AQUATIC
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An overview of *Synchaeta* Ehrenberg, 1832 (Rotifera: Monogononta: Synchaetidae) species in the Eastern Gotland Basin, Baltic Sea, with complementary characteristics for the trophi of *S. fennica* Rousselet, 1902 and *S. monopus* Plate, 1889

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Abstract. Four species of the genus *Synchaeta* were identified in the waters of Liepaja harbour (coastal Eastern Gotland Basin, Baltic Sea). *Synchaeta baltica* and *S. monopus* are common in the Baltic Sea and they co-dominated most of the samples. *Synchaeta fennica* was abundant during spring, but *S. triophthalma* was detected in October 2014 for the first time in Latvian waters. During sample analysis particular attention was paid to insufficiently described trophi of *S. monopus* and *S. fennica*. Subsequently, brief descriptions were made during analysis and complemented with images.

Key words: Rotifera, illoricate, soft-bodied, identification, taxonomy, Baltic Sea.

1. INTRODUCTION

The genus *Synchaeta* Ehrenberg, 1832 is euryhaline and widespread in fresh, brackish, and marine waters (Hollowday, 2002) all around the world. It consists of 37 sufficiently described species, five *species inquirendae,* and four to six insufficiently described taxa or unnamed *species inquirendae* (Hollowday, 2002). The abundance of *Synchaeta*, as of most rotifers, is underestimated or missing from studies conducted in thalassic systems because routine sampling is mainly performed using nets with a mesh size of 100–200 μm, which is unsuitable for reliable and representative rotifer sampling. This is particularly typical for long-term standardized monitoring programmes (Mironova et al., 2008; Telesh et al., 2009; HELCOM, 2013) and this issue has led to disparity in available information about fresh and thalassic rotifers in favour of the former (Fontaneto et al., 2006).

Many *Synchaeta* species are specialized to live in brackish waters (Ruttner-Kolisko, 1974). Up to 11 species have been reported as present in the Baltic Sea (Berzinsh, 1960; Kutikova, 1970; Hollowday, 2002; Telesh and Heerkloss, 2002; Telesh et al., 2009). They can make up more than 80% of the mesozooplankton biomass in the most eutrophicated areas (Johansson, 1983; Telesh et al., 2009; Ojaveer et al., 2010) and contribute significantly to the total zooplankton production (Johansson, 1983; Ojaveer et al., 2010). In addition, *Synchaeta* species are one of the key organisms linking microbial and classical food web in food-rich systems, such as the Baltic Sea (Dolan and Gallegos, 1992; Arndt, 1993).

Our research area is located at the eastern coast of the Eastern Gotland Basin, the Baltic Sea. Species lists of the genus *Synchaeta* for this region differ between available publications (Berzinsh, 1960; Telesh et al., 2009), but they agree on the presence of *S. baltica* Ehrenberg, 1834, *S. monopus* Plate, 1889, *S. curvata* Lie-Pettersen, 1905 (after Hollowday, 2002: *species*

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inquirenda, possibly synonym with *S. tavina* Hood, 1893), *S. fennica* Rousselet, 1909, *S. gyrina* Hood, 1887, and *S. triophthalma* Lauterborn, 1894 in the Baltic Proper, which combines six sub-regions, including the Eastern Gotland Basin.

Furthermore, *Synchaeta* species are a great challenge for taxonomists as it is difficult, time consuming, and sometimes even impossible to identify individuals to species level based only on external general morphology, especially in preserved samples (e.g. Ruttner-Kolisko, 1974; Koste, 1978). Live examination is suggested as preferable, but usually it is not feasible in ecological studies when many samples are collected simultaneously or within a short time period. In many studies *Synchaeta* species are lumped together as *Synchaeta* spp., thus creating a knowledge gap in the distribution and ecology of individual species.

A method based on the internal structure of hard parts of the mastax (henceforward: trophi) has been recommended for ecological studies (De Smet, 1998; Obertegger et al., 2006); however, there are still some gaps and discrepancy in descriptions of trophi morphology for certain species. The trophi of *S. baltica* and *S. triophthalma* are well described and more information can be found in identification guides (e.g. Hollowday, 2002). The trophi of *S. curvata* are described and drawn although more profound investigation of details is needed, but the descriptions of *S. monopus*, *S. gyrina*, and *S. fennica* trophi are insufficient (Kutikova, 1970; Hollowday, 2002) and should be improved to be used in species identification. Thus, the elaboration of descriptions of *Synchaeta* trophi was set as the main aim of the present study. In order to achieve it, we collected samples during late spring and early autumn, i.e. the periods when *Synchaeta* are the most abundant in the Baltic Proper (Dippner et al., 2000), and identified specimens based on both general and trophi morphology. Hereby we hope to encourage more studies to identify *Synchaeta* to species level and thus promote comprehensive knowledge of the factual regional biodiversity of *Synchaeta* species.

2. MATERIALS AND METHODS

The study was carried out in Liepaja harbour, as part of a holistic baseline monitoring programme for early detection of non-indigenous species at Latvian ports. Liepaja harbour is located in the eastern part of the Baltic Proper (Fig. 1). Liepaja is one of the international ports in Latvia. Its main activities are export and transit services, but it is also used by passenger ferries. Liepaja harbour is shallow: its deepest area reaches a depth of 12 m.
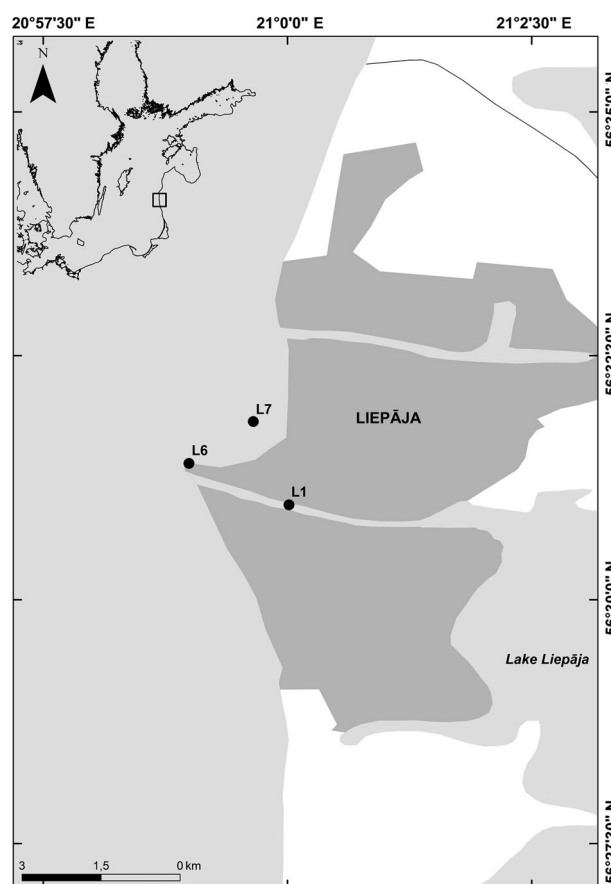

Fig. 1. Map of the Liepaja region. Light grey areas represent water bodies, dark grey designates urban territories and white, rural territories. Black dots stand for sampling stations. The location of the study site in the Baltic Sea is shown in the upper left corner.

Three closely located sampling sites were monitored (Fig. 1, Table 1) according to the Joint HELCOM/OSPAR Guidelines, Regulations A-4 (HELCOM, 2013). One of the busiest piers is located between stations L6 and L7, but station L1 is located in a channel connecting the Baltic Sea to Lake Liepaja. The sampling stations were 5–8 m deep.

Zooplankton samples were collected during daytime by vertical hauls using an Apstein plankton net with a mesh size of 53 μm and opening of 0.09 m^2. Thereafter samples were preserved with 4% formaldehyde solution

Table 1. Coordinates of the sampling stations

Station	Coordinates	
L1	56°30.974′ N	21°00.016′ E
L6	56°31.395′ N	20°58.992′ E
L7	56°31.876′ N	20°59.702′ E

in seawater. Two parallel zooplankton samples in each location were collected. Measurements of water temperature and water salinity were conducted in each station at every sampling using a CTD water probe.

Before analysis, zooplankton samples were filtered through a 50 μm sieve to remove the formaldehyde solution and diluted with tap water as necessary, and then a drop of detergent was added. The volume of the sample was measured in a graduated plastic phial. A calibrated Stempel pipette was used to acquire subsamples for analysis, beforehand it had been made sure that all organisms were evenly distributed in the sample volume. Each sample was analysed in a Bogorov counting chamber under a compound microscope until three to five taxonomic groups reached 100 individuals. An average of abundance obtained from both parallel samples for each taxonomical group was calculated.

Rotifers were analysed using identification guides by Koste (1978) and Holloway (2002). Trophi of 30 individuals of each species, appropriate for identification, were analysed following the method described by De Smet (1998) with some alterations. The trophi were prepared as follows. An individual was collected in a small drop of water on a glass microscope slide (76 mm × 26 mm) and covered with a coverslip (18 mm × 18 mm). Then a drop of household bleach ACE[©] (NaOCl < 5%) was added next to the coverslip ensuring they were both in contact and bleach was drawn under the coverslip. After a few minutes all soft tissues were dissolved and only trophi were left. The trophi preparation and dissolving process was closely followed using bright-field microscopy at ×100 magnification under compound microscope. Images were taken using Leica Application Suite[©] software.

The length and width of the fulcrum, the distance between both ends of the manubrium, and the total length of the trophi were measured for ten individuals of *S. fennica* and *S. monopus*. Lamella and alulae were not well visible in bright-field microscopy and captured images (Fig. 2), so we used dark-field microscopy, which improved the visibility. However, we were not able to acquire good quality images and they are described only in the text.

3. RESULTS

The sampling was performed in shallow waters, in depths of up to 7 m, and consequently the water column was well mixed in every sampling event. Hydrological conditions in stations L6 and L7 showed similar tendencies and did not vary greatly. Station L1, located in the channel, tended to have slightly lower salinity, especially during the autumn sampling (Table 2).

Altogether four *Synchaeta* species were found in the samples (Fig. 2, Fig. 3). The total abundance was noticeably higher in samples collected in May 2014 and May 2015 from stations L6 and L7. *Synchaeta baltica* (Fig. 2A,B) dominated in most of the samples, but usually it was co-dominated by smaller species – *S. fennica* (Fig. 2C,D) and/or *S. monopus* (Fig. 2E,F). *Synchaeta triophthalma* (Fig. 2G–I) appeared only on 21 October 2014 in stations L6 and L7, ranging from 130 to 413 ind m^{-3} (Fig. 3).

As mentioned in Introduction, trophi of *S. baltica* and *S. triophthalma* are well described and suitable for use in the species identification, so we focused on the insufficiently described trophi of *S. fennica* and *S. monopus*. We observed that *S. fennica* had fragile, relatively small (89.1 ± 2.5 μm) trophi with asymmetric unci. Both unci had a strong frontal hook with a small spur. The right uncus had one well-defined sharp tooth but the left uncus had two teeth. The remaining part of the unci was serrated and variable with four to seven identifiable notches. The fulcrum was massive, with an average width of 14.1 ± 1.2 μm and length of 51.9 ± 2.8 μm (Fig. 2D). Both manubria usually broke during preparation, so we did not have an opportunity to take a good quality picture. However, the manubria were slender and slightly curved, and the average distance between both ends was 69.0 ± 2.7 μm. The outer lamella was half the manubrium length and the inner surface was with a triangular plate. As for *S. monopus*, the trophi had six separate teeth on each uncus. The first one was broad and short (Fig. 2F '0'); the other teeth were arranged in two groups divided by a cleft in a set of three and a set of two (Fig. 2F '1-5'). The fulcrum with an average length of 38.8 ± 2.4 μm was slender with a thickened distal end (Fig. 2F 'f'). Manubria

Table 2. Environmental characteristics of sampling sites. Temp – average water temperature; Sal – average water salinity

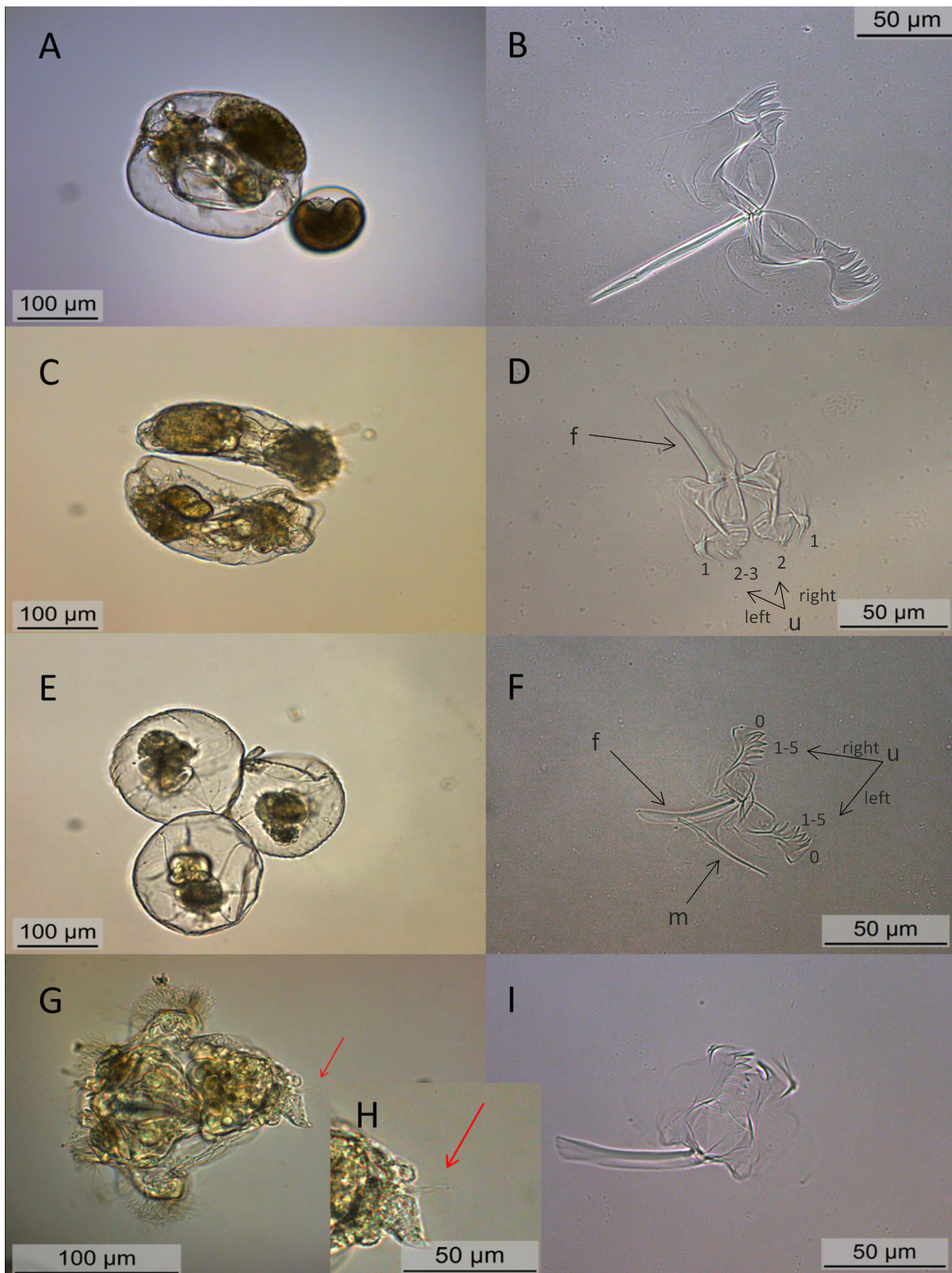| Date	Station	Layer, m	Temp, C°	Sal, PSU
13 Sep 2013	L1	0−5	17.5	5.5
	L6	0−6	17.4	6.6
	L7	0−5	17.4	6.6
27 May 2014	L1	0−5	15.9	6.5
	L6	0−6	16.2	6.6
	L7	0−5	15.8	6.7
21 Oct 2014	L1	0−5	11.0	1.0
	L6	0−5	11.1	5.7
	L7	0−5	11.2	5.9
21 May 2015	L1	0−3	11.7	6.1
	L6	0−5	11.1	6.2
	L7	0−5	11.4	6.2

Fig. 2. Pictures of preserved animals (left) and respective trophi (right): A,B – *S. baltica*; C,D – *S. fennica*; E,F – *S. monopus*; G,H,I – *S. triophthalma*. Black arrows point to the described parts of trophi: f – fulcrum; m – detached manubrium (if captured, otherwise it has broken off and missing); u – unci with uncial teeth. Red arrow points to the typical feature of *S. triophthalma* – asymmetrical lateral antenna.
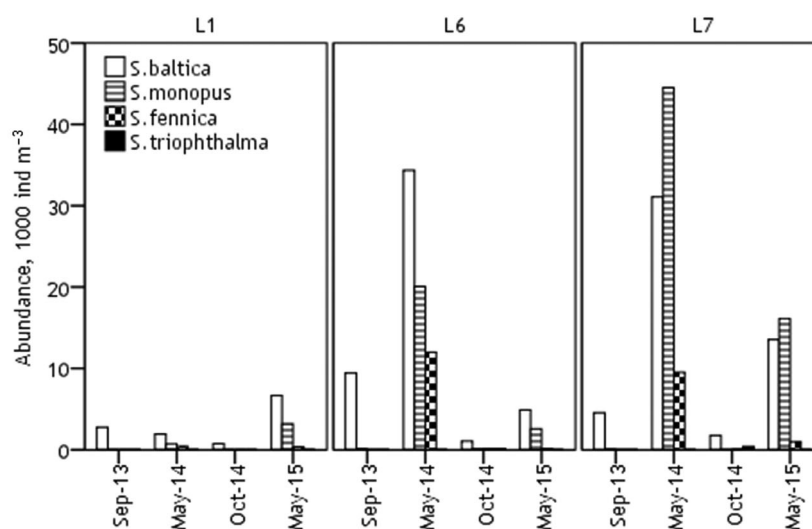
Fig. 3. Abundance of *Synchaeta* species in three sampling stations (L1, L6, L7) located in Liepaja harbour.

usually broke off during preparation, but we managed to capture one in good quality (Fig. 2F 'm'). It was straight and slender, with a rounded outer lamella and a smaller triangular inner plate; rami had rounded alulae.

4. DISCUSSION

Trophi as a morphological feature of rotiferans were described in the substantial book *The Rotifera: or, Wheel-Animalcules* by Hudson and Gosse (1886), showing that the investigation of trophi had already been started in the 19th century. Nevertheless, more thorough studies were made during the 20th century, especially after the invention and commercialization of Scanning Electron Microscopy (SEM) in the 1960s. *Synchaeta* species have virgate trophi (Hollowday, 2002); the most important feature of this type of trophi is the position and number of uncial teeth. Although SEM could provide better resolution than light microscopy for such details, particularly for small and fragile trophi, we did not encounter resolution issues during the present study as the trophi of *Synchaeta* are relatively large. Undeniably light microscopy is only the first step towards sufficient description of trophi, and SEM should follow for comparison and finer image in further studies.

The expectations to find all six previously reported *Synchaeta* species in the region (Berzinsh, 1960; Telesh et al., 2009) remained unfulfilled. Assumedly, the outcome was affected by the low frequency of sampling, although investigation of other pelagic-related habitats, such as sediments (Lokko et al., 2014) or connecting

freshwater bodies like Lake Liepaja (Fig. 1), could give an additional opportunity to obtain more *Synchaeta* species for trophi investigation.

The existing description of *S. monopus* (Hollowday, 2002) mainly outlines two characteristics: broad uncial plates with five strong teeth, the first three teeth being separated by a cleft from the other two (Hollowday, 2002), which only partly coincides with the results of the present study. The difference was in the number of unci teeth. We observed six teeth, although five of them were arranged in the same way as the existing description (Fig. 2F '1-5'; Hollowday, 2002), only with slightly deeper cracks between the grouped teeth. The presence of sixth unci tooth (Fig. 3F '0') led to a conclusion that more detailed analysis of *S. monopus* trophi needs to be made. As for *S. fennica*, a brief description of trophi morphology can be found in the identification guide by Kutikova (1970), although it only states that unci teeth are asymmetrical with one tooth on the right uncial plate and two teeth on the left, which fully coincides with the results of the present study.

Finding *S. triophthalma* was unexpected as it has never been reported in Latvian waters. However, we did not find it again in May 2015. *Synchaeta triophthalma* has a unique feature: an asymmetric lateral antenna (Hollowday, 2002), which makes it easily recognizable and, more importantly, the antenna is often visible (Fig. 2G–H), because *S. triophthalma* contracts only slightly when preserved (Fig. 2G–H), as we observed in most cases. Information about the distribution of *S. triophthalma* in the Baltic Sea is poor. Several researches show that it occurs in the southern Baltic Sea, in the Arkona and

Table 3. Abundance (ind m^{-3}) of calanoid copepods (N − nauplii; C I−III − first three copepodite stages; C IV−V − last two copepodite stages; AD − adult copepods). NO − not observed during sample analysis; * − presence of *Synchaeta triophthalma*

Date	Station	N	C I−III	C IV−V	AD
13 Sep 2013	L1	14 791.7	6 333.3	1 833.3	1 222.2
	L6	8 180.9	685.8	90.7	115.7
	L7	38 511.9	4 444.4	158.7	119.0
27 May 2014	L1	3 442.1	6 481.5	5 822.9	3 251.2
	L6	3 287.0	4 305.6	1 875.0	925.9
	L7	5 777.8	4 019.8	956.3	158.7
21 Oct 2014	L1	944.4	NO	NO	111.1
	L6*	583.3	NO	NO	NO
	L7*	1 173.1	288.5	21.4	NO
21 May 2015	L1	2 121.2	101.0	NO	NO
	L6	656.6	50.5	151.5	50.5
	L7	1 088.0	347.2	69.4	23.1

Bornholm basins (Arndt et al., 1990), as well as in the Western Baltic Sea (Telesh et al., 2009), but we have not found any reports of observations further north or east. At first the assumption that the recent salt-water inflow in the Baltic Sea (IOW Press Release, 2014) might have caused the range extension of *S. triophthalma* was made, but as hydrological conditions did not change (Table 2), the reason of its appearance remained unclear. *Synchaeta triophthalma* could either have been brought to the study area by ballast waters of cargo ships, or possibly has always been there unnoticed, controlled by predation and competition. In the Mediterranean Sea a negative correlation between the abundance of calanoid nauplii and *S. triophthalma* was observed in a coastal lagoon (Rougier et al., 2000), and it was linked to interspecies competition. Furthermore, it might also be the case in the Baltic Sea, as *S. triophthalma* was observed in samples with low abundance of calanoid nauplii (Table 3). However, the absence of adult calanids in both samples in which *S. triophthalma* was present is noteworthy (Table 3). Soft-bodied rotifers with no effective defence mechanism, such as *Synchaeta* (Williamson, 1987), are suitable and easy prey for adult calanids (Williamson and Butler, 1986; Stoecker and Egloff, 1987; Rougier et al., 2000), although no study implies a particular preference for *S. triophthalma*.

To our knowledge, some studies conducted in the Baltic Sea region present analysis of *Synchaeta* individuals to species level (e.g. Arndt et al., 1990; Johansson, 1992; Ikauniece, 2001; Werner and Auel, 2004; Telesh et al., 2009; Lokko et al., 2014; this study);

however, they cover mostly coastal areas. As for the open Baltic, deeper investigation of biodiversity of rotifers is lacking (Mironova et al., 2008) and the majority of studies either report on most abundant *S. baltica* and/or *S. monopus* populations (e.g. Ojaveer et al., 1998; Dippner et al., 2000; Kornilovs et al., 2004) or identify to genus level and lump all the species together as *Synchaeta* spp. Ojaveer et al. (2010) also state that microplankton (ciliates and rotifers) is the most species-rich component of the Baltic Sea zooplankton, yet it lacks continuous attention in environmental studies. To fully comprehend the diversity and distribution of *Synchaeta* species in the Baltic Sea and its subregions more species-focused investigations are needed, and they are not possible without adequate and handy descriptions.

ACKNOWLEDGEMENTS

REFERENCES

Arndt, H. 1993. Rotifers as predators on components of the microbial web (bacteria, heterotrophic flagellates, ciliates) – a review. *Hydrobiologia*, **255**, 231–246.

Arndt, H., Schröder, C., and Schnese, W. 1990. Rotifers of the genus *Synchaeta* – an important component of the zooplankton in the coastal waters of the Southern Baltic. *Limnologica (Berlin)*, **21**, 233–235.

Berzinsh, B. 1960. Rotatoria I. Genus: *Synchaeta. Conseil International Pour L'Exploration de la Mer.* Zooplankton Sheet No 84.

De Smet, W. H. 1998. Preparation of rotifer trophi for light and scanning electron microscopy. *Hydrobiologia*, **387/388**, 117–121.

Dippner, J. W., Kornilovs, G., and Sidrevics, L. 2000. Long-term variability of mesozooplankton in the Central Baltic Sea. *J. Marine Syst.*, **25**, 23–31.

Dolan, J. R. and Gallegos, C. C. 1992. Trophic role of planktonic rotifers in the Rhode River Estuary, spring–summer 1991. *Mar. Ecol. Prog. Ser.*, **85**, 187–199.

Fontaneto, D., De Smet, W. H., and Ricci, C. 2006. Rotifers in saltwater environments, re-evaluation of an inconspicuous taxon. *J. Mar. Biol. Ass. U.K.*, **86**, 623–656.

HELCOM. 2013. Joint HELCOM/OSPAR Guidelines for the Contracting Parties of OSPAR and HELCOM on the granting of exemptions under International Convention for the Control and Management of Ships' Ballast Water and Sediments, Regulation A-4. HELCOM Ministerial Declaration.

Hollowday, E. D. 2002. Family Synchaetidae Hudson & Gosse, 1886. In *Guides to the Identification of the Micro-invertebrates. ROTIFERA.* Vol. 6 (Nograndy, T. and Segers, H., eds), pp. 87–264. Backhuys Publishers, Leiden.

Hudson, C. T and Gosse, P. H. 1886. *The Rotifera: or, Wheel-Animalcules.* With illustrations. In two volumes. Longmans, Green, and Co, London.

IOW Press Release. 2014. A small wave of relief: oxygen measured in the deep water of the Baltic Proper. http://www.io-warnemuende.de/tl_files/news/presse/2014/20140807_presse_Salzwassereinbruch_english.pdf (accessed 2016-10-15).

Ikauniece, A. 2001. Long-term abundance dynamics of coastal zooplankton in the Gulf of Riga. *Environ. Int.*, **26**, 175–181.

Johansson, S. 1983. Annual dynamics and production of rotifers in an eutrophication gradient in the Baltic Sea. *Hydrobiologia*, **104**, 335–340.

Johansson, S. 1992. *Regulating Factors for Coastal Zooplankton Community Structure in the Northern Baltic Proper.* Doctoral Thesis. University of Stockholm.

Kornilovs, G., Möllmann, C., Sidrevics, L., and Berzinsh, V. 2004. Fish predation modified climate-induced long-term trends of mesozooplankton in a semi-enclosed coastal gulf. In *ICES CM 2004/L:13*, pp. 1–26.

Koste, W. 1978. *Rotatoria. Die Rädertiere Mitteleuropas. Ein Bestimmungswerk begründet von Max Voigt.* In two volumes. Borntraeger, Berlin.

Kutikova, L. A. 1970. *Kolovratki fauny SSSR (Rotatoria).* Akademia Nauk SSSR, Leningrad (in Russian).

Lokko, K., Virro, T., and Kotta, J. 2014. Taxonomic composition of zoopsammon in fresh and brackish waters of Estonia, a Baltic province ecoregion of Europe. *Estonian J. Ecol.*, **63**, 242–261.

Mironova, E., Telesh, I., and Skarlato, S. 2008. Biodiversity of microzooplankton (ciliates and rotifers) in the Baltic Sea. In *US/EU-Baltic International Symposium, 2008 IEEE/OES.* Conference Paper. doi: 10.1109/BALTIC.2008.4625505.

Obertegger, U., Braioni, M. G., Arrighetti, G., and Flaim, G. 2006. Trophi morphology and its usefulness for identification of formalin-preserved species of *Synchaeta* Ehrenberg, 1832 (Rotifera: Monogononta: Synchaetidae). *Zool. Anz.*, **245**, 109–120.

Ojaveer, E., Lumberg, A., and Ojaveer, H. 1998. Highlights of zooplankton dynamics in Estonian waters (Baltic Sea). *ICES J. Mar. Sci.*, **55**, 748–755.

Ojaveer, H., Jaanus, A., MacKenzie, B. R., Martin, G., Olenin, S., Radziejewska, T., et. al. 2010. Status of biodiversity in the Baltic Sea. *PLoS ONE*, **5**(9), e12467.

Rougier, C., Pourriot, R., and Lam-Hoai, T. 2000. The genus *Synchaeta* (rotifers) in a north-western Mediterranean coastal lagoon (Etang de Thau, France): taxonomical and ecological remarks. *Hydrobiologia*, **436**, 105–117.

Ruttner-Kolisko, A. 1974. *Plankton Rotifers. Biology and Taxonomy.* Supplementary edition. Schweizerbart, Stuttgart.

Stoecker, D. K. and Egloff, D. A. 1987. Predation by *Acartia tonsa* Dana on planktonic ciliates and rotifers. *J. Exp. Mar. Biol. Ecol.*, **110**, 53–68.

Telesh, I. and Heerkloss, R. 2002. *Atlas of Estuarine Zooplankton of the Southern and Eastern Baltic Sea.* Verlag Dr. Kovač, Hamburg.

Telesh, I., Postel, L., Heerkloss, R., Mironova, E., and Skarlato, S. 2009. *Zooplankton of the Open Baltic Sea: Extended Atlas.* BMB Publication No. 21 – Meeres-wissenschaftliche Berichte, Warnemünde, **76**.

Werner, I. and Auel, H. 2004. Environmental conditions and overwintering strategies of planktonic metazoans in and below coastal fast ice in the Gulf of Finland (Baltic Sea). *Sarsia*, **89**, 102–116.

Williamson, C. E. 1987. Predator–prey interactions between omnivorous diaptomid copepods and rotifers: the role of morphology and behaviour. *Limnol. Oceanogr.*, **32**, 167–177.

Williamson, C. E. and Butler, N. M. 1986. Predation on rotifers by the suspension-feeding calanoid copepod *Diaptomus pallidus. Limnol. Oceanogr.*, **31**, 393–402.

Ülevaade perekonna *Synchaeta* Ehrenberg, 1832 (Rotifera: Monogononta: Synchaetidae) liikidest Ida-Gotlandi basseinis Läänemeres: täiendavate andmetega *S. fennica* Rousselet, 1902 ja *S. monopus*'e Plate, 1889 lõugade kohta

Astra Labuce ja Solvita Strake

Liepāja sadama vetest (Läti; Läänemeri) tuvastati neli keriloomaliiki perekonnast *Synchaeta*. *Synchaeta baltica* ja *S. monopus* on tüüpilised Läänemere liigid ning domineerisid koos enamikus proovidest. *Synchaeta fennica* oli arvukas kevadel, seevastu leiti 2014. aasta oktoobris esimest korda Läti vetest ka *S. triophthalma* esindajaid. Proovide analüüsimisel pöörati erilist tähelepanu ebapiisavalt kirjeldatud *S. monopus*'e ja *S. fennica* lõugadele, mille kohta on esitatud lühike ülevaade.