-226)	5	1
Torrenticola brevirostris	36	[1]	234	[1]	7.5	[1]	148	1	1
Unionicola crassipes	49 (20-100)	[16]	283 (88-431)	[16]	(6.7-8.5)	[12]	132 (2-359)	17	1
Unionicola figuralis	42	[1]	247	[1]	6.6	[1]	16	1	
Unionicola gracilipalpis	44 (36-55)	[4]	246 (198-292)	[4]	(6.6-7.5)	[3]	9 (3-16)	4	1
Unionicola minor	62 (32-100)	[7]	342 (219-431)	[7]	(7.7-8)	[7]	207 (97-313)	7	1

SUPERFAMILY EYLAOIDEA

Family Eylaidae

There is an urgent need for taxonomic revision of the European species within the genus *Eylais* Latreille, 1796 (Gerecke et al. 2022). This is also reflected in BOLD, where most records are published without a species name, or where different names are attributed to representatives of one genetic cluster. Within the CMM project, three species of the genus were recorded: *Eylais infundibulifera* Koenike, 1897, first described from Germany (BOLD:ACS0089, further sequenced material already published in BOLD), *E. koenikei* Halbert, 1903, first described from

Ireland (BOLD:ADY8728) and a protonymph not identified to species level, forming its own BIN (BOLD:AFD8084). We found these three taxa in lakes, *E. infundibulifera* also in an oxbow lake in Southeastern Norway (*E. infundibulifera*: calcium concentration 32-58 mg/l, conductivity 289-323 µS/cm, *E. koenikei* (calcium concentration 32 mg/l, conductivity 219 µS/cm).

Additional records of the genus from Norway in BOLD are *Eylais rimosa* Piersig, 1899, first described from Germany (BOLD:ACS1138) and a further unclear species, morphologically close to *E. infundibulifera* (BOLD:AEG3948). The latter and the above-mentioned protonymph might represent two of the five additional *Eylais* species previously recorded from the country (see Gerecke et al. 2022). To date, *E. extendens* (Müller, 1776) and *E. setosa* Koenike, 1897, both first described from Danmark, have only uncertain records in BOLD, and DNA barcodes of *E. discreta* Koenike, 1897, *E. muelleri* Koenike, 1897, and *E. mutila* Koenike, 1897, all described from Germany, have not yet been published.

Family Limnocharidae

Limnochares aquatica (Linnaeus 1758), first described from Sweden, in BOLD is forming two BINs (BOLD:ACS0438 – Montenegro, The Netherlands and Italy; BOLD:AFV0270 – Portugal). The species has a Holarctic distribution and has been recorded from riparian sediments of permanent stagnant waters or pools of streams, often in decaying wood, roots and litter, including eutrophic or acidic water bodies (Davids et al. 2007). Within this survey the species was found in standing waters in Southeastern, Central and the southern part of Northern Norway, as well as in a slow flowing outlet stream in Central Norway (calcium concentration 28 –100 mg/l, conductivity 132 –594 µS/cm).

SUPERFAMILY HYDRACHNOIDEA

Family Hydrachnidae

We recorded four *Hydrachna* O. F. Müller, 1776 species; *H. conjecta* Koenike, 1895, first described from Syria, *H. cruenta* Müller, 1776 and *H. geographica* Müller, 1776, both first described from Danmark and *H. globosa* (Geer, 1778), first described from Sweden, all from lakes but also a tiny forest pond (*H. geographica*) and an oxbow lake (*H. globosa*). The two latter species were recorded in Southeastern Norway and *H. cruenta* in Central Norway, *H. conjecta* in southern part of Northern Norway (*H. geographica*: calcium concentration 82 mg/l, conductivity 391 µS/cm; *H. globosa*: calcium concentration 32-158 mg/l, conductivity 323-675 µS/cm; *H. conjecta*: calcium concentration 36 mg/l, conductivity 247 µS/cm). In BOLD, our specimen of *H. conjecta*, forming its own BIN (BOLD:AFW6453), is 10.39% different from its nearest neighbour (BOLD:ACS0798) with specimens from The Netherlands. The Norwegian *H. cruenta* (a larva, detached from the rostrum of the common water strider *Gerris lacustris* (Linnaeus, 1758)) is in the same BIN as specimens from Georgia and Canada (BOLD:ADF2377), 3.04% different from *H. cruenta* specimens from The Netherlands (BOLD:ACS1131).

SUPERFAMILY HYDRYPHANTOIDEA

Family Hydrodromidae

Before Gerecke (1991) recognized *Hydrodroma pilosa* Besseling, 1940, first described from The Netherlands, as a separate species, it had often been recorded as *H. despiciens* (Müller, 1776), first described from Danmark (see also Gerecke 2017). The habitat of both species includes a high variety of standing waters (Di Sabatino et al. 2010). *Hydrodroma despiciens* prefers waters of lower alkalinity (Wiles 1985, Gerecke 1991), while *H. pilosa* was found in waters with higher alkalinity including mesohaline brackish waters (Davids et al. 2007). In our project, *H. despiciens* was the most frequently recorded species, collected from standing waters from all parts of the study area, while *H. pilosa* was only found in lakes and one oxbow lake in Southeastern Norway (calcium concentration 32–82 mg/l and conductivity 219–439 µS/cm for *H. pilosa*, calcium concentration 20–158 mg/l and conductivity 111–675 µS/cm for

H. despiciens. Our *H. despiciens* DNA barcodes all group in BIN BOLD:ACS0426.

Family Hydryphantidae

Subfamily Euthyadinae

According to Di Sabatino et al. (2010), *Panisus michaeli* Koenike, 1896, first described from Switzerland, 1896 colonizes helocrenes, preferably in montane areas, including sites with moderate organic pollution. The species has a Western Palaearctic distribution (Di Sabatino et al. 2010). Pozojević & Pešić 2022 report *P. michaeli* from karst springs in the Western Balkans. Our records concern exclusively springs and spring brooks in Central Norway and the southern part of Northern Norway, at elevations from 25 to 781 m a.s.l. (calcium concentration 36–70 mg/l, conductivity 173–355 µS/cm). In Norway, the species was previously recorded only from the northernmost county of Troms and Finnmark (Thor 1900). In BOLD all our Norwegian specimens of *P. michaeli* cluster together in one BIN (BOLD:AFH1842), while *P. michaeli* from Montenegro form another BIN (BOLD:ADT7504) at 7.71% distance.

Our *Parathyas* records include four species. *Parathyas inepta* (Lundblad, 1925), first described from Sweden, was found for the first time in Norway. The species is reported from various types of small water bodies, more frequent in standing than in running waters (Di Sabatino et al. 2010) – our specimen was collected in Northern Norway from a lake without water vegetation and lot of submersed tree trunks and branches (calcium concentration 40 mg/l, conductivity 188 µS/cm). The other three *Parathyas* species, *P. dirempta* (Koenike, 1912), *P. pachystoma* (Koenike, 1914), and *P. thoracata* (Piersig, 1896) are mostly confined to small water bodies, the latter two occasionally also found in slow flowing streams (Di Sabatino et al. 2010). We recorded all three species sympatric from lake Gjellumvannet in Asker municipality, Southeastern Norway (calcium concentration 32 mg/l, conductivity 219 µS/cm).

The *P. inepta* specimen from our study was documented for the first time with a COI sequence (BIN BOLD:AFX3430). Our single Norwegian specimen of *P. dirempta* forms a distinct COI cluster together with specimens from The Netherlands and Russia (BIN BOLD:ACS0539). *Parathyas thoracata* is a highly distinct species characterized by a large frontal eye sclerite. For this reason, the taxon was neither questioned, nor was eventual variation in other morphological features investigated in detail over the past decades. Specimens in BOLD form three distinct COI clusters: specimens from The Netherlands form two separate clusters, both clearly separated from a third cluster with exclusively Norwegian specimens (BIN BOLD:AFC5702). Thus, *Parathyas thoracata* is possibly an aggregate consisting of at least three species, two of which are undescribed. To define which cluster contains the nominal species and which cluster contains the new taxa, material from the area of the type locality close to Leipzig (Germany) should be analysed. For specimens attributed to *P. pachystoma*, a species with type localities in Silesia (Poland) and around Bremen (Germany), data in BOLD indicate the existence of two distinct clades. Our specimen from Norway shares a BIN with populations from The Netherlands (BOLD:ACS0159), separated from southern Central Europe (BOLD:ADT2649).

Thyasides dentatus (Thor, 1897), first described from Norway, is a widespread species in Central, Northern, and Northeastern Europe (Di Sabatino et al. 2010). The reported preferred habitat of *T. dentatus*, temporary vernal pools and bogs (Di Sabatino et al. 2010), agrees with our findings from a small lake in Troms and Finnmark that occasionally dries out. One larval specimen was collected from *Aedes* sp. (Culicidae) nearby that lake. In BOLD, barcodes of our Norwegian specimens form a BIN with a specimen collected in Georgia (BOLD:AEO0651).

SUPERFAMILY LEBERTIOIDEA

Family Lebertiidae

Data in BOLD show that specimens attributed to *Lebertia* (*s. str.*) *fimbriata* Thor, 1899, are likely members of a broad species aggregate. As the species was first described from Norway, and our

material is homogeneous (BIN BOLD:ADP3144), we likely have sampled the nominal species. Specimens of the same BIN are recorded from Austria, Bulgaria, Germany, Greece, and Russia. Each of the four additional BINs given in BOLD under this name are geographically rather distinct and likely represent separate species. A future revision will necessitate evaluation of some of the numerous taxa currently listed as junior synonyms of *L. fimbriata*. The geographical distribution of records per BIN are as follows: BOLD:AEI5359, Germany, Montenegro, North Macedonia, Portugal, Spain; BOLD:AEI4632, North Macedonia; BOLD:ADF5657, Germany, France, Italy, Montenegro, The Netherlands. Consequently, ecological data published for *L. fimbriata* s. l. (in detail from Germany: Gerecke 2002) cannot be applied to *L. fimbriata* s. str. and we include only data from Sweden (Lundblad 1968): low to high-order streams, on mosses and under stones, also in oligotrophic lakes, and the present study: streams in Southeastern and Northern Norway, a lake in Northern Norway (calcium concentration 25–58 mg/l, conductivity 125–428 µS/cm).

Lebertia (*s. str.*) *brigantina* K. Viets, 1933 specimens from Norway cluster with a specimen from The Netherlands (BOLD:ACR9597), no further data are available under this name in BOLD. Specimens with this BIN from Norway which were previously reported as *L. pusilla* Koenike, 1911 (Gerecke et al. 2022) belong to this species. *Lebertia brigantina* was first described from the Austrian part of Lake Constance; the species prefers high order lowland streams and clear lakes, often on sandy bottoms (Di Sabatino et al. 2010). Lundblad (1968) found the species in numerous Swedish lakes up to the Arctic Circle. Records from Sweden and Northern Russia under the name of *L. gladiator* Thor, 1913 (spec. incerta, see Gerecke 2009) probably refer to *L. brigantina* as well. Our material derives from a lake in Northern Norway as well as a lake and a river in southeastern Norway (calcium concentration 26–46 mg/l, conductivity 193–234 µS/cm).

For *Lebertia* (*s. str.*) *glabra* Thor, 1897, the situation resembles that of *L. fimbriata*. The species was first described from Norway, and our Norwegian specimens form a single BIN (BOLD:ACS0595) together with representatives of populations from a wide geographical range in Central and Southeastern Europe. Further BINs (BOLD:AEI2925, Montenegro; BOLD:ACR9598, The Netherlands and Montenegro) are likely representing two species other than *L. glabra*. We collected *L. glabra* from a stream in Northern Norway (calcium concentration 24 mg/l, conductivity 88 µS/cm). In Central Europe the species is considered rhithrobiont and in the Mediterranean crenobiont (Di Sabatino et al. 2010). Spring-dwelling populations are also reported from Sweden (Lundblad 1968) and Luxembourg (Gerecke et al. 2005) with a preference for mineral substrata and elevated conductivity.

The sequence of *Lebertia* (*Mixolebertia*) *brevipora* Thor, 1899, another species first described from Norway, is for the first time recorded here. It forms a cluster (BOLD:ACI9536) together with unidentified *Lebertia* specimens from Canada, showing a transatlantic, possibly circumpolar distribution. Previously known only from standing waters in Northern Norway and Sweden (Lundblad 1968), we record *L. brevipora* from oxbow lakes with dense water vegetation in Central and Northern Norway (calcium concentration 25–36 mg/l, conductivity 155–257 µS/cm).

Lebertia (*Mixolebertia*) *contracta* Thor, 1900, also first described from Norway, is a very rare species so far only found four times in Fennoscandia (the type locality, a stream in Stjørdal in Central Norway, two lakes in Sweden and one lake in Russian Karelia), and at one riparian site of Lake Constance in Germany (Lundblad 1968). We recorded specimens from an oxbow lake and a lake in Central Norway (calcium concentration 42–46 mg/l, conductivity 247–253 µS/cm) and present the first DNA barcodes (BOLD:AFH0926).

Lebertia (*Mixolebertia*) *holsatica* K.Viets 1920 was first described from Northern Germany. Our record from a spring in Central Norway is the first finding in Norway (calcium concentration 42 mg/l, conductivity 196 µS/cm). Other previous Fennoscandian records origin from four springs and one cold stream in Southern Sweden

(Lundblad 1968). In BOLD, the specimen clusters with representatives of the species from Germany (BOLD:ADU6053). *Lebertia holsatica* is crenobiont. In Luxembourg the species is typically found in habitats rich in macrophytes and fine detritus (Gerecke et al. 2005).

The separation of *Lebertia* (*Mixolebertia*) *sefvei* Walter, 1911 from *L.* (*Mixolebertia*) *crenophila* K.Viets, 1920 has frequently been discussed and remains still an open question (see also Gerecke 2009). Our Norwegian specimens cluster together with other specimens from Norway, Germany, and Austria identified as *L. crenophila,* a species first described from Germany, as well as with specimens identified as *L. sefvei* from Austria, Germany, and The Netherlands (BOLD:ACN9808). As *L. sefvei* has its type locality in Northern Sweden, this BIN likely represents the true *L. sefvei*, while one or both of the additional, genetically close clusters with the same name in BOLD might represent *L. crenophila* (BOLD:ADS7130, Austria; BOLD:AEE8084, Montenegro, distance between BINs 4.83%). Morphological characters separating the two species require reconsideration and therefore, ecological data for *L. sefvei* is based here on material from Fennoscandia only. Lundblad (1968) found the species in Sweden all over the country, preferably in springs and cold streams - mostly on siliceous bedrock, but also in streams with strong limestone precipitation. He regarded it as cold-stenotherm, rhitrobiont and crenophile. We recorded *L. sefvei* in a spring and spring brook in Central Norway and a stream in Northern Norway (calcium concentration 24–42 mg/l, conductivity of 88–196 µS/cm). It was also found in streams and rivers in limestone-poor areas of Southern Norway (Gerecke et al. 2022).

Lebertia (*Mixolebertia*) *stigmatifera* Thor, 1900 was first described from Norway. DNA barcodes of specimens from our samples are placed in the same BIN as records from Austria, Croatia, Germany, Serbia, Sweden and The Netherlands (BOLD:ACS0579). The species is regarded as cold-stenotherm, inhabiting waters with both high and low conductivity (Di Sabatino et al. 2010). In the north of Europe, *L. stigmatifera* is found both in springs and streams (Lundblad 1968, Martin & Speth 1996), in Central, Western and Southern Europe it is regarded as crenobiont (Gerecke & Martin 2006). This is in accordance with our findings from springs and streams in Central and Northern Norway and a stream in southeastern Norway (calcium concentration 22–96 mg/l, conductivity 88–434 µS/cm).

Lebertia (*Pilolebertia*) *gibbosa* Lundblad, 1926, first described from Sweden, was recently re-established and defined as a separate species (Tyokosova et al. 2022). DNA barcodes from our specimens are unified in a distinct cluster (BOLD:ACR9744) with specimens from a wide geographical area (Germany, The Netherlands, Poland, Portugal). The fact that some specimens in this cluster were determined as *L. longiseta* Bader, 1955, or *L. inaequalis* (Koch, 1837), indicates the need for a more detailed characterization of diagnostic features of these three species. In our material, *L. gibbosa* s. str. was recorded from two lakes in Northern Norway (calcium concentration 22–36 mg/l, conductivity 153–174 µS/cm).

Lebertia (*Pilolebertia*) *inaequalis*, the earliest described species in the genus, with its type locality in Southern Germany, clearly represents a species aggregate. Disregarding a few obvious misidentifications, specimens in BOLD attributed to this species are grouped in six BINs. All specimens from Norway are placed in one cluster (BOLD:ACR6228) together with representatives across the Holarctic region including Canada, The United States, Russia, Finland, but also one singleton from Northern Germany. Among the remaining clusters, BIN BOLD:ADF6223 includes material from Southern Germany, Montenegro, Greece, The Netherlands and Russia; BOLD:AAF1093 from Canada and The Netherlands; BOLD:AEJ7769 from Bulgaria and Georgia; BOLD:AEF5683 from North Macedonia, and BOLD:AEF2742 from Montenegro. As no type material exists that can be compared morphologically with specimens of these BINs, we propose to select records of BIN BOLD:ADF6223 to redefine the nominal *Lebertia inaequalis* since its members are collected closer to the type locality. It remains to be seen if one of the numerous junior synonyms of *L. inaequalis* can be reinstated for the cluster that includes DNA

barcodes of Norwegian specimens. The species s. l. is reported from pools of higher order streams, the macrophyte belt and wave belt of larger standing waters, both oligo-, dys- and eutrophic (Lundblad 1968, Smit & Van der Hammen 2000). Our specimens were collected from lakes and streams in Northern Norway (calcium concentration 36–64 mg/l, conductivity 149–394 µS/cm).

The DNA barcodes of our specimens identified as *Lebertia* (*Pilolebertia*) *insignis* Neuman, 1880, first described from Sweden, cluster with records from Montenegro, Portugal, Slovakia and Russia (BOLD:AEB9107). Since the species was first described from Norway, our material likely represents the nominal species, while the BIN BOLD:AFW6960 (a record from Portugal) probably represents a different distinct species (genetic distance over 9.7%). *Lebertia insignis* is reported mostly from pools in streams, rarely in larger standing waters, but probably with a preference for relatively warm water (Lundblad 1968). Our material was sampled from lotic waters in Northern and Southeastern Norway, as well as from a lake in Northern Norway (calcium concentration 18–30 mg/l, conductivity 71–153 µS/cm).

Results of recent molecular investigation of the *Lebertia* (*Pilolebertia*) *porosa* aggregate (Tyukosova et al. 2022) demonstrate the existence of no less than seven previously undetected taxonomic clades. In a first step it was possible to redefine *L. porosa* Thor, 1900 s. str., first described from Norway and to re-establish two species previously considered junior synonyms of *L. porosa* s. str., namely *L. gibbosa* Lundblad, 1926, first described from Sweden, and *L. obscura* Thor, 1900, first described from the same site in Norway as *L. porosa*. One further clade ("clade B" of Tyukosova et al. 2022) was since described as *L. litoralis* Zawal & Szenejko, 2024 (Zawal et al. 2024). In the material of the present project, we identified, in addition to *L. porosa* s. str., *L. obscura*, *L. gibbosa* and *L. litoralis*, also representatives of two still undescribed species, "clade A" and "clade E" in Tyukosova et al. (2022). *Lebertia porosa* s. str. specimens are unified in one cluster (BOLD:ACQ9049) together with specimens recorded from Germany and Serbia, reported from standing waters and pools of streams. *Lebertia* (*Pilolebertia*) *obscura* is genetically slightly less homogenous, albeit the BINs are only separated by 1.3–3% genetic distance (BOLD:ACT5154, BOLD:ADY7060, BOLD:AAM5138). The species has a wide Holarctic distribution with specimens also from Canada, Russia, and Austria. We recorded *L. obscura* from a lake in Central Norway and lakes and streams in Northern Norway (calcium concentration 28–48 mg/l, conductivity 118–247 µS/cm). *Lebertia litoralis* (BOLD:ACS9706) was first described from Poland and Norway and since then recorded also from Bulgaria and Russia. We found it in lakes in all parts of the study area as well as a river in Southeastern Norway (calcium concentration 22–50 mg/l, conductivity 147–338 µS/cm). *Lebertia porosa* aggr. sp. A (BOLD:ACP5319) is a taxon with a very wide distribution (in addition to Norway, records in BOLD are from Germany, Portugal, and Serbia). In our project, it was sampled from streams, rivers, lakes, and springs in Northern Norway (calcium concentration 28–64 mg/l, conductivity 118–394 µS/cm). *Lebertia porosa* aggr. sp. E has a documented transatlantic distribution (Norway and Canada). Within our project we recorded a single specimen from a stream in Northern Norway (calcium concentration 28 mg/l, conductivity 118 µS/cm), but the species has previously been found in various low-calcareous waters in Norway (Tyukosova et al. 2022).

Family Oxidae

Oxus angustipositus K. Viets, 1908 was first described from Germany. The species has records in BINs BOLD:AEB9099 (Montenegro) BOLD:AED9576 and BOLD:AET9442 (both Portugal); the first BIN includes sequences identified as *Oxus ovalis* (Müller, 1776) from Norway and North Macedonia. We have not been able to barcode specimens identified as *O. angustipositus* form Norway. The true identity of the species is uncertain, and a redescription based on fresh specimens from N Germany and type material is required. Our specimens were recorded from a lake in Northern Norway and an oxbow

lake in Central Norway (calcium concentration: 30–42 mg/l, conductivity: 156–247 µS/cm.

Oxus carpenteri (Halbert, 1911), first described from Ireland, is represented by BIN BOLD:ACT137 with records from Norway. Our specimens were recorded from lakes in all parts of the study area, as well as from slow-flowing outlet streams in Northern Norway (calcium concentration: 20–62 mg/l, conductivity: 88–439 µS/cm).

Oxus longisetus (Berlese, 1885), first described from Italy, has records in BOLD:ACT0479 from Norway, Finland and Russia, with the Russian record identified as *Oxus setosus*. *Oxus longisetus* is also represented in BOLD:ACS0505 (The Netherlands) and BOLD:ACS0570 (The Netherlands and Russia), two clusters that are >12% divergent from BOLD:ACT0479.
The true identity of the species is uncertain and redescription based on fresh specimens from Northern Italy is required. Our specimens were recorded from lentic waters in Southeastern and Northern Norway (calcium concentration: 24–54 mg/l, conductivity: 157–342 µS/cm).

Oxus musculus (Müller, 1776) was first described from Danmark. Records on BOLD are grouped in two clearly divergent clusters (>12%) with specimens from Norway and The Netherlands (BOLD:ACS0571 and BOLD:AEB9100) and Norway, Portugal and Russia (BOLD:AFC2154) respectively. It is uncertain which of the two clusters corresponds to *O. musculus* sensu stricto. Given the absence of type material, a provisional decision is required, preferably based on specimens from Denmark. Our specimens were recorded from lakes in Central and Northern Norway, as well as from an oxbow lake in Southeastern Norway (calcium concentration: 32–48 mg/l, conductivity: 266–353 µS/cm).

Oxus ovalis (Müller, 1776), first described from Danmark, is present in four divergent BINs in BOLD: BOLD:ACR9985 with records from Norway and The Netherlands; BOLD:AEB9099 from Norway and North Macedonia; BOLD:AFA6731 from Greenland and Canada; BOLD:AFP5747 from Portugal. This is likely an aggregate of cryptic species. In the absence of type material, a provisional decision is required, preferably based on specimens from Denmark. Our specimens were recorded from lakes in all parts of the study area (calcium concentration: 30–55 mg/l, conductivity: 174–378 µS/cm).

Oxus setosus (Koenike, 1898) was first described from Switzerland and Poland (Silesia) [with a remark in the collection site list that Thor recorded the species as *O. strigatus* in South Varanger ("Bach zwischen dem zweiten und dritten Kirchwasser"), but this is not regarded as a type locality]. The species has records in BIN BOLD:ACS0808 with specimens from The Netherlands and Portugal, but there is also one Russian record of *O. setosus* within the *Oxus longisetus* BIN BOLD:ACT0479. The species should be redefined based on material at best from Switzerland. Our specimens were recorded from a slow-flowing stream in Northern Norway (calcium concentration: 28 mg/l, conductivity: 118 µS/cm).

Oxus strigatus (Müller, 1776), first described from Danmark, has records in BOLD:ADF6180 from The Netherlands and Norway. Our specimens were recorded from lakes in all parts of the study area (calcium concentration: 26–66 mg/l, conductivity: 155–431 µS/cm).

Family Sperchontidae

We recorded five species distributed across eight BINs in the genus *Sperchon* (Figure 2). In the original description of *S.* (*s. str.*) *brevirostris* Koenike, 1895 based on a specimen from Switzerland, Koenike (1895) also assigned specimens from the Azores to this taxon. DNA barcode records in BOLD show that *S. brevirostris* s. str. is widespread in Central, Northern, and Southeastern Europe forming three neighbouring BINs, here interpreted as intraspecific genetic variation: BOLD:ACP6107 with specimens from Germany and Norway; BOLD:AED3857 with specimens from North Macedonia and Montenegro; BOLD:AFD0340 with records from Germany and Montenegro. The DNA barcodes of a population from the Azores form a distant and separate BIN (BOLD:AGK2886), indicating that these specimens do not belong to the nominal species. *Sperchon brevirostris* avoids

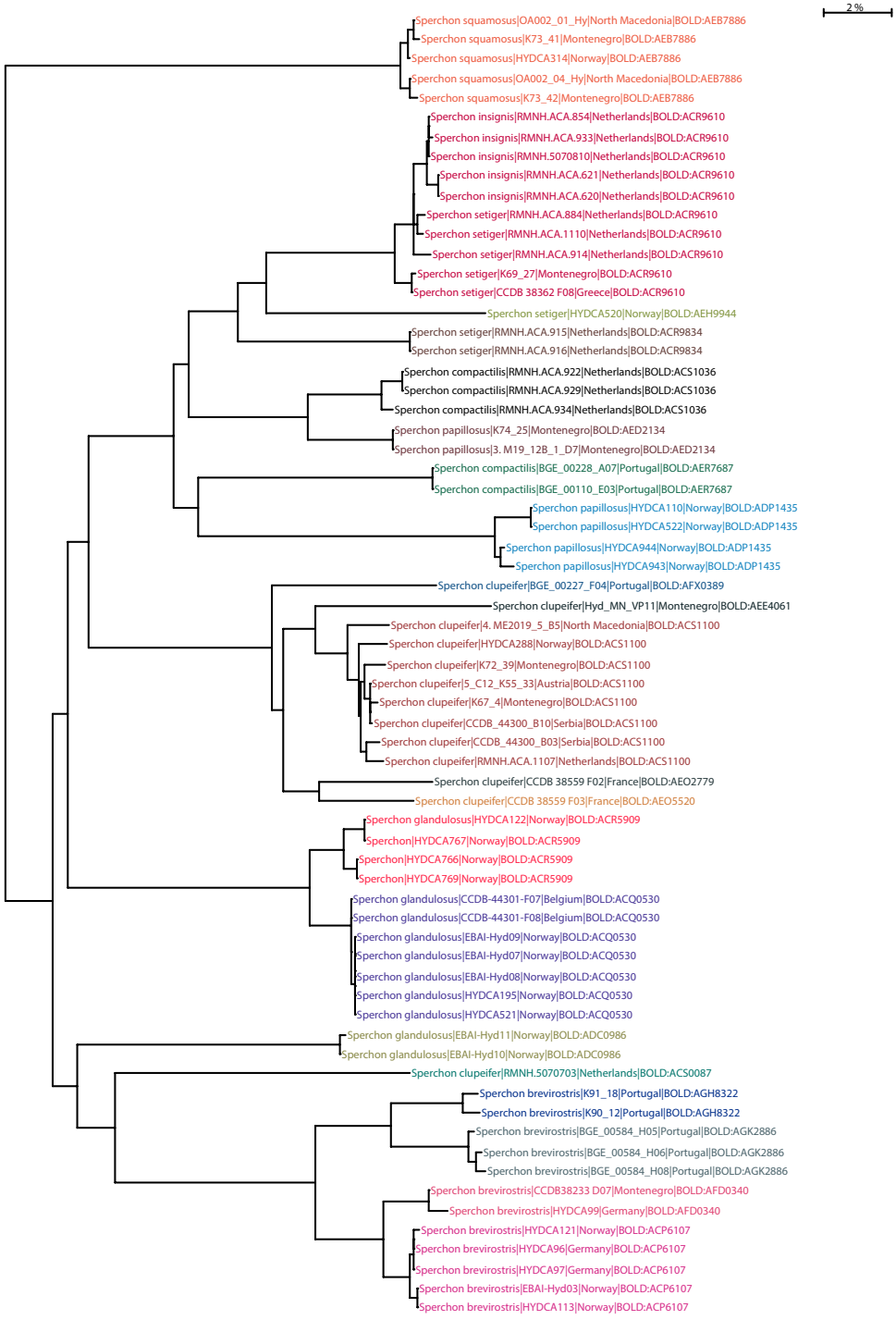

FIGURE 2. Neighbour Joining taxon ID tree of selected public *Sperchon* records generated in BOLD using K2P pairwise distances with pairwise deletion of gaps. Terminals are labelled with species name, Specimen ID, country and BIN.

spring habitats and lives in low- and middle-order streams, at the northern border of the distribution area also in lake littoral (Di Sabatino et al. 2010). This is in accordance with our findings from streams and rivers in Southeastern and Northern Norway as well as a lake in Northern Norway (calcium concentration 18–58 mg/l, conductivity 71–269 µS/cm).

The taxonomy of species in the *Sperchon glandulosus* group, an aggregate first defined by Bader (1974), is challenging and at present rather confusing. The nominal *Sperchon glandulosus* Koenike, 1886, first described from Germany, appears to correspond to the taxon redescribed by Bader as *S. thienemanni* Koenike, 1907, another species first described from Germany, while the latter is most probably a complex of two undescribed species (Pešić, pers. comm.). In literature (e.g. Di Sabatino et al. 2010), both species names appear for populations from many parts of Europe, with *S. thienemanni* sensu Bader most frequently found in springs, and *S. glandulosus* sensu Bader in streams. Before the ecological affinities are reconsidered, however, a large-scale revision of the species group is necessary. Despite this confusion, the situation in Norway is surprisingly clear: No populations of *S. glandulosus* or *S. thienemanni* sensu Bader have been found. Norwegian specimens in agreement with morphological diagnostics given in Di Sabatino et al. (2010) for *S. glandulosus* represent two morphologically distinct clusters. Most probably, these two groups represent species described by Thor, but previously considered junior synonyms of *S. brevirostris* or *S. glandulosus*: *Sperchon multiplicatus* Thor, 1901 is currently a junior synonym of *S. glandulosus,* and is suspected to be represented by multiple records including specimens from Norway, Romania, and Belgium in BIN BOLD:ACQ0530. *Sperchon lineatus* Thor, 1899 is currently a junior synonym of *S. brevirostris* and might be represented by records in BIN BOLD:ADC0986, all from Norway.

DNA barcodes of *Sperchon* (s. str.) *squamosus* Kramer, 1879, first described from Germany, form a single BIN (BOLD:AEB7886) with specimens from Norway, Montenegro, and North Macedonia. The species is rhitrobiont and crenophilous, often found in helocrenes, in the northern part of its distribution area also present in lake littoral (Di Sabatino et al. 2010). Our records include streams in Southeastern and Central Norway, as well as a lake in Southeastern Norway (calcium concentration 26–66 mg/l, conductivity 110–431 µS/cm).

Sperchon (*Hispidosperchon*) *clupeifer* Piersig, 1896, first described from Saxony (Germany), is a distinct morphological species in both sexes. Specimens published under this name in BOLD are clustering in five genetically rather close groups: BOLD:ACS1100 from Austria, Germany, Italy, Montenegro, Norway, North Macedonia, Russia, Serbia and The Netherlands; BOLD: AEE4061 from Montenegro; BOLD:AFX0389 from Portugal; BOLD:AEO2779 and BOLD:AEO5520 from France (Figure 2). Independent of the question if this clustering indicates presence of five sister species or, more probably, intraspecific genetic variety, Norwegian specimens all belong to one BIN with records distributed in Central Europe. Our material was collected from rivers in Southeastern Norway (calcium concentration 18–36 mg/l, conductivity 71–234 µS/cm).

DNA barcode records indicate that the identity of *Sperchon* (*Hispidosperchon*) *papillosus* Thor, 1901, a species first described from Norway, is unclear. Records attributed to this species in BOLD are found in two separate clusters, both mixed with records classified as *S. compactilis* (Koenike, 1911), a species first described from Northern Germany as a subspecies of the former. One of these groups is genetically homogenous (BOLD:ADP1435), and as it is formed exclusively by Norwegian material, it likely represents the nominal *S. papillosus*. We recorded the species from a river in Northern Norway (calcium concentration 28 mg/l, conductivity 153 µS/cm). We suggest that the second, genetically less homogenous group is *S. compactilis*, with two BINs, embracing specimens from Germany, The Netherlands and Türkiye (BOLD:ACS1036), and Iran (BOLD:AED2135). Most probably, diagnostic features separating these two species have not been appropriately weighted and should be reconsidered, along with properties of a further,

genetically more distant BIN with records from Austria, Portugal and Spain (BOLD:AER7687).

A similar situation is found in *S.* (*Hispidosperchon*) *setiger* Thor, 1898, a further species first described from Norway but not found in the course of this project: Typical *S. setiger* from Norway cluster together (BOLD:AEH9944) while specimens from central Europe are found in their two separate BINs: BOLD:ACR9610 from Germany, Greece, Italy, Montenegro, Russia and The Netherlands; BOLD:ACR9834 from The Netherlands. At least parts of the Central European populations should represent *S. insignis*, a sister species first described from Switzerland, while specimens recorded under this name from Greenland (BOLD:ACT4074) likely belong to a species new to science.

Before molecular data was used to analyse species relationships, the taxonomic status of species in the genus *Sperchonopsis* in Europe appeared manageable. There was one widespread species, *Sperchonopsis verrucosa* (Protz, 1896), first described from Russia, and another one, the hyporheobiont *S. procera* Láska, 1965, first described from Czechia (see Di Sabatino et al. 2010), in BOLD with the name of the junior synonym *S. phreaticus* Biesiadka, 1975, BIN BOLD:ADD6841 (Dabert et al. 2016). With more comprehensive DNA barcode data, there are now ten BINs in BOLD with records labelled *S. verrucosa*. Three of these include records from Norway: BOLD:ACS9705 with records also from Belgium, Croatia, Montenegro, North Macedonia and Portugal; BOLD:ACS0909 with records also from Germany, Russia and The Netherlands; BOLD:AEI18826 with records only from Norway. The latter two BINs are genetically close, only 2.7% apart.

In Norway, specimens of the *Sperchonopsis verrucosa* aggr. were found in habitats as already described for members of the species aggregate s. l., mostly in lower order streams, also with weak flow and elevated contents of organic matter (Di Sabatino et al. 2010). First attempts to morphologically disentangle the two clades present in Norway were unsuccessful. Members of the genus require a sound, Europe-wide revision for better understanding of their habitat preference.

Family Teutoniidae

Records of *Teutonia cometes* Koch, 1837, first described from Germany, form two BINs in BOLD that are 6.6% distant from each other: BOLD:AEN6005 with records from Türkiye; BOLD:ACH7884 with records from Montenegro, Norway, and Portugal. *Teutonia cometes* has been recorded from cold montane lakes, preferably in the littoral, as well as from pools of shaded streams (Lundblad 1968, Di Sabatino et al. 2010). Our material was sampled from lakes 2–255 m a.s.l. in Southeastern and Northern Norway (calcium concentration 26–48 mg/l, conductivity 142–339 µS/cm).

Family Torrenticolidae

Torrenticola amplexa (Koenike, 1908) was first described from streams near Bremen in Northern Germany (Koenike 1908). In the same paper, a similar *Torrenticola* species, *T. connexa* (Koenike, 1908), was introduced based on material from another Northern German stream some 50 km SW of Bremen and from a stream in Southwestern Norway ("Herikstad, Roslandsaa", probably the stream Roslandsåna near Bryne). In the following decade, the opinion was that the latter is a junior synonym of *T. amplexa*. Koenike (1908) stated that *T. spinirostris* Thor, 1897a, first described from Norway, would be identical to his *T. connexa*, without considering that *T. spinirostris* should be the older, prioritized name. Consequently, all records published under *T. amplexa* and its synonym *T. connexa* should refer to *T. spinirostris*. However, we continue to use the name *T. amplexa* until the question of priority is clarified through taxonomic revision or by the ICZN (as exchanging established with unused names should be avoided). Many records under *T. amplexa* in BOLD form a rather homogenous group (BOLD:ACR0665) from Croatia, Germany, Greece, Montenegro, Norway, Poland, Portugal and Russia that likely represent the typical *Torrenticola amplexa*. Its nearest neighbour, 5.2% distant, is BOLD:ACS0261 with records

from Croatia, Russia and The Netherlands. In this taxonomic neighbourhood, the species present in Norway is likely identical with *T. spinirostris* sensu Thor, 1897. *Torrenticola amplexa* is reported to have a Palaearctic distribution and to prefer middle and higher order streams with sediments rich in organic material (Di Sabatino et al. 2010). Our records include rivers and streams in Southeastern and Northern Norway (calcium concentration 18–58 mg/l, conductivity 71–428 µS/cm).

Torrenticola brevirostris Halbert, 1911, first described from Ireland, was recently discovered in Scandinavia (Gerecke et al. 2022). Our specimens share a BIN with records from a wide geographical range in Eastern Europe (BOLD:AED9586) with specimens from Montenegro, North Macedonia, Norway, Russia and Serbia. The species has Holarctic distribution and inhabits low order streams (Di Sabatino et al. 2010). We recorded the species from a river in Southeastern Norway (calcium concentration 36 mg/l, conductivity 234 µS/cm).

SUPERFAMILY HYGROBATOIDEA

Family Aturidae

The Norwegian material of *Aturus scaber* Kramer, 1875, a species first described from Germany, clusters homogenously in BOLD:ACQ9097. The cluster contains records also from Germany and Portugal, confirming the reported wide distribution of the species. *Aturus scaber* has a Western-Palaearctic distribution and is considered rhithrobiont (Gerecke et al. 2016). Our records include streams and rivers in Southeastern Norway (calcium concentration 36–58 mg/l, conductivity 234–428 µS/cm).

Kongsbergia materna Thor, 1899, first described from Norway, has records in BIN BOLD:ACR0033 from Norway. Our specimens were recorded from lotic waters in Southeastern Norway (calcium concentration: 18–58 mg/l, conductivity: 71–428 µS/cm).

The DNA barcodes of specimens attributed to *Ljania bipapillata* Thor, 1898, a distinctive, widespread species first described from Norway, cluster into three BINs in BOLD: BOLD:ADT4351 from Austria and Germany; BOLD:ADT4350 from Austria; BOLD:ADZ1334 from Belgium, France, Germany and Norway. All our specimens belong to the latter BIN. Since *Ljania bipapillata* was first described from Norway, specimens of BIN BOLD:ADZ1334 likely represent the nominal species. *L. bipapillata* has a Holarctic distribution, inhabits low-order streams, and frequently colonizes rheocrenic springs. (Gerecke et al. 2016). We recorded the species from streams in Southeastern Norway (calcium concentration 18–96 mg/l, conductivity 71–434 µS/cm).

Brachypoda versicolor (Müller, 1776) was first described from Danmark. Gerecke et al. (2022) reported the species from Norway to be represented in two different BINs. Reexamination of the specimens revealed that records in one of these (BOLD:AEB7647) represent *Ocybrachypoda celeripes* (K. Viets, 1910). Although this species was not collected from calcareous waters, we here report it for the first time from Fennoscandia based on the records given in Gerecke et al. (2022). All remaining *B. versicolor* specimens from Norway and elsewhere belong to one BIN (BOLD:ACS0119) with records from Germany, North Macedonia, Montenegro, Norway, The Netherlands and Russia. The species is Palaearctic and reported to be restricted to standing waters (Gerecke et al. 2016), in line with our findings from lakes in Southeastern and Northern Norway, as well as a pool of a river in Northern Norway (calcium concentration 25–82 mg/l, conductivity 125–409 µS/cm).

Family Hygrobatidae

Atractides (s. str.) *nodipalpis* Thor, 1899 was first described from Norway. Gerecke (2003) designated a neotype from Gudbrandsdalen and documented the morphological variability of the species, based on specimens collected in Southern Germany. In BOLD, numerous DNA barcodes of specimens from Norway cluster with records from all over Europe and Greenland (BOLD:ACR0209); a single Norwegian specimen appears with BIN BOLD:AFD5286, at 3.4% genetic distance from the former. *Atractides nodipalpis* is known as

rhithrobiont (Gerecke et al. 2016), confirmed by our findings from streams and rivers, but we also recorded one specimen from a lake in Northern Norway (calcium concentration 18–58 mg/l, conductivity 71–428 µS/cm).

Further Norwegian specimens with characteristics similar to *A. nodipalpis* are grouped in two other distinct clusters in BOLD. One of these, a distinct group with four Norwegian specimens (BOLD:AFA3227) that are >10% divergent from its nearest neighbour, cannot be separated morphologically from typical *A. nodipalpis*. The remaining specimens ("*Atractides* (s. str.) *nodipalpis* aggr. sp.") differ from *A. nodipalpis* s. str. in the shape of the genital field in both sexes. They cluster with specimens from Germany and Canada into three BINs that are no more than 5% divergent from each other (BOLD:ADZ1306, BOLD:ADY7881, BOLD:ADP2485). One or more of the eight synonyms of *A. nodipalpis* listed in Gerecke (2003) could probably be represented by this genetically diversified cluster. *A. nodipalpis* is rhithrobiont (calcium concentration 40–58 mg/l, conductivity 187–394 µS/cm).

Atractides (s. str.) *ovalis* Koenike, 1883, first described from Sweden, is a morphologically very distinct species for which we provided the first DNA barcode data in a previous project (BOLD:AEC4631). Within the genus, *A. ovalis* is the only known lenitobiont species, favoring clear standing waters with low nutrient content, occasionally also inhabiting lake outlets or slow-flowing streams (Gerecke et al. 2016). In our project, the species was recorded exclusively from lakes in Southeastern Norway (calcium concentration 48–100 mg/l, conductivity 256–439 µS/cm).

Atractides (s. str.) *tener* Thor, 1899 was first described from Norway. A neotype from Ljanselva in Oslo was designated by Gerecke (2003). In BOLD, all *A. tener* specimens form a homogeneous cluster with specimens from Norway, Germany and Romania (BOLD:ACG4776). Some earlier records might refer to the similar *A. samsoni* (Sokolow 1936), only recently reported from Norway. *Atractides tener* is rhithrobiont (Gerecke et al. 2016). In our project the species was recorded from streams and rivers both in Southeastern and Northern Norway (calcium concentration 26–496 mg/l, conductivity 110–34 µS/cm).

Atractides (*Tympanomegapus*) *lacustris* (Lundblad, 1925), first described from Sweden, has records in BIN BOLD:AFA2865 with one specimen from Norway. The specimen was recorded from a lake in Southeastern Norway (calcium concentration: 48 mg/l, conductivity: 188 µS/cm).

The redescription of *Hygrobates* (*Rivobates*) *norvegicus* (Thor, 1897), first described from Norway, revealed at least two separate species which are currently classified under this name (Gerecke & Stur 2025). *Hygrobates norvegicus* s. str. is now documented across a wide geographic area in Central and Northern Europe (BOLD:ACH7323, BOLD:AER1329). The undescribed, presumably sister lineage is known from Central Europe only, with records clustering in three close BINs (BOLD:ADS0502, BOLD:ADV5105, BOLD:AEK7690). The species is crenobiont or crenophilous, with a preference for detritus-rich habitats (Gerecke et al. 2016, Gerecke & Stur 2025). In the present study it was recorded from springs and streams (calcium concentration 26–96 mg/l, conductivity 110–434 µS/cm), other Norwegian records include also lakes (Gerecke et al. 2022).

Pešić et al. (2022) showed that *Hygrobates* (s. str.) *calliger* Piersig, 1896, first described from Germany, is an aggregate of at least six distinct lineages and described two of these as separate species. All specimens from Norway cluster with specimens from a wide geographical range including Bosnia and Herzegovina, Germany, Greece, Montenegro, Norway, Portugal and Serbia (BOLD:AEF4261). This BIN is <5% distant from an additional three BINs (BOLD:AEO0848, BOLD:AFE0075, BOLD:AET1162) with records from Germany, Italy and Portugal. In addition, there are five BINs in BOLD with DNA barcodes of *H. calliger* that are > 10% divergent from barcodes of *H. calliger* from Norway. Thus, taxonomic revision including material from the type locality is required to designate a BIN to the nominal species, and our statements about the habitat preference of the *H. calliger* aggr.

species from Norway are restricted to data from Scandinavia. In our material, the species was only found in rivers in the Southeastern part of the country (calcium concentration 18–36 mg/l, conductivity 71–234 µS/cm).

Hygrobates (s. str.) *fluviatilis* (Ström, 1768), first described from Norway, was recognized as a species aggregate by Pešić et al. (2017) who provided also a redefinition of the nominal species, the only representative of the aggregate known to live in Scandinavia. In BOLD, specimens of *H. fluviatilis* s. str. cluster in BOLD:ACB4846 with records from throughout Europe. Older habitat preference data for the species s. l. are no longer useful, but recent data confirm a remarkable tolerance to organic pollution as it was earlier stated for *H. fluviatilis* s. l. (e.g., Gerecke & Schwoerbel 1991). In addition to rivers, we found *H. fluviatilis* s. str. also in lakes in Central and Northern Norway (calcium concentration 18–44 mg/l, conductivity 71–394 µS/cm).

DNA barcodes of Norwegian *Hygrobates* (s. str.) *foreli* (Lebert, 1874), first described from Switzerland, cluster in BOLD:AAM5259 together with records from Canada. There are sequences of *H. foreli* in BOLD from Italy (BOLD:AEP0079) and Montenegro (BOLD:AEE3281) that are distinctly divergent from the BIN with Norwegian records. The type locality of *H. foreli* is in Lake Geneva. Older data suggest that two "forms" of the species exist: the lake profundal dwelling *H. foreli foreli*, and the torrenticolous *H. foreli titubans* (Koenike, 1908). This contrasting ecological preference supports the interpretation that *H. foreli* might be a species complex, as found in many other species of the genus. We recorded *H. foreli* from the littoral of lakes and streams in Northern Norway, as well as from streams in Central Norway (calcium concentration 22–64 mg/l, conductivity 113–394 µS/cm).

Hygrobates (s. str.) *longiporus* Thor, 1898, first described from Norway, also represents a species aggregate still waiting to be unraveled. All DNA barcoded Norwegian *Hygrobates longiporus* specimens form one cluster (BOLD:AEB8359) with records from throughout Europe. Additional European records are found in four separate BINs (BOLD:AEO0825 (France), BOLD:AEM7299 (Greece, Serbia, and Türkiye), BOLD:AFV9997 (Portugal), BOLD:AFW1423 (Portugal)). Considering the taxonomic situation, published data on the habitat preference of *H. longiporus* should be revised. The Norwegian records for *Hygrobates longiporus* s. str. include specimens from rivers and lakes in Southeastern Norway (calcium concentration of two of these lakes 26–66 mg/l, conductivity 209–431 µS/cm).

Hygrobates (s. str.) *prosiliens* Koenike, 1915, first described from Germany, was recognized as separate species only recently (Pešić et al. 2019). Most of the older Scandinavian records listed as *H. longipalpis* refer to *H. prosiliens*. In BOLD, our records of this species cluster in BIN BOLD:AAX2654 with specimens from multiple countries throughout Europe, including a few likely misidentifications as *H. longipalpis*. Habitat preference differences between the two species are not well documented. *Hygrobates prosiliens* is lenitobiont, recorded in all parts of the study area, mostly in lakes and oxbow lakes, but also in slow-flowing streams in Northern Norway (calcium concentration 22–64 mg/l, conductivity 113–439 µS/cm).

Hygrobates (s. str.) *setosus* Besseling, 1942, first described from The Netherlands, was recognized as separate species by Martin et al. (2010). DNA barcodes from our specimens cluster in BIN BOLD:AAM1668 with records from Austria, Germany, Montenegro, Norway, Switzerland, The Netherlands and United Kingdom (some records still listed under the name of *H. nigromaculatus* Lebert, 1879). In contrast to the lenitobiont sister species *H. nigromaculatus* (BOLD:AAM1669 with records from Norway and The Netherlands), *H. setosus* is rhithrophilous, frequently found in quiet areas of larger rivers, also in pools of low order streams; our localities include a stream in Southeastern Norway and a lake in Central Norway (calcium concentration 20–58 mg/l, conductivity 173–428 µS/cm).

Hygrobates (s. str.) *trigonicus* Koenike, 1895, first described from Switzerland, is found in BOLD in two separate BINs: BOLD:AEN6851 with records from Greece, and BOLD:AAM9602 with records from Germany. No material from Northern Europe has been successfully sequenced

so far. The species is rhithrophilous but also found in the riparian area of lakes (Lundblad 1968). We recorded the species from a lake in Northern Norway (calcium concentration 36 mg/l, conductivity of 187 µS/cm).

Mesobates forcipatus Thor, 1901 is a rare species, first described from Norway, but also known from Southeastern Europe (BOLD:ACT3796). The species is found both in lowland streams and standing waters (Gerecke et al. 2016). In our study it was recorded from running waters and from pools of streams in Northern Norway (calcium concentration 28–44 mg/l, conductivity 153–394 µS/cm).

Mixobates processiger Thor, 1905 is a rare, little-known species, first described from Norway. In BOLD, there is only one Norwegian specimen represented (BOLD:AEJ2872). The preferred habitat is mossy riffles of low order streams (Gerecke et al. 2016). We found the species in a river with mossy bottom and in a lake in Northern Norway (calcium concentration 42–44 mg/l, conductivity 187–339 µS/cm).

Family Limnesiidae

Limnesia connata Koenike, 1895, first described from Germany, is reported to prefer lime-poor waters, especially moorland pools (Schwoerbel 1956, Lundblad 1968, Van Haaren & Tempelman 2009), temporary waters and quagfens (Smit & van der Hammen 1996). We collected a single specimen from a lake in Southeastern Norway (calcium concentration 50 mg/l, conductivity 337 µS/cm) but cannot provide a DNA barcode. The two Russian records in BOLD have been harvested from GenBank (BOLD:AEH7733) (Klimov et al. 2022).

Limnesia curvipalpis Tuzovskij, 1997, first described from Russia, was recently recorded for the first time from Norway (Gerecke et al. 2022). In BOLD, sequence data are available from Norway and Russia (BOLD:AEG1890). The species is so far known from ponds, slightly acidic moorland pools, and canals (Gerecke et al. 2016). In the present project we found *L. curvipalpis* in lakes in Central Norway and one oxbow lake in Southeastern Norway (calcium concentration 30–48 mg/l, conductivity 167–378 µS/cm).

The species *Limnesia fulgida* Koch, 1836 was first described from Germany. DNA barcodes from our specimens cluster in BIN BOLD:ACR9738 together with records from The Netherlands and Russia. The species is mainly reported from standing waters (ditches, pools and lakes), more rarely from temporary waters or streams (Gerecke et al. 2016). In The Netherlands, the species prefers waters with relatively low nutrient level and avoids clayish and brackish waters (Smit & Van der Hammen 2000, Van Haaren & Tempelman 2009). Lundblad (1968) found *L. fulgida* in Sweden in eutrophic, as well as in dystrophic and lime-rich waters. Our records are from lakes rich in water vegetation in Southeastern Norway (calcium concentration 50–54 mg/l, conductivity 342–594 µS/cm).

Four BINs in BOLD are assigned to records of *Limnesia koenikei* Piersig, 1894, first described from Germany. The two genetically most divergent BINs (> 12% p-distance) contain specimens from Norway and The Netherlands (BOLD:ACS0816, BOLD:AFD0145), and the two further, genetically closer BINs contain specimens from The Netherlands and Portugal (BOLD:ADF6559) and Russia (BOLD:AGK8752). Two additional clusters with *Limnesia* specimens, one from Kyrgyzstan (BOLD:ADF8368) and another one from Canada (BOLD:AAX5271) must be taken into consideration when revising this species group. We cannot exclude that the true *Limnesia koenikei* is absent from Norway. *Limnesia koenikei* s. l. is reported from lakes and ponds (Lundblad, 1968, Bagge 1986), moorland pools (Duursema 1996) and natural and canalized lowland streams (Smit & van der Hammen 1996). We collected *L. koenikei* from lakes and oxbow lakes in Central and Northern Norway (calcium concentration 30–48 mg/l, conductivity 142–378 µS/cm).

DNA barcodes from specimens attributed to *Limnesia maculata* Müller, 1776, first described from Danmark, cluster in two BINs: BOLD:ACS0248 from Norway and The Netherlands, and BOLD:AFW6935 from Portugal. These nearest neighbours are 4.3% divergent. BIN BOLD:ACS0248 also contains specimens identified as *L. marmorata* Neuman, 1880, a

species that was redefined rather recently (Van Haaren & Tempelman 2009). *Limnesia maculata* is typically associated with the macrophyte belt and deeper littoral of larger standing waters (Davids et al. 1994, Van der Hammen & Smith 1996), but it has also been recorded in smaller ponds and lowland streams in oligo- to eutrophic waters (Böttger & Mierwald 1990, Böttger & Hoerschelmann 1991, Steenbergen 1993, Smit & Van der Hammen 2000). Our findings include lakes throughout the entire study area, as well as one oxbow lake in Southeastern Norway and one stream in Northern Norway (calcium concentration 20–100 mg/l, conductivity 88–594 µS/cm).

Limnesia undulata Müller, 1776 was first described from Danmark. In BOLD, DNA barcodes of this species are found in one larger cluster with three BINs: BOLD:AAX5286 with various specimens from Georgia, North Macedonia, The Netherlands, Norway, Montenegro, and one specimen from Canada; BOLD:ACA5286 with many records from Canada and USA (identified as *Limnesia* sp.), and one specimen from Greece; BOLD:ACV1123 with one specimen (*Limnesia* sp.) from Canada. The reported habitats for the species include all kinds of standing and slowly running waters (Gerecke et al. 2016). We collected *L. undulata* from lakes with or without water vegetation in Southeastern Norway (calcium concentration 26–80 mg/l, conductivity 209–439 µS/cm).

Limnesia undulatoides Davids, 1997, first described from The Netherlands, was long confused with *L. undulata*. Data in BOLD confirm the distinctness and wide distribution of the species with numerous records from Canada, Norway, The Netherlands, Russia, USA in BOLD:AAJ2660. Due to its recent detection, habitat and ecological preferences of *L. undulatoides* are not yet clear. The species can be found in various types of standing waters (Gerecke et al. 2016) and is probably not tolerant to strong eutrophication (Smit & van der Hammen 2000). We collected the species in lakes throughout the entire study area, but also in a slow flowing stream in Northern Norway (calcium concentration 22–50 mg/l, conductivity 193–353 µS/cm).

Family Pionidae

Subfamily Foreliinae

DNA barcodes of *Forelia liliacea* (Müller, 1776), first described from Danmark, originate from specimens collected in Norway and Russia (BOLD:ACT0241). The species occurs predominantly in lakes, pools and ditches, occasionally also in slow running streams (Gerecke et al. 2016). Most of our records are from lakes, in Central and Northern Norway, and less frequently from streams (calcium concentration 20–55 mg/l, conductivity 88–350 µS/cm).

Forelia longipalpis Maglio, 1924, first described from Italy, is recorded here for the first time from Norway. However, the presence of several genetically divergent BINs in BOLD assigned to the species indicates the presence of cryptic diversity. BIN BOLD:ACR9683 holds records from Norway and The Netherlands; BOLD:ADF6960 from The Netherlands; BOLD:AFV3893 from Portugal. Thus, the species needs a taxonomic revision that includes material from the type locality. *Forelia longipalpis* has been found in the littoral of large lakes (Gerecke et al. 2016). We recorded the species from lakes in Southeastern and Northern Norway (calcium concentration 20–48 mg/l, conductivity 88–328 µS/cm).

Forelia variegator (Koch, 1837), first described from Germany, is here recorded for the first time from Norway. DNA barcodes attributed to this species are found in two genetically divergent BINs (>12% p-distance). The Norwegian specimens cluster with specimens from numerous countries in BOLD:ACS0537: Greece, The Netherlands, Norway, North Macedonia, Russia, while the second BIN contains specimens from Portugal (BOLD: AFU5459). The species lives preferably in the littoral of large lakes but is found frequently also in pools of running waters (Gerecke et al. 2016). We recorded the species from a lake in Southeastern Norway (calcium concentration 26 mg/l, conductivity 209 µS/cm).

Pionacercus leuckarti Piersig, 1894 was first described from Germany. No DNA barcodes are available so far and our attempts to sequence this

species were unsuccessful. According to Lundblad (1968), the habitat of the species is mostly ponds, more rarely lakes, streams and limnocrenes, with a preference for oligotrophic and dystrophic waters. We recorded the species mostly as singletons, from eight lakes in Central and Northern Norway (calcium concentration 30–55 mg/l, conductivity 142–266 µS/cm).

Pionacercus norvegicus Thor, 1898, first described from Norway, is represented in BOLD (BIN BOLD:AEC6045) only by Norwegian specimens. The species is recorded from all kinds of standing waters, both temporary and permanent (Lundblad 1968). Within the present project, only one specimen was detected from a sparsely vegetated spring pond in Central Norway (calcium concentration 42 mg/l, conductivity 227 µS/cm).

Pionacercus uncinatus (Koenike, 1885), first described from Northern Germany, is a morphologically very distinct species, represented in BOLD with one BIN (BOLD:ACR9568 with records from Norway and The Netherlands). The species is reported from ponds and ditches with oligotrophic waters in addition to lakes (Lundblad 1968). Our records include lakes in Northern Norway (calcium concentration 20–36 mg/l, conductivity 88–239 µS/cm).

Subfamily Huitfeldtiinae

Water mite larvae detached from *Metacnephia tredecimata* (Edwards, 1920) (Diptera, Simuliidae) (coll. Dominiak) could be identified by matching DNA barcodes to records on BOLD identified as *Huitfeldtia rectipes* Thor, 1898, a species first described from Norway. Data in BOLD indicate a transatlantic distribution (BOLD:AEO1345 from Canada, Norway and The Netherlands). This species has been reported in Northern Europe from large lakes and ponds, in the southern part of its distribution area (Central Europe) from the profundal of lakes (Lundblad 1968). Our records come from the littoral zone of lakes and oxbow lakes in Northern Norway (calcium concentration 36–45 mg/l, conductivity 212–350 µS/cm).

Subfamily Hydrochoreutinae

Hydrochoreutes krameri Piersig, 1896, first described from Germany, has records in BOLD that cluster in BIN BOLD:ACR9737 from North Macedonia, The Netherlands, Norway and Portugal. Published data indicate that *H. krameri* has a preference for standing waters with rich macrophyte vegetation (Lundblad 1968). This is in line with our records from lakes, mainly with dense water vegetation, in all parts of the study area (calcium concentration 20–80 mg/l, conductivity 88–431 µS/cm).

Subfamily Pioninae

Piona alpicola (Neuman, 1880) has its type locality in Sweden. Three distinct clusters contain specimens identified as *P. alpicola* in BOLD, indicating the presence of cryptic species. The only specimen from our project clusters with records from Canada and The Netherlands (BOLD:AAG1454). Further genetically divergent BINs are BOLD:ACS0973 with records from Iran, Russia and The Netherlands, and BOLD:ACR9570 with records from The Netherlands and Türkiye. Based on these findings, the ecological information in published literature currently is not meaningful. Our specimens were recorded from oxbow lakes in Central and Northern Norway (calcium concentration 25–36 mg/l, conductivity 155–257 µS/cm).

DNA barcodes in BOLD indicate that *Piona carnea* (Koch, 1836), first described from Germany, is a species aggregate. Specimens from our project are distributed in two distinct BINs: BOLD:ACS0622, *Piona carnea* s. str., with records from Finland, Germany, Norway, Portugal, The Netherlands, and United Kingdom; BOLD:ACT1401, *Piona carnea* aggr. sp. 1, with records from Norway. First attempts to find diagnostic features separating members of these two clusters failed. No type material of this species exists, and we decided to consider the cluster including a specimen from Germany as the *Piona carnea* s. str.. *Piona carnea* aggr. sp. 1 might represent one of three species described by Neuman (1880) from Sweden and subsequently

synonymized with *P. carnea*, namely *P. alpina* (Neuman, 1880), *P. brevipalpis* (Neuman, 1880), and *P. unguiculata* (Neuman, 1880) (see Lundblad 1954). Moreover, a further cluster includes specimens assigned to *P. carnea* from a wide geographical range: BOLD:ACM0527 with records from Canada, The Netherlands, Portugal and United Kingdom. Populations attributed to the *Piona carnea* aggr. were recorded from all kinds of standing waters, occasionally in temporary waters or in slow running streams. Mostly in waters with relatively low nutrient conditions (Lundblad 1968, Smit & van der Hammen 2000). We recorded *Piona carnea* s. str. from lakes, in Southeastern and Central Norway, as well as in an outlet stream (calcium concentration 40–70 mg/l, conductivity 190–439 µS/cm). *Pona carnea* aggr. sp. 1 was recorded from oxbow lakes in Central and Northern Norway and a pond in Central Norway (calcium concentration 25–83, conductivity 155–364).

DNA barcodes in BOLD attributed to *Piona coccinea* (Koch, 1836) are assembled in one distinct cluster with three genetically close BINs (< 3% divergent). BOLD:ABX5061, BOLD:ABY5445 and BOLD:AAU1219 hold records from Norway, Sweden and The Netherlands. The species is reported from varying types of lentic and slowly running waters; in The Netherlands, the species shows a preference for alkaline fresh water (Gerecke et al. 2016). We recorded *P. coccinea* from vegetation-rich lakes and oxbow lakes in Central and Southeastern Norway (calcium concentration 25–66 mg/l, conductivity 127–431 µS/cm).

Piona coccinoides Thor, 1897, first described from Norway, apparently has a transatlantic distribution, with records from Canada and Norway in the same cluster consisting of three very close BINs (BOLD:AEO2706, BOLD:AEO2707, BOLD:AEO2708, BOLD:AAM9499). *Piona coccinoides* is reported from standing waters, mainly oligotrophic-dystrophic ponds, but has also been found in the littoral of lakes (Lundblad 1968). In Norway most records were from mountainous areas (Gerecke et al. 2016). Our records are from a lowland lake and an oxbow lake in Central Norway, both with dense water vegetation (calcium concentration 42–45 mg/l, conductivity 247–292 µS/cm).

Piona conglobata (Koch, 1837), first described from Germany, is likely a species aggregate. We consider the nominal species to be represented by BIN BOLD:ACS0245 (following Gerecke et al. 2016) and identify two additional clusters sharing diagnostic features with *P. conglobata.* Both represent taxa previously considered junior synonyms of *P. conglobata* (Lundblad 1962) but can be distinguished by morphological characteristics (Gerecke & Stur in prep.). *Piona punctata* (Neuman, 1875), originally described from Sweden is represented in BINs BOLD:AFA2526, BOLD:AFA2527 and BOLD:ACS0324 with records from Norway and The Netherlands. *Piona lacustricola* K. Viets, 1949, described from Ireland has records from Norway in BIN BOLD:AEC4987 (Gerecke & Stur in prep.). The record of *P. dispersa* Sokolow, 1926 in Gerecke et al. (2022) is a misidentification and refers to *P. lacustricola*, no records of *P. dispersa* are confirmed from Norway. In view of this new data, the ecology and distribution of *P. conglobata* must be reconsidered. The species s. l. was reported from all kinds of standing waters, rarely from pool areas of streams, and regarded to be tolerant towards pollution and elevated salt concentrations (Smit & van der Hammen 2000). We recorded the species s. str. from lakes in Southeastern, Central and Northern Norway (calcium concentration 26–66 mg/l, conductivity 209–439 µS/cm), *P. punctata* from lakes and oxbow lakes in Southeastern Norway (calcium concentration 44–80 mg/l, conductivity 198–387 µS/cm), and *P. lacustricola* in a pond in Central Norway and a lake in Northern Norway (calcium concentration 22–48 mg/l, conductivity 111–353 µS/cm).

Piona discrepans (Koenike, 1895) was first described from Germany. In BOLD, records attributed to this species (all exclusively from Norway) are found in a distinct cluster with three genetically close BINs (BOLD:AFT9504; BOLD: AFC1955; BOLD:AFD2230). The species is reported from lakes in Central and Northern Norway (calcium concentration 35–45 mg/l, conductivity 174–212 µS/cm).

Piona laminata (Thor, 1901), first described from Norway, belongs to a widely split species aggregate in need of revision. Specimens currently attributed to this species were in part treated as junior synonyms or subspecies of *P. annulata* (Thor, 1900) or *P. nodata* (Müller, 1776). DNA barcodes of specimens morphologically resembling *P. laminata* are distributed across four genetically very divergent and geographically distinct clusters, which most likely represent four distinct species; BOLD:AEL3248 with records from Montenegro, BOLD:AEC1082 from Norway, BOLD:ACR9614 from Norway, and BOLD:ACR9615 from The Netherlands. Due to the unclear taxonomic status of taxa within the *P. nodata* species group, most faunistic data are uncertain (Gerecke et al. 2016). All our sequenced records represent *P. laminata* aggr. sp. 1 (BOLD:AEC1082); the other BIN with specimens reported from Norway (BOLD:ACR9614) contains material from the far North, collected by Harry Smit. However, we also have examined specimens without DNA barcodes from the *P. laminata* aggregate that differ in morphology (*P. laminata* aggr. sp. 2 and 3). Our records of *P. laminata* aggr. sp. 1 come from lakes of all parts of the study area as well as from a pond in Central Norway (calcium concentration 42–142 mg/l, conductivity 190–741 µS/cm). *Piona laminata* aggr. sp. 2 was recorded from a lake in Southeastern Norway (calcium concentration 48 mg/l, conductivity 328 µS/cm) and *P. laminata* aggr. sp. 3 from lakes and a slow-flowing outlet stream in Northern Norway (calcium concentration 25–38 mg/l, conductivity 125–223 µS/cm).

Piona longipalpis (Krendowskij, 1878), first described from Russia, is reported to have a Palaearctic distribution (Gerecke et al. 2016). In BOLD, specimens attributed to this species are found in one distinct cluster (BOLD:AAU0587) with records from Norway, The Netherlands and Sweden. The species is reported from standing waters of varying sizes, slow running streams and ditches (Böttger & Ullrich 1974, Smit & van der Hammen 2000) and from eutrophic, oligotrophic as well as dystrophic waters (Lundblad 1968). We recorded the species from lakes, including an oxbow lake, in Southeastern, Central and the southern part of Northern Norway (calcium concentration and conductivity were 25–66 mg/l and 142–439 µS/cm).

Piona neumani (Koenike, 1883), first described from Germany, is a species with Holarctic distribution and widespread in Europe. DNA barcodes from our specimens attributed to this species cluster in one BIN together with specimens from The Netherlands (BOLD:ACS0699). BOLD contains two other records of this species with DNA barcodes that differ markedly from the barcodes of our species. One is imported from GenBank and published in Klimov et al. (2022) and the other is grouped with our *Piona laminata* aggr . (BOLD:AEC1082). The species is reported from standing waters, e.g. ditches, canals and lakes, but also channelized lowland streams (Gerecke et al. 2016). Our records include lakes in Southeastern and Northern Norway (calcium concentration 48–54 mg/l, conductivity 205–342 µS/cm).

Piona paucipora (Thor, 1897), first described from Norway, has subsequently been recorded from many parts of the Palaearctic. In BOLD, DNA barcodes attributed to this species are assembled in one distinct BIN (BOLD:ACS0569) with records from Norway and The Netherlands. Our records include lakes in Northern Norway (calcium concentration 30–45 mg/l, conductivity 142–350 µS/cm).

As reported previously by Stålstedt et al. (2013), *Piona pusilla* (Neuman, 1875), first described from Sweden, represents a species aggregate. In BOLD, DNA barcodes assigned to this species are spread over five genetically distinct clusters, all reported from Central and Northern Europe: BOLD:AAU1152 – Norway, Russia, Sweden (*Piona pusilla* s. str., according to Stålstedt et al. 2013); BOLD:AAT9736 – The Netherlands, Norway, Sweden (*Piona pusilla* aggr. sp. 1, corresponds to *Piona* sp. A near *pusilla* in Stålstedt et al. 2013); BOLD:AAT9737 – Norway, The Netherlands, Sweden (*Piona pusilla* aggr. sp. 2, corresponds to *Piona* sp. B near *pusilla* in Stålstedt et al. 2013); BOLD:ACS0357 from The Netherlands (*Piona pusilla* aggr. sp. 3); BOLD:AFA8511 – Norway (*Piona pusilla* aggr. sp. 4). The species s. l. was reported from

standing waters, preferably lakes (Gerecke et al. 2016). We recorded *Piona pusilla* s. str. from lakes in Southeastern and Northern Norway, as well as a stream in Central Norway (calcium concentration 40–52 mg/l, conductivity 256–387 µS/cm); *Piona pusilla* aggr. sp. 1 was sampled from lakes in all parts of the study area (calcium concentration 30–56 mg/l, conductivity 205–353 µS/cm), whereas *Piona pusilla* aggr. sp. 4 was recorded from lakes in Southeastern Norway (calcium concentration 64–82 mg/l, conductivity: 308–391 µS/cm).

Piona rotundoides (Thor, 1897), first described from Norway, has an apparent transatlantic distribution. In BOLD, DNA barcodes attributed to this species are found in one cluster with four genetically close BINs that indicating an intraspecific genetic divergence of 1–4% (BOLD:AFA9597 has records from Canada and Norway; BOLD:AAY3657 from Norway, The Netherlands and Sweden; BOLD:ADZ0334 and BOLD:AFC6024 from Norway). The species was recorded from lakes in Southeastern and Northern Norway, as well as from an outlet stream in Northern Norway (calcium concentration 30–66 mg/l, conductivity 156–431 µS/cm).

Piona stjordalensis (Thor, 1897), first described from Norway, was over a long time treated as subspecies of *P. coccinea*. It has a wide Palaearctic distribution, but the BIN with records from Norway is only shared with a record from Russia (BOLD:AFH1741). A second, genetically distant BIN with DNA barcodes of *P. stjordalensis* in BOLD contains records from Sweden and The Netherlands (BOLD:AAU0687). Our records include lakes and oxbow lakes in Central Norway as well as lakes from the southern part of Northern Norway (calcium concentration 30–48 mg/l, conductivity 227–353 µS/cm).

Piona variabilis (Koch, 1836), first described from Germany, is considered to be a Holarctic species (Gerecke et al. 2016). In BOLD, DNA barcodes attributed to this species are found in three neighbouring clusters: BOLD:AAU0702 with records from Norway and Sweden, BOLD:AAU0701 with records from Norway, The Netherlands, Sweden and Portugal, and BOLD:AGK5340 with a record from Russia. Morphological differences between Norwegian representatives of the different BINs have not been found so far. The species is recorded from many different types of lentic waters - from ditches and ponds to large lakes. In The Netherlands, it favors clear, fresh waters, but is also tolerating elevated nutrient levels (Smit & van der Hammen 2000). In our project, the species was found in lakes in Southeastern and Northern Norway (calcium concentration 36–82 mg/l, conductivity 178–594 µS/cm).

Subfamily Tiphyinae

Pionopsis lutescens (Hermann, 1804), first described from France, was regarded a clearly recognizable and distinct species with a wide Holarctic distribution. However, DNA barcodes attributed to this taxon are distributed across three distinct clusters in BOLD: BOLD:ACR9955 with records from Norway and The Netherlands; BOLD:AFV3897 with records from Portugal; and the genetically close BOLD:ACS0644 + BOLD:AET1848 + BOLD:AGE7285 with records from Greece, Montenegro, Norway, Portugal and The Netherlands. These clusters likely represent three distinct species awaiting morphological definition. The more widely distributed group with specimens from Central and Northern Europe is probably the nominal species. The species s. l. is reported from many kinds of standing waters, also in stream pools and small habitats with brief, temporary water coverage (Gerecke et al. 2016). In our project it is recorded from lakes, oxbow lakes and ponds in Southeastern and Central Norway (calcium concentration 24–83 mg/l, conductivity 157–594 µS/cm).

Tiphys bullatus (Thor, 1899) was first described from Norway and has a wide Holarctic distribution (Gerecke et al. 2016). The attempt to sequence the single specimen detected during our study was unsuccessful and no DNA barcodes are available in BOLD. *Tiphys bullatus* lives in temporary and permanent ponds, ditches and lakes (Lundblad 1968). Our record comes from a lake in Central Norway (calcium concentration 48 mg/l, conductivity 167 mg/l).

Tiphys latipes (Müller, 1776) was first described from Denmark and has a Palaearctic distribution

(Gerecke et al. 2016). DNA barcodes attributed to this species from Norway and The Netherlands form one distinct cluster with two genetically close BINs (BOLD:ACS0328, BOLD:ACS0329). The species is reported from temporary and permanent ponds, pools in reedbeds, coastal dune waters and springs (Gerecke et al. 2016, Lundblad 1968). Our records were from lakes in southeastern and Northern Norway (calcium concentration 32–36 mg/l, conductivity 174–219 µS/cm).

Tiphys scaurus (Koenike, 1892), first described from Germany, has reliably identified records in BIN BOLD:AEC1488, all from Norway. The species was recorded from a lake in Northern Norway (calcium concentration: 40 mg/l, conductivity: 178 µS/cm).

Tiphys torris (Müller, 1776) was first described from Denmark and has a Palaearctic distribution (Gerecke et al. 2016). DNA barcodes from Montenegro, Norway, Portugal and The Netherlands attributed to this species form one distinct cluster with 3.3% intraspecific genetic variation (BOLD:ACR9977). The species has a Palaearctic distribution and is widespread in Europe (Gerecke et al. 2016). It lives in temporary and permanent ponds and ditches, occasionally lakes and slow running streams, in eutrophic, oligotrophic and dystrophic waters (Lundblad 1968). Our records include lakes in Central and Northern Norway, as well as a pond in Central Norway (calcium concentration 40–46 mg/l, conductivity 193–378 µS/cm).

Family Unionicolidae

Neumania callosa (Koenike, 1895), first described from Germany, is widespread across Europe and has also been recorded from Asia. So far only two records from Norway are present in BOLD, one of which is from this project (BOLD:AEF2878). The species is considered cold-stenothermous and reported from the profundal and sublittoral of oligotrophic and dystrophic lakes (Gerecke et al. 2016). We collected it from the littoral of a lake in Northern Norway (calcium concentration 22 mg/l, conductivity 153 µS/cm).

Neumania limosa (Koch, 1836), first described from Germany, is Palaearctic and widespread in Europe. DNA barcodes attributed to this species are found in two divergent clusters with three BINs: BOLD:AEC3112 with records from Norway and Russia, and BOLD:AEF5902 + BOLD: ACS0551 with records from Montenegro, Portugal, The Netherlands, and Türkiye. In absence of type material, a revision of these two clades - and, if possible, a decision about diagnostic features of *N. limosa* s. str. - must be based on the prevailing interpretation of the species in literature. Records of the species s. l. are from oligotrophic and eutrophic lakes, ditches and ponds (Gerecke et al. 2016). We recorded *N. limosa* from lakes in Southeastern Norway (calcium concentration 26–158 mg/l, conductivity 209–675 µS/cm).

Neumania spinipes (Müller, 1776), first described from Denmark, is a Holarctic species. DNA barcodes attributed to this species are found in one cluster with two genetically close BINs (BOLD:AKG6980, BOLD:ACS0478) with specimens from Norway, Russia, and The Netherlands. The habitat of this species is eutrophic to dystrophic standing waters, more rarely slowly flowing waters, limnocrenes, and temporary waters (Gerecke et al. 2016). Our records include ponds, lakes and oxbow lakes in Central and Northern Norway (calcium concentration 22-50 mg/l, conductivity 111-594 µS/cm).

Neumania vernalis (Müller, 1776), first described from Denmark, is a Palaearctic species. DNA barcodes attributed to this species are all found in one single BIN (BOLD:ACS0012) with records from Norway, North Macedonia, Russia, and The Netherlands. The species is recorded from standing waters, the macrophyte belt of small ponds and lakes, from eutrophic and oligotrophic habitats and waters with high lime content (Lundblad 1968, Gerecke et al. 2016). We sampled *N. vernalis* from two lakes in Southeastern Norway (calcium concentration 48–50 mg/l, conductivity 337–594 µS/cm).

Unionicola crassipes (Müller, 1776), first described from Denmark, is known from the Holarctic region and is regarded as widespread in Europe. However, many records, especially from outside Europe, are questionable. In BOLD, most specimens attributed to this species are found in two main clusters. One of them shows

a comparatively high internal divergence with five BINs (BOLD:ADY4996, BOLD:AAT9942, BOLD:AAT9943, BOLD:AFD3924, BOLD:ACS0304) with records from Canada, Norway, Russia, Sweden and The Netherlands). The other cluster contains specimens from Canada, Norway, Sweden, and The Netherlands distributed across three BINs (BOLD:AAT9944, BOLD:AFB9577, BOLD:ACS0405). Most probably, records of *U. crassipes* in BOLD that belong to other groups than these are misidentifications. The species is very common in standing and slowly flowing waters of different trophic states (Gerecke et al. 2016). Our records are from lakes in all parts of the study area, as well as an oxbow lake in Southeastern Norway (calcium concentration 20–100 mg/l, conductivity 88–431 µS/cm).

Unionicola figuralis (Koch, 1836), first described from Germany, is ascertained from many parts of Europe, while non-European records require confirmation. In BOLD, two DNA barcodes from our project are the only records so far (BOLD:AFH2327). The species has been documented from lakes, ditches and other small water bodies (Lundblad 1968), with a preference for relatively nutrient-poor freshwaters (Smit & van der Hammen 2000). We collected the species from a vegetation rich oxbow lake in Central Norway (calcium concentration 42 mg/l, conductivity 247 µS/cm).

Unionicola gracilipalpis (K. Viets, 1908), first described from Germany, has a Holarctic distribution. In BOLD, DNA barcodes attributed to the species are found in a distinct BIN (BOLD:ACS0097). The species is present both in standing and slowly flowing waters (Gerecke et al. 2016). In our project it was registered in lakes with dense water vegetation in Central Norway and southern parts of Northern Norway, as well as in one oxbow lake in Central Norway (calcium concentration 36–55 mg/l, conductivity 198–292 µS/cm).

Unionicola minor (Soar, 1900), first described from England, was long considered a subspecies, or even a synonym, of *U. crassipes.* Its geographical distribution is therefore unclear. DNA barcode data in BOLD suggest that this is a species aggregate in need of revision as records attributed to *U. minor* are distributed over six distinct and genetically divergent clusters – three were named "sp. near minor A-C" in Stålstedt et al. (2013). BOLD:AAU0336 with records from Norway, Sweden, and The Netherlands [Stålstedt et al. (2013) sp. B], BOLD:AEF4865 with records from Montenegro, BOLD:ACS0643 from The Netherlands, BOLD:AFO2171 from Portugal, BOLD:AAU0335 from Montenegro, North Macedonia, Sweden, and The Netherlands [Stålstedt et al. (2013) sp. A], BOLD:AAU337 from Sweden [Stålstedt et al. (2013) sp. C] and BOLD:AEG7018 from China. Since the specimens from our study were not successfully sequenced, it is not possible to determine which of the above-mentioned clusters our *U. minor* material belongs to. The reported habitats of *U. minor* s. l. are ponds, ditches and both the littoral and profundal areas of lakes (Gerecke et al. 2016). Our records are from littoral areas of lakes in the Southeastern parts of Norway (calcium concentration 32–100 mg/l, conductivity 219–431 µS/cm).

SUPERFAMILY ARRENUROIDEA

Family Arrenuridae

Arrenurus (*Arrenurus*) *albator* (Müller, 1776), first described from Denmark, has a Western Palaearctic distribution. The species is reported from small lakes, ditches and ponds (Gerecke et al. 2016). In BOLD, specimens attributed to this species are found in one homogeneous cluster forming two BINs: BOLD:ACR9639, BOLD:ACR9638 3.2% divergent, with specimens from Norway, Portugal, Russia, and The Netherlands. Our material comes from lakes and oxbow lakes in Southeastern, Central and southern parts of Northern Norway (calcium concentration 24–100 mg/l, conductivity 157–409 µS/cm).

Arrenurus (*Arrenurus*) *bicuspidator* Berlese, 1885, first described from Italy, has a Palaearctic distribution. It is reported from all kinds of lentic waters including moorland pools and stagnant areas of lowland streams, in Sweden preferably from lakes (Gerecke et al. 2016). Specimens attributed to this species cannot be separated

by COI sequencing from the morphologically distinct *A.* (*A.*) *radiatus* Piersig, 1894, not reported from Scandinavia. In BOLD, these two species are found in a homogeneous cluster with one BIN (BOLD:ACS0403) with records from Kyrgyzstan, Norway, Portugal, South Africa, and The Netherlands. We recorded the species from lakes and one oxbow lake in Southeastern Norway (calcium concentration 32–82 mg/l, conductivity 256–391 µS/cm).

Arrenurus (*Arrenurus*) *bruzelii* Koenike, 1885, first described from Germany, has a Palaearctic distribution (Gerecke et al. 2016). In BOLD, all specimens attributed to *A. bruzelii* are found in one cluster with two BINs: BOLD:ACS0482 with records from Germany, and The Netherlands; BOLD:ACS0212 from Norway, Serbia, and The Netherlands. The species is reported from all kinds of lentic waters including stagnant parts of lowland streams, but sensitive to eutrophication (Gerecke et al. 2016). Our material was sampled from lakes in Southeastern and Central Norway (calcium concentration 40–100 mg/l, conductivity 204–594 µS/cm).

Arrenurus (*Arrenurus*) *compactus* Piersig, 1894, first described from Germany, has a Palaearctic distribution (Gerecke et al. 2016). In BOLD, DNA barcodes attributed to this species are found in three somewhat divergent BINs (2.8-6%), all with specimens from Norway: BOLD:AEB8851, BOLD:AEJ6492, and BOLD:AFA3417. The species is reported from lakes and moorland pools, often with acidic waters (Gerecke et al. 2016). Our material was recorded from lakes in Central Norway (calcium concentration 34–45 mg/l, conductivity 193–292 µS/cm).

Arrenurus (*Arrenurus*) *crassicaudatus* Kramer, 1875, described from Germany, has a Palaearctic distribution (Gerecke et al. 2016). In BOLD, all DNA barcodes attributed to this species cluster in BIN BOLD:ACS0558 with records from Norway, Poland, Russia, and The Netherlands. Our material was sampled from lakes in Southeastern Norway (calcium concentration 50–82 mg/l, conductivity 308–594 µS/cm).

Arrenurus (*Arrenurus*) *kjerrmanni* Neuman, 1880, first described from Sweden, is reported only from Northern and Northeastern Europe (Gerecke et al. 2016). Sequencing of the barcode-fragment of COI was attempted on a total of nine specimens, but without success, and so far, no DNA barcode data are available in BOLD. The species is reported from all kinds of standing or slowly flowing waters, but preferably from ponds, both permanent and temporary; in oligo- to eutrophic or acid waters (Lundblad 1968). We recorded it from all parts of the study area, mostly in lakes, but also one in an oxbow lake (calcium concentration 24–55 mg/l, conductivity 132–378 µS/cm).

Arrenurus (*Arrenurus*) *leuckarti* Piersig, 1894, first described from Germany, is reported from Western, Central and Eastern Europe, and recently for the first time from Scandinavia (Gerecke et al. 2022). Attempts to sequence specimens from this project have been unsuccessful. In BOLD, *A. leuckarti* DNA barcodes form one distinct cluster (BOLD:ACR9670) from The Netherlands. The species is reported from ponds, ditches and moorland pools, occasionally from streams, in fresh to eutrophic and neutral to acid waters (Gerecke et al. 2016). Our material was recorded from lakes in Southeastern and Central Norway (calcium concentration 44–58 mg/l, conductivity 190–298 µS/cm).

Arrenurus (*Arrenurus*) *neumani* Piersig, 1895, first described from Germany, has a Palaearctic distribution. In BOLD, most DNA barcodes attributed to this species cluster in BIN BOLD:ACR9801 with records from Norway, Poland, and The Netherlands. This species is reported from various types of standing waters, also at subalpine elevations (Gerecke et al. 2016). Our material was sampled exclusively from lakes, in all parts of the study area (calcium concentration 20–82 mg/l, conductivity 88–594 µS/cm).

Arrenurus (*Arrenurus*) *pustulator* (Müller, 1776), first described from Denmark, has a Western Palaearctic distribution. In BOLD, four DNA barcodes attributed to this species cluster in BIN BOLD:ADD6576 with records from Norway and Poland. The species is reported from oligo- to mesotrophic and dystrophic lakes (Gerecke et al. 2016). In our project it is recorded from a lake in the southern part of Northern Norway (calcium

concentration 44 mg/l, conductivity 208 µS/cm).

Arrenurus (*Arrenurus*) *subarcticus* Lundblad, 1917, first described from Sweden, is known from a few sites in northern and northeastern Europe only, and here reported for the first time from Norway. Our COI sequences are the first in BOLD and cluster in BOLD:AFH3605. *Arrenurus subarcticus* is reported from ponds and oligo- to mesotrophic lakes (Gerecke et al. 2016). Our material includes specimens from lakes in Central and Northern Norway (calcium concentration 30–45 mg/l, conductivity 147–212 µS/cm).

Arrenurus (*Arrenurus*) *tricuspidator* (Müller, 1776), first described from Denmark, has a Palaearctic distribution. In BOLD, DNA barcodes attributed to this species cluster in BIN BOLD:ACS0825 with records from Germany, Norway and The Netherlands. This species is reported from all types of standing waters but avoiding higher nutrient levels and brackish conditions (Gerecke et al. 2016). We recorded the species from lakes in Southeastern Norway (calcium concentration 48–58 mg/l, conductivity 256–328 µS/cm).

Arrenurus (*Megaluracarus*) *buccinator* (Müller, 1776), first described from Denmark, has a Western Palaearctic distribution. In BOLD, DNA barcodes attributed to this species cluster in BIN BOLD:ACS0129 with records from Norway and The Netherlands. *Arrenurus buccinator* is reported from a high variety of standing waters including iron-rich seepages and avoids elevated degrees of eutrophy (Gerecke et al. 2016). Our material was collected throughout the entire study area, from lakes, oxbow lakes, ponds and a spring (calcium concentration 22–142 mg/l, conductivity 111–741 µS/cm).

Arrenurus (*Megaluracarus*) *globator* (Müller, 1776), first described from Denmark, has a Palaearctic distribution. In BOLD, DNA barcode records cluster with records of *A. tubulator* in BIN BOLD:ACS0765 with specimens from North Macedonia, Norway, Poland, Russia, and The Netherlands. Further records of *A. globator* from Portugal are clustered in the nearest neighboring BIN BOLD:AFO3503, 5.4% distant, indicating the existence of a sister species in SW Europe. *Arrenurus globator* is extremely eurytopic and very common, reported from all types of standing and slow-flowing waters, only conditions of strong pollution or elevated salt contents are avoided (Gerecke et al. 2016). Our specimens were recorded from Southeastern, Central and southern parts of Northern Norway, primarily from lakes, but also oxbow lakes, a pond, and a slow-flowing outlet stream (calcium concentration 22–158 mg/l, conductivity 111–675 µS/cm).

Arrenurus (*Megaluracarus*) *mediorotundatus* Thor, 1898, first described from Norway, has a Western Palaearctic distribution. In BOLD, DNA barcodes of this species are found in two clearly divergent BINs, 14% apart: BOLD:ADD6107 with specimens from Norway and Germany and BOLD:ACR9673 from The Netherlands. The species is reported from springs, temporary and permanent ponds, ditches and quagfens, rarely from pool areas of streams, in oligo-, eu- and dystrophic waters (Gerecke et al. 2016). We recorded the species from a lake in Southeastern Norway (calcium concentration 100 mg/l, conductivity 377 µS/cm).

Arrenurus (*Megaluracarus*) *membranator* Thor, 1901, first described from Norway, is reported to have a Palaearctic distribution, with records also from the Faroe Islands, Iceland and Greenland (Gerecke et al. 2016). In BOLD, DNA barcodes attributed to the species are found in two clearly divergent BINs (10.4% p-distance): BOLD:ADY9283 with specimens from Norway, BOLD:AAJ3099 from Canada and Norway, indicating high intraspecific variation and a transatlantic distribution of the species. *Arrenurus membranator* is reported from various types of lentic habitats, mostly in oligotrophic waters (Gerecke et al. 2016). Our material was sampled in lakes in Southeastern and Northern Norway, but also a pond and a spring in the latter area (calcium concentration 28–52 mg/l, conductivity 118–387 µS/cm).

Arrenurus (*Megaluracarus*) *securiformis* Piersig, 1895, first described from Germany, has a Western Palaearctic distribution. DNA barcodes attributed to the species in BOLD cluster in BOLD:ACR9591 with records from Germany, Norway, and The Netherlands. The species is reported from a high variety of lentic habitats

with fresh to oligohaline, and meso- to eutrophic waters (Gerecke et al. 2016). Our specimens were recorded from lakes and a slow-flowing stream in Central Norway (calcium concentration 34–44 mg/l, conductivity 183–212 µS/cm).

Arrenurus (*Megaluracarus*) *stjordalensis* Thor, 1899, first described from Norway, has a Western Palaearctic distribution, but is absent from the Mediterranean. In BOLD, DNA barcodes attributed to the species cluster in BIN BOLD:AAE0675 with specimens from Canada and Norway. The species is reported from lakes (also in profundal) and larger streams, in the northern part of the area ponds, in oligo- to eutrophic waters (Gerecke et al. 2016). We recorded it from two lakes in Northern Norway (calcium concentration of 36–40 mg/l, conductivity 147–187 µS/cm).

Arrenurus (*Megaluracarus*) *zachariae* Koenike, 1886, first described from the present-day Czech Republic, has a European distribution. In BOLD, all DNA barcodes attributed to the species cluster in BIN BOLD:ADF7386 with records from Norway and The Netherlands. The species is reported from limnocrene springs and pools of spring streams (Gerecke et al. 2016). Our material was collected in a lake in Southeastern Norway and a pool of a spring brook in Northern Norway (calcium concentration 26–70 mg/l, conductivity 209–355 µS/cm).

Arrenurus (*Micruracarus*) *biscissus* Lebert, 1879, first described from Switzerland, has a European distribution (Gerecke et al. 2016). DNA barcodes attributed to this species in BOLD cluster in BIN BOLD:ACS0128 with records from Germany, and The Netherlands. The species is reported from meso-, more rarely eutrophic lakes, canals and lowland streams (Gerecke et al. 2016). Our material was recorded in one lake in Southeastern Norway (calcium concentration 54 mg/l, conductivity 342 µS/cm).

Arrenurus (*Micruracarus*) *forpicatus* Neuman, 1880, first described from Sweden, has a European distribution. DNA barcodes attributed to the species in BOLD cluster in BIN BOLD:ACS0201 with records from Norway, Russia, and The Netherlands. The species is reported from various types of lentic habitats, with a preference for dystrophic waters, but also in mesotrophic conditions (Gerecke et al. 2016). Our material was sampled from all parts of the study area, in lakes, oxbow lakes, and ponds (calcium concentration 22–80 mg/l, conductivity 111–339 µS/cm).

Arrenurus (*Micruracarus*) *inexploratus* K. Viets, 1930, first described from Germany, is reported from not numerous sites scattered all over Central, Northern and Western Europe (Gerecke et al. 2016). There is one BIN under this name in BOLD (BOLD:ACR9561) with records from Poland and The Netherlands. Our attempts to sequence specimens from Norway was unsuccessful. The species is reported from temporary and permanent ponds, ditches, quagfens and helocrenes, from oligo- to eutrophic and dystrophic waters (Gerecke et al. 2016). Our material is recorded from a lake in Southeastern Norway (calcium concentration 32 mg/l, conductivity 219 µS/cm).

Arrenurus (*Micruracarus*) *sinuator* (Müller, 1776), first described from Denmark, has a Western Palaearctic distribution. DNA barcodes attributed to this species in BOLD cluster in BIN BOLD:ADD5461 with records from Germany, Norway, Poland, and The Netherlands. The species is reported from all types of standing waters and obviously tolerant against eutrophication (Gerecke et al. 2016). We recorded it from a lake in Southeastern Norway (calcium concentration 50 mg/l, conductivity 256 µS/cm).

Arrenurus (*Truncaturus*) *stecki* Koenike, 1894, first described from Switzerland, has a Western Palaearctic distribution. DNA barcodes attributed to the species in BOLD cluster in BIN BOLD:ACR9564 with records from Norway, Poland, and The Netherlands. The species is reported from ditches, moorland pools and semiaquatic habitats like quagfens (Gerecke et al. 2016). Our material comes from two lakes in Southeastern Norway (calcium concentration 64–100 mg/l, conductivity 308–377 µS/cm).

Arrenurus (*Truncaturus*) *truncatellus* (Müller, 1776), first described from Denmark, has a Palaearctic distribution. DNA barcodes attributed to the species in BOLD cluster together in a group containing four different BINs that are diverging by approximately 2-6% (BOLD:AFB0887

from Norway; BOLD:ACR9752 from Poland and The Netherlands; BOLD:AFA5399 from Norway; BOLD:ACR9753 from Norway and The Netherlands). The species is reported from temporary or permanent ditches, moorland pools and semiaquatic habitats like quagfens (Gerecke et al. 2016). Our records come from lakes in Southeastern Norway (calcium concentration 32–100 mg/l, conductivity 219–594 µS/cm).

Family Mideidae

Midea orbiculata (Müller, 1776), first described from Denmark, is widespread in Europe. In BOLD, the only available sequence originates from a Norwegian specimen from a previous project (Gerecke et al. 2022) (BOLD:ACS0045). In the present project, the species was sampled from lakes and oxbow lakes in Southeastern Norway (calcium concentration 32–100 mg/l, conductivity of 290–391 µS/cm).

Family Mideopsidae

Mideopsis crassipes Soar, 1904, first described from England, has a Holarctic distribution. DNA barcodes attributed to the species cluster in one BIN (BOLD:ACR9760) that contains records from North Macedonia, Norway, Poland, Russia and The Netherlands. Our records include a lake in Southeastern Norway and a stream in Northern Norway (calcium concentration 44–64 mg/l, conductivity 308–394 µS/cm).

Mideopsis orbicularis (Müller, 1776), first described from Denmark, is reported from many parts of the Palaearctic, but represents possibly an aggregate of several species related also to *M. roztoczensis* Biesiadka & Kowalik, 1979, first described from Poland. Until recently (Gerecke et al. 2016), *M. roztoczensis* was regarded as a rhithrophilous sister taxon of the lenitobiont *M. orbicularis*, but a clear genetic separation between the two species is not evident. In BOLD, all specimens attributed to these two species are intermixed in two distinct clusters: BOLD:ACR9763 contains *M. orbicularis* from Norway and The Netherlands as well as *M. roztoczensis* from Norway; the genetically close BOLD:ACS0476 and BOLD:AFW3120 both also contain specimens attributed to these species, with records from Germany, Norway, Poland and The Netherlands. Until the species boundaries are analysed in more detail, it is not possible to separate the two species. Our material attributed to *M. orbicularis* was sampled from lakes in Southeastern and Northern Norway (calcium concentration 26–82 mg/l, conductivity 156–431 µS/cm).

Mideopsis roztoczensis, first described from Poland, has been subsequently reported from many parts of Europe (Gerecke 2016, see also above). In BOLD, DNA barcodes attributed to this species are found in nine BINs in addition to those mentioned above, indicating that it represents a species aggregate with geographically distinct genetic lineages. The Norwegian records are found in two BINs: BOLD:AEN6785 together with a record from Serbia, and BOLD:ACI1492 with records from Bosnia and Herzegovina, Greece, Montenegro, Russia, Serbia, and Türkiye. This species, like the preceding one, needs taxonomic revision and it does not make sense to discuss older ecological data. Our specimens were recorded from a lake and rivers in Southeastern Norway (calcium concentration 18–48 mg/l, conductivity 71–328 µS/cm).

Water mite preference for calcareous habitats

The available literature on calcium preference for water mite species is rather scanty, and statements about their ecological preferences are in general often inconsistent. It is evident that aquatic mites are not directly reliant on dissolved calcium in the same way as molluscs and crustaceans, which require $CaCO_3$ for their shells and exoskeletons. However, calcium concentration is a parameter that describes the hydrological conditions influenced by the geology of the studied limnic habitats (Martin et al. 2015). This can result in contradictory results when selected habitats on different types of bedrock are compared in a rather restricted geographical area. A good example is Schwoerbel's (1959) investigation of the water mite communities in springs and running waters

of the Black Forest and its surroundings, a highly diverse area in terms of hydrogeology in SW Germany. The majority of the 18 species in this study that were considered "limestone avoiding" have later been found in highly calcareous waters or have an unclear taxonomic status. Vice versa, most species found in SW Germany by Schwoerbel (1959) exclusively in limestone streams are widely distributed in waters with low calcium concentrations, particularly in Fennoscandia (Lundblad 1968). In general, year-round flow stability appears to be a prevalent factor for the presence or absence of water mites. Vulnerability to unstable flow conditions might be direct, due to drought intolerance of all developmental stages of the mites, or indirect, due to the absence of suitable insect hosts. Adverse conditions may originate from fluctuating water tables in large karstic catchments rich in calcium, but also on granitic or sedimentary bedrock poor in calcium if groundwater bodies feeding isolated springs are small. A comparison of spring faunas at various elevations in German National Parks, recorded the highest species diversity in calcareous springs at intermediate elevations where the groundwater flow stability is at maximum (Gerecke & Martin 2006, Lichtenwöhrer et al. 2019, Gerecke, unpublished data). By contrast, in acidic springs, a distinctly less diverse water mite fauna was found at intermediate elevations (Gerecke & Martin 2006, Lichtenwöhrer et al. 2019, Gerecke, unpublished data). In both cases, the presence or lack of a species is probably not related to the calcium content of the habitat, but to a sensitivity to unstable water conditions.

The principal aim of the project was to increase the general knowledge of the diversity of water mites in calcareous rich habitats in Norway. Although the study was not designed to make specific inferences about the preference for calcareous habitats for individual species, the data collected allows for some reflections around our observations.

A total of 19 species were recorded in Norway for the first time in this study. A possible explanation is that these prefer calcareous waters, but most of the species were either recognized for the first time using molecular data and are awaiting taxonomical description, or they were recorded from a single site only (*Arrenurus biscissus*, *Arrenurus inexploratus*, *Arrenurus sinuator*, *Atractides lacustris*, *Forelia variegator*, *Lebertia holsatica*, *Parathyas inepta*, *Unionicola figuralis*). Populations of most of these species are recorded also from waters with low calcium contents in other geographical areas (Lundblad 1968, Smit & Van der Hammen 2000, Viets 1933, 1938). Only for the lake-dwelling *Arrenurus biscissus* and the crenobiont *Lebertia holsatica*, published records support a preference for calcareous waters (e.g. Davids et al. 1994, Gerecke & Martin 2006). For *Parathyas inepta*, which until recently had an unclear taxonomy, the ecology is still unclear.

Four species new to Norway were recorded from more than one site (number of recorded sites in brackets): *Arrenurus securiformis* (4), *Arrenurus subarcticus* (5), *Lebertia brigantina* (3) and *Oxus angustipositus* (2). Lundblad (1968) recorded all these species from multiple sites in Sweden and found *Arrenurus subarcticus* in oligo- as well as polyhumose water, while *Arrenurus securiformis*, *Lebertia brigantina* and *Oxus angustipositus* were considered to avoid habitats with dystrophic water and might be considered characteristic species of calcareous water bodies. Six additional species previously not recorded by us in Norway, but here collected at a higher number of sites, *Huitfeldtia rectipes* (5), *Piona stjordalensis* (6), *Arrenurus bicuspidator* (8), *Pionacercus leuckarti* (8), and *Panisus michaeli* (5) could prefer calcareous waters, but data from Lundblad (1968) and records in Artskart (https://artskart.artsdatabanken.no/) signify no such preference.

Considering the remaining species in our list (Table 2), the rich base of ecological information for Fennoscandian water mite species published by Lundblad (1968) indicates that most of them do not necessarily prefer limestone habitats and are widely independent of calcium content in the water. Similarly, eight species in Sweden, rarely or not found in calcareous water (Lundblad 1968), are recorded by us at sites with elevated calcium contents of the water (*Arrenurus compactus*, *A. kjerrmanni*, *A. neumani*, *A. stjordalensis*, *Limnochares aquatica*, *Mideopsis orbicularis*, *Oxus carpenteri* and *Piona coccineoides*). Nearly

one third (39) of the recorded species that were frequently collected (> 5 % of the sites), are obviously well adapted to calcareous waters, but numerous records published from Sweden show that none of these are bound to limestone habitats (e.g. Lundblad 1968). Two species considered by Lundblad (1968) as potentially preferring calcareous waters, *Eylais koenikei* and *Mideopsis crassipes*, were recorded by Gerecke et al. (2022) at sites with low calcium concentrations suggesting an indifference against this parameter.

Porolohmanella violacea (Kramer, 1879), the only representative of Halacaridae in our study, represents a family not investigated by Lundblad (1968). The species is frequently found in dystrophic sites, but obviously tolerant against a wide range of water quality parameters (Bartsch 2007). A further thirteen taxa in our list are recently detected groups of unclear taxonomy provided with non-Linnean names and therefore not suitable for ecological interpretation: *Atractides nodipalpis* aggr. sp., *Lebertia porosa* aggr. clade A, *Lebertia porosa* aggr. clade E, *Piona laminata* aggr. sp. 1-3, *Piona pusilla* aggr. sp. 1/4, *Pionopsis lutescens* aggr. sp. 1/2, *Sperchonopsis verrucosa* aggr. sp. 1/2, *Mideopsis roztoczensis* aggr. sp. 2.

In conclusion, our findings, together with evidence from the published literature, strongly suggest that only a few water mite species exhibit a preference for calcium-rich habitats. Other environmental factors, such as water flow conditions, are likely more influential in determining the presence or absence of water mites. Nevertheless, as the first systematic investigation of water mite fauna in calcareous waters in Norway, this study provides an important baseline for future ecological research on habitat and water condition preferences within this group.

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