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Oligochaeta (Annelida) from some temporary water bodies of Eastern Estonian forests

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Abstract

Oligochaeta of forest vernal pools and small draining ditches were sampled together with other aquatic macroinvertebrates yearly in spring 2013–2018 at six sites in the eastern part of Tartu County, Estonia. In 298 samples, a limited number of oligochaete taxa (23) was found. The most common species were *Lumbriculus variegatus* (2/3 of all individuals sampled), *Cognettia glandulosa, Tubifex tubifex* and *Aulodrilus limnobius*, all able to reproduce rapidly in asexual way, either by architomy or parthenogenesis. The phytophilous Naididae were rare or lacking, as were most of the other Tubificidae, common in permanent water bodies, and the majority of the soil-inhabiting Enchytraeidae and Lumbricidae. Some in general rheophilous Lumbriculidae (*Rhynchelmis tetratheca, Stylodrilus heringianus, S. brachystylus*) apparently live permanently in the humid soil under several temporary pools. Vernal temporary waters seem to be a specific habitat for the naidid *Bratislavia palmeni*. The oligochaete fauna was almost similar in the natural pools of drained and undrained forests, slightly more diverse in draining ditches, and the poorest in recently dug mitigation pools.

Key words: Oligochaeta, forest pools, forest ditches, Estonia

Introduction

Temporary water bodies as a specific habitat for aquatic Oligochaeta have been only occasionally studied by different researchers. The targets of investigation have included small pools in settlements (Kenk 1949, Holzer 1981), floodplain puddles at river margins (Sekera 1907), and periodically drained rice fields (Saraswathy *et al.* 2015, Yachi *et al.* 2012). In some cases, seasonally dried-up pools were studied as a habitat for a certain oligochaete species, e. g., *Lumbriculus variegatus* by Mrázek (1913a), *Lumbriculus* sp. by Kreuzer (1940) or *Tenagodrilus musculus* by Eckroth & Brinkhurst (1996). Williams (1983) reported from two Canadian snowmelt-fed ponds (Sunfish Pond in Ontario, and Page's Pond on Vancouver Island) *Lumbriculus variegatus* and *Nais* sp. The Oligochaeta of a seasonally dried-up forest pond have been studied specifically by Krodkiewska & Spyra (2015). The present study focuses on small woodland pools and drainage ditches, filled with snowmelt in spring, which supposedly dry up during the summer at least in some years, when aquatic animals can only survive in the sediment that remains moist under the forest canopy. The work was part of the second author's doctoral thesis project "The impact of forest drainage on macroinvertebrates and amphibians in small waterbodies and opportunities for cost-effective mitigation" (Vaikre 2020).

Material and methods

Macroinvertebrates were collected yearly from 2013 to 2018 in late May or early June, at mixed forest sites (mainly silver birch, *Betula pendula*; Scottish pine, *Pinus sylvestris*; and Norwegian spruce, *Picea abies*) in the eastern part of Tartu County, north and south of the lower Emajõgi River (Fig. 1). Three clusters of sampling spots in drained

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forests were studied repeatedly in all six years: Kirepi (58.56º N, 27.05º E) north, and Valgma (58.31º N, 25.02º E) and Ropka (58.28º N, 27.18º E) south of the Emajõgi River. All the sampling sites included different natural pools, drainage ditches, and mitigation pools dug in conjunction with ditch networks maintenance (removal of vegetation and sediments) carried out in 2015 in Ropka and Valgma, and in 2017 in Kirepi (Fig. 2). For comparison, the pools at undrained forest sites were sampled in three clusters in 2015–2016: Padakõrve (58.59º N, 27.07º E) north, and Võõpste (58.33º, 27.05º) and Ahunapalu (58.32º N, 27.30º E) south of the Emajõgi River (Fig. 1). Average water depth in the sampling time in natural pools was 20.5 (2–86) cm. Vegetative detritus (decomposing forest litter, etc.) was the main component of bottom sediment. The vegetation consisting mostly of different grasses, *Carex*, *Scirpus*, *Callitriche,* and *Lemna* spp., covered on average 25% of surface. The average water depth in ditches before ditch network maintenance was 23 cm (3–50 cm), and dropped to 9 (1–45) cm after the maintenance. Ditches had either standing or slowly flowing water and apparently dried up during the summer like natural pools, and even more so after the maintenance. The mitigation pools dug in or alongside the ditches (as separate ponds) to alleviate the unfavourable effect of ditch network maintenance on macroinvertebrates and amphibians, were on average 57 (4–160) cm deep when sampled, poor in the vegetation (cover 11% on average), and presumably permanent, at least some of them (Vaikre *et al.* 2020). Water pH was on average 6.2 in the studied water bodies.

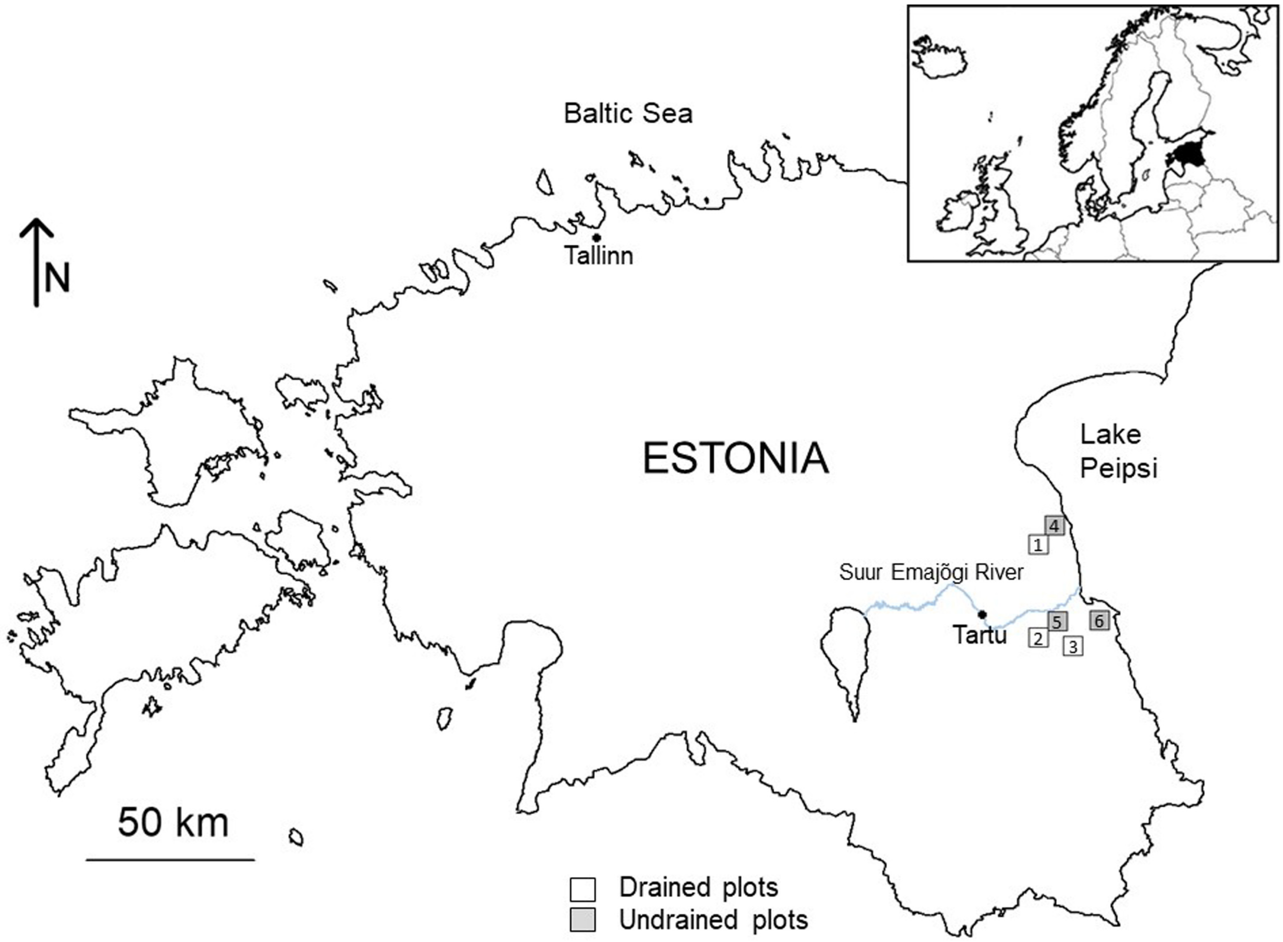

FIGURE 1. Location of the sampling plots in Tartu County, Estonia, sampled during the years 2013–2018. 1—Kirepi; 2—Valgma; 3—Ropka; 4—Padakõrve; 5—Võõpste; 6—Ahunapalu.

Macroinvertebrates were sampled by the second author with a 0.5 mm mesh D-frame net (17 x 19 cm) from four m^2 of water during 20 sec, once every spring. Active sweeps were made covering different aquatic microhabitats. The samples were preserved on site with 90% ethanol and the animals were sorted in the laboratory without magnification (Vaikre *et al.* 2015). All in all, 470 qualitative samples were collected, of these 298 (63%) contained Oligochaeta. The share of oligochaetes (a total of 4980 specimens) in the collected macroinvertebrate fauna was about 4%, while the rest of the bulk was made up of various insects (particularly Chironomidae and *Aedes* sp.), and

Asellus aquaticus. Oligochaeta were identified by the first author, as whole mounts in glycerine, under magnification 10–600x depending of their size and species.

FIGURE 2. Examples of the studied water bodies in Tartu County, Estonia, sampled during the years 2013–2018. 1—natural pool, 2—ditch, 3—4—mitigation pools (3—separate pond; 4—ditch enlargement). Photo credits: Maarja Vaikre.

Results

A total of 23 oligochaete taxa were identified (about 15% of the 156 species known so far in Estonia), 18 of them to species level. The majority (95%) of the individuals represented only four species: *Lumbriculus variegatus* (Lumbriculidae), *Cognettia glandulosa* (Enchytraeidae), *Tubifex tubifex* and *Aulodrilus limnobius* (Tubificidae), see Table 1.

L. variegatus was by far the most dominant species in all types of water bodies under study. It was also the fifth most abundant taxon of all collected macroinvertebrates. It was found in 2/3 of the samples (containing Oligochaeta), making up about 2/3 of the specimens (Table 1). Following ditch network maintenance, the total abundance of this species was more than doubled (2.5 times), indirectly demonstrating its ability to inhabit newly created habitats as a pioneer organism. Its physical prevalence was emphasised by its much larger dimensions in comparison with other aquatic oligochaetes. *L. variegatus* reproduces mostly by architomy (fragmentation). The presence of the genital system (with male pores on segment VIII) was only noted in two individuals out of 3,436, and one sample contained several tiny individuals that had probably hatched from a cocoon.

C. glandulosa, an amphibiotic enchytraeid, was the second most common species, represented in 39% of samples (but as many as 57% in natural pools), accounting for 18% of all specimens. It is architomic as is *L. variegatus*; all collected specimens were sexually immature.

TABLE 1. Total number of samples, number of samples containing Oligochaeta, and number of specimens (in brackets) from different types of water bodies in Tartu County, Estonia, sampled during the years 2013–2018.

	Natural pools	Ditches	Mitigation pools	Total	%
Total number of samples	162	178	130	470	
Samples with Oligochaeta (and number of specimens)	143 (3208)	116 (1488)	39 (284)	298 (4980)	
Lumbriculus variegatus (Müller, 1774)	101(2184)	95(1027)	27(225)	275(3436)	75(69)
Cognettia glandulosa (Michaelsen, 1888)	81(760)	24(125)	10(23)	115(908)	39(18)
Tubifex tubifex (Müller, 1774)	24(150)	25(74)	3(5)	52(229)	17(5)
Aulodrilus limnobius Bretscher, 1899	5(19)	17(129)	3(6)	25(154)	8(3)
Limnodrilus hoffmeisteri Claparède, 1862	2(4)	12(53)	1(2)	15(59)	5(1)
Nais communis Piguet, 1906	4(9)	4(4)	5(13)	13(26)	4(1)
Rhynchelmis tetratheca Michaelsen, 1921	10(33)	3(4)	0	13(37)	4(1)
Bratislavia palmeni (Munsterhjelm, 1905)	4(5)	4(52)	1(1)	9(58)	3(1)
Stylodrilus heringianus Claparède, 1862	5(13)	2(2)	1(2)	8(17)	3(<1)
Globulidrilus riparius (Bretscher, 1899)	5(7)	1(4)	1(2)	7(13)	2(<1)
Spirosperma ferox Eisen, 1879	1(1)	3(3)	0	4(4)	1(<1)
Stylodrilus brachystylus Hrabě, 1929	2(11)	1(1)	0	3(12)	1(<1)
Fridericia sp.	2(6)	1(1)	0	3(7)	1(<1)
Mesenchytraeus armatus (Levinsen, 1884)	2(2)	1(1)	0	3(3)	1(<1)
Rhynchelmis limosella Hoffmeister, 1843	2(2)	1(1)	0	3(3)	1(<1)
Nais variabilis Piguet, 1906	0	1(1)	1(4)	2(5)	<1(<1)
Dendrobaena octaedra (Savigny, 1826)	2(2)	0	0	2(2)	<1(<1)
Lumbricidae gen. sp.	0	1(2)	0	1(2)	<1(<1)
Limnodrilus udekemianus Claparède, 1862	0	1(1)	0	1(1)	<1(<1)
Mesenchytraeus sp.	0	1(1)	0	1(1)	<1(<1)
Enchytraeus sp.	0	1(1)	0	1(1)	<1(<1)
Achaeta sp.	0	1(1)	0	1(1)	<1(<1)
Cognettia sphagnetorum (Vejdovský, 1878)	0	0	1(1)	1(1)	<1(<1)

T. tubifex (with 5% of specimens) and *A. limnobius* (3%) occupied the third and the fourth place, respectively, according to their relative abundance. *A. limnobius* is architomic and the collected specimens were usually immature like *L.variegatus* and *C. glandulosa*. On the contrary, *T. tubifex* occurred often as sexually mature. It is known as a pioneer species that can efficiently colonize new habitats even with a single individual, due to the ability to reproduce by parthenogenesis.

The remaining 19 taxa appeared to be relatively rare in the studied temporary water bodies. Among them were several soil-inhabiting or amphibious Enchytraeidae (*Globulidrilus riparius, Cognettia sphagnetorum, Mesenchytraeus armatus*, *Mesenchytraeus* sp., *Enchytraeus* sp., *Fridericia* sp., *Achaeta* sp.), terrestrial Lumbricidae (*Dendrobaena octaedra* and an unidentified lumbricid), and aquatic Lumbriculidae (*Stylodrilus heringianus*, *S. brachystylus*, *Rhynchelmis tetratheca, R. limosella*), Tubificidae (*Limnodrilus hoffmeisteri, L. udekemianus, Spirosperma ferox*) and Naididae (*Nais communis, Nais variabilis, Bratislavia palmeni*) (Table 1).

There was no significant difference in the share of dominating species in pools and ditches, except for the higher frequency and abundance of *C. glandulosa* in natural pools (56% and 24% in pools, and 21% and 8% in ditches, respectively). Besides, *A. limnobius* and *L. hoffmeisteri* were more common in ditches. The overall number of species was higher in ditches (21) than in pools (16), possibly due to the comparative isolation of the latter for possible new settlers. Interestingly, the lumbriculids *S. heringianus* and *R. tetratheca*, although being elsewhere more common in flowing water, were more often found in the (drained forest) pools than in ditches. The repeated findings of the rare naidid *Bratislavia palmeni* in all types of water bodies under study is remarkable (58 specimens in 9 samples). Among them, five sexually mature, but no paratomic (budding) individuals were identified (Table 1).

The natural pools of recently drained forests (Kirepi, Valgma and Ropka sites) and those of intact forests (Padakõrve, Võõpste and Ahunapalu sites) yielded an almost similar list of 14 species for either group (Table 2). However, the proportion of *L. variegatus* was the highest in intact forest pools. At the same time, *C. glandulosa* was much more abundant in drained forest pools (Table 2).

TABLE 2. Number of samples and specimens of Oligochaeta in the natural pools of drained and undrained forests in Tartu County, Estonia, sampled during the years 2013–2018.

	Drained forests		Undrained forests	
Number of samples	100	%	43	%
Number of specimens (given in brackets)	1722	(%)	1486	(%)
Lumbriculus variegatus (Müller, 1774)	65(931)	65(54)	36(1253)	84(84)
Cognettia glandulosa (Michaelsen, 1888)	58(600)	58(35)	23(160)	53(11)
Tubifex tubifex (Müller, 1774)	17(115)	17(7)	7(35)	16(2)
Rhynchelmis tetratheca Michaelsen, 1921	6(28)	6(2)	4(5)	9(<1)
Stylodrilus heringianus Claparède, 1862	5(13)	5(1)	0	0
Aulodrilus limnobius Bretscher, 1899	3(12)	3(1)	2(7)	5(<1)
Globulidrilus riparius (Bretscher, 1899)	4(6)	4(<1)	1(1)	1(<1)
Nais communis Piguet, 1906	3(8)	3(<1)	1	2(<1)
Limnodrilus hoffmeisteri Claparède, 1862	2(4)	2(<1)	0	0
Bratislavia palmeni (Munsterhjelm, 1905)	1(1)	1(<1)	3(4)	7(<1)
Stylodrilus brachystylus Hrabě, 1929	0	0	2(11)	5(1)
Spirosperma ferox Eisen, 1879	0	0	1(1)	2(<1)
Fridericia sp.	1(1)	1(<1)	1(5)	2(<1)
Mesenchytraeus armatus (Levinsen, 1884)	1(1)	1(<1)	1(1)	2(<1)
Rhynchelmis limosella Hoffmeister, 1843	1(1)	1(<1)	1(1)	2(<1)
Dendrobaena octaedra (Savigny, 1926)	1(1)	1(1)	1(1)	2(<1)

Only 11 species were found in mitigation pools and only 30% of the samples contained Oligochaeta (versus 64% for ditches and 88% for natural pools). The order of species dominance was almost similar to that of ditches (Table 1), although the third most dominant species in our study, i. e. *T. tubifex,* was largely absent in the mitigation pools for unknown reasons.

Discussion

There exist a few terrestrial species of the otherwise aquatic genera of the Oligochaeta, particularly *Pristina*, *Schizodrilus* and *Bothrioneurum*, described from forest soils (Stout 1956; Collado & Schmelz 2002; Wang *et al.* 2000). However, they are not known to occur in Europe.

Many aquatic oligochaetes have adaptations for surviving drought and could therefore utilize temporary habitats. There are a number of examples of oligochaetes that survive in the bottom sediments of temporarily dried-up water bodies. Sometimes formation of protective cysts that slow desiccation has been reported. Kenk (1949) has fetched live Naididae, *Pristina* and *Lumbriculus variegatus*, from the infusion of the dry sediment of a temporary pond in Michigan, USA. Cysts of *Aeolosoma* spp. (Polychaeta), but not oligochaete cysts were observed in the sediment; aestivation in egg cocoons was suspected in the case of Naididae (inclusive *Pristina*). Wiggins *et al.* (1980) have noted that asexual reproduction and cyst-forming promote colonization of temporary pools by *L. variegatus.*

Oligochaete communities in the soil of some Indian rice fields with dominating Naididae (Vineetha *et al.* 2015) and in Japanese rice fields with the dominating Tubificidae (Yachi *et al.* 2012) have been found to remain generally similar during the annual dry and inundated seasons, although the Naididae were most abundant and diverse in flooding season. Apparently, the worms survive the "terrestrial" period in the moist soil.

Berestov (1948) has described the survival of some tubificids (*Tubifex tubifex, Limnodrilus hoffmeisteri,* and *L. udekemianus)* after the World War II in the temporarily drained Dniepr Reservoir. The worms were burrowed into the soil, at depths up to 40 cm, and were enveloped in an up to 1 mm layer of slime. Montalto & Marchese (2005) have described regular formation of thin slimy cysts in two Neotropical oligochaetes, *Dero multibranchiata* Stieren, 1892 and *Trieminentia corderoi* (Harman, 1969), in gradually drying river sediment.

Mrázek (1913a) found small individuals of *L. variegatus* when moistening bottom sediment from a dried-up woodland pool in Czechia; however, no cysts were seen in the sample. In some other temporary pools on the Elbe River floodplain, cysts of another lumbriculid, identified by him as *Claparediella*, were found. The cysts, formed already before the dry period, had a dense wall, and the worms reproduced within them regularly by architomy (Mrázek 1913b). Hrabě (1929) described that lumbriculid as a new species, *Lamprodrilus mrázeki*. Stephenson (1922) reported numerous findings of irregular thin-walled, slimy cysts of *L. variegatus* from Scotland, in shallow water or near the water's edge during a summer drought. In some cases, they were produced by a single worm, in other cases, by a clump of worms, while architomy was proceeding inside the cysts, with up to 16 regenerated individuals per cyst. Stephenson rejected the possibility for these worms belonging to the species observed by Mrázek (1913b) and afterwards named as *L. mrazeki*. However, years later, Brinkhurst (1963) supposed that these cysts may be an evidence for presence of *L. mrazeki* on the British Isles. This was denied by Cook (1967), who observed and described cysts made by *L. variegatus* as thin-walled structures covered with adhering particles of substrate.

Hrabě (1929) had also observed thin-walled cysts of *Tubifex tubifex* in a dried-up mud culture. Unlike *L. mrazeki*, *T. tubifex* left the cysts in half an hour when watered. The first author of the present study has seen a similar soft, slimy cyst of *T. tubifex* in an aquarium. Roundish "tests" of *Tubifex tubifex* described by Kaster & Bushnell (1981), were certainly not cysts, but egg cocoons with offspring just leaving them.

Krodkiewska & Spyra (2015) observed an oligochaete community consisting of *Limnodrilus* spp., *Tubifex tubifex, Ripistes parasita* (Schmidt, 1847), *Dero digitata* (Müller, 1774), *Chaetogaster diaphanus* (Gruithuisen, 1828), *Nais* spp. and *Stylaria lacustris* (L.) in the near- permanent woodland pond "Wspólny" in southern Poland, which dried up for only two winter months. Although *Lumbriculus variegatus* was abundant, it was only present in 58% of samples. Diversity of the naidids was similar to that in the vegetated zone of larger water bodies. Apparently, the short and cool dry period in this pond allowed successful hibernation of phytophilous naidids.

For the small water bodies in our study, presumably drying up for a longer period already during the summer, the species list was somewhat different. Here the phytophilous, paratomic Naididae like *Stylaria, Ripistes, Dero* and *Slavina* were either lacking or very rare (except for *Nais communis*), as were most of the sediment-dwelling Tubificidae. Even the ubiquitous tubificid *Limnodrilus hoffmeisteri* was mostly found in ditches (a network fostering rapid distribution) but seldom in pools. Among the four dominating species in the studied water bodies (Table 1), two (*L. variegatus* and *T. tubifex*) are reputedly able to encyst in the dry period, while all can reproduce in an asexual mode (*T. tubifex* by parthenogenesis, and *L. variegatus, A. pluriseta* and *Cognettia glandulosa* by architomy). As *C. glandulosa* is amphibious, it can successfully inhabit humid soil in the active state. The naidid *Nais communis* may survive the dry period and the subsequent winter in egg cocoons.

One could anticipate that terrestrial Enchytraeidae are common in small forest pools. However, only the amphibious *C. glandulosa* was common here, while all other enchytraeids (including the amphibious *Globulidrilus riparius* and *Mesenchytraeus armatus*) were rare if not lacking. It was particularly surprising that *Cognettia sphagnetorum*—the most common enchytraeid in forest soils in Estonia and elsewhere (Schmelz *et al.* 2005, Reeves *et al.* 2021)—was lacking in the studied water bodies. Most likely, periodical inundation is unsuitable for them. The mysterious tubificid *Rhyacodrilus falciformis* Bretscher, 1901—a species that occurs in oligotrophic lakes and spring-fed streams as well as among enchytraeids in terrestrial soils (Schmelz *et al.* 2005, Schlaghamerský & Kobetičová 2006)—was also absent here.

The occurrence of two oxyphilous lumbriculids, *Rhynchelmis tetratheca* and *Stylodrilus heringianus*, more often in forest pools then in ditches, was surprising. Elsewhere in Estonia, they are rather common in flowing waters and springs. Presumably, for them the better aerated habitat in detritus-rich upper soil layers beneath the pool bed is more suitable compared to the denser sediment of recently reconstructed drainage ditches, many of which containing flowing water only in the short spring period (Vaikre 2020). Because of their perennial life cycle and exclusively sexual reproduction (Timm 2020), these species seem to live permanently in the moist, temporarily inundated soil under some pools. Neither encystment nor any other mode of dormancy is known in these lumbriculids.

A rare lumbriculid species, *Stylodrilus brachystylus*, was found in three cases in our material. It may be an inhabitant of moist soil like the above two species, since having been found also in some springs and in shallow, densely vegetated littoral zone of lakes in Estonia.

A rare naidid, *Bratislavia palmeni* deserves special attention. It was found repeatedly in all types of small water bodies (Tables 1 & 2). It occurred in three consecutive years (2016–2018) in a ditch in Valgma with a maximum of 39 individuals per sample, including three sexually mature worms. None of them showed budding zones. The species has been previously foünd in other temporary pools in Estonia (Timm 1970, as *Pristina* sp.).

Several records of *B. palmeni* originate from Europe and West Siberia. These included temporal vernal or early summer pools and ditches in Finland (Munsterhjelm 1905, original description as *Pristina palméni*) and in Slovakia (Košel 1976, description of the reproductive system and creating of the genus *Bratislavia*), a stream and flooded meadow in Austria (Šporka *et al.* 2008), and the littoral zone of a tundra lake in northern Russia (Finogenova 1966, original description of the synonymous *Pristina elegans*). No signs of paratomy or regenerating ends, indicating architomy, were observed in these cases. Pop (1973) reported the presence of an unsegmented budding zone in some individuals of *Pristina napocensis* found in a wetland in Romania. However, those zones were not seen in the paratypes of *P. napocensis* re-described by Košel (1976) and synonymized with *Bratislavia palmeni*. In all probability, cool temporal water bodies are a preferable biotope for this species, where its active period lasts a few months in spring and early summer, until the drying of the biotope. Its reproduction is either exclusively sexual or also combined with architomy, but without paratomy, characteristic of most other naidids that are abundant among macrophytes in summer. *B. palmeni* may spend the most part of the year dormant (as egg cocoons?) in dried and probably also in frozen soil.

Conclusion

Only a limited number of oligochaete taxa (23) were found in the temporary pools and draining ditches of East Estonian forests. *Lumbriculus variegatus* was by far the most common and abundant species, followed by *Cognettia glandulosa, Tubifex tubifex* and *Aulodrilus limnobius*. These species are known by the ability of rapid asexual reproduction by architomy or parthenogenesis, and some of them also by formation protective cysts in drying sediment. The phytophilous Naididae were rare or lacking, as were the majority of otherwise common aquatic Tubificidae and terrestrial Enchytraeidae. The elsewhere ubiquitous species *Limnodrilus hoffmeisteri* was found rather in ditches then in pools. Some oxyphilous, elsewhere rheophilous lumbriculids (*Rhynchelmis tetratheca* and *Stylodrilus heringianus*) apparently inhabit perennially the humid soil under temporary pools. The vernal water bodies seem to be a specific habitat for the naidid *Bratislavia palmeni*. Oligochaete fauna was almost similar in the natural pools in the drained and undrained forests, slightly more diverse in draining ditches, and the poorest in the recently dug permanent mitigation pools.

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