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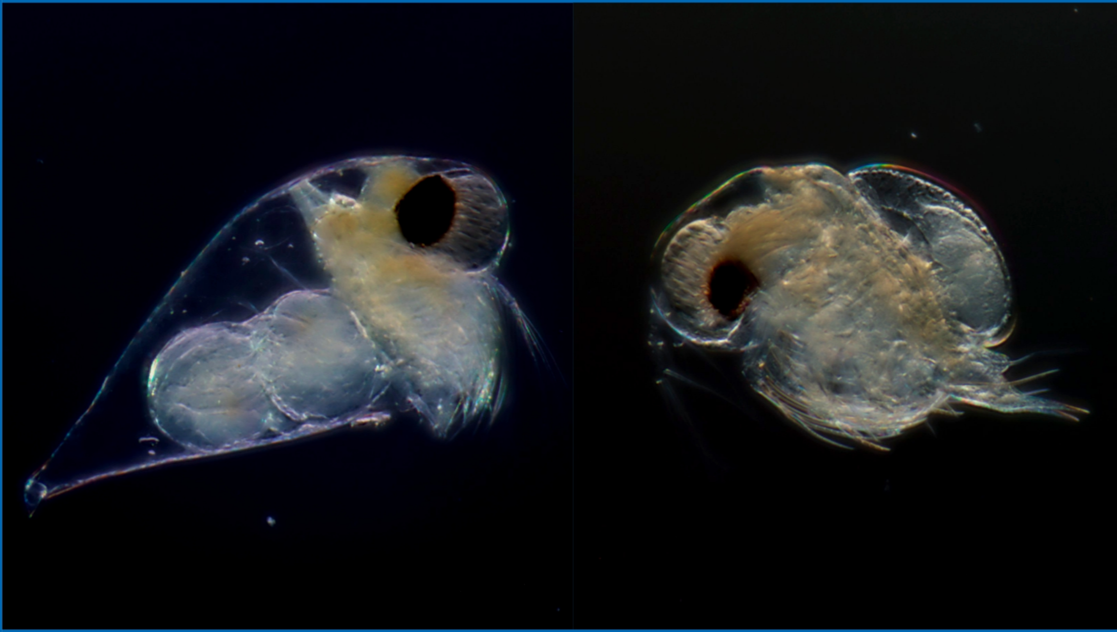

Zooplankton of the Baltic Sea: General Aspects and Identification Hints

Heft 32

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Heft 32

Universität Rostock
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Content

Preface

Zooplankton is an important biotic component of aquatic ecosystems. These tiny organisms (usually 0.02–20.0 mm in size) transfer organic matter and ensure energy flow from primary producers to secondary consumers. They serve as food for fish and mammals (whales) and can be used as biological indicators of water quality. Zooplankton also play a significant role in the formation and maintaining of natural biological diversity and thus secure ecosystem stability.

This RMB volume contains an extended and updated version of the booklet "Zooplankton of the Baltic Sea: Introduction to the Distant Learning Module" (Telesh et al., 2015). This publication, originally thought to serve as background material, preparing students and scientists for determination courses, has been sold out within a few years, indicating high demand for its content. In addition, working with it for a couple of years the need for additions and updates became obvious. So in order to make it available for all colleagues, publication of a reviewed and, revised version was seen as a better option than copying the former one.

This volume provides the general information on zooplankton organisms inhabiting the Baltic Sea: their morphology, biodiversity, ecology and roles in the food webs, picture key to the higher invertebrate taxa, and methodological recommendations for sampling, identification and counting of zooplankton. The contents is enhanced by tables, line drawings, and colour photographs depicting some of the most common species of Protozoa, Cnidaria, Ctenophora, Turbellaria, Rotifera, Phyllopoda, Copepoda, Chaetognatha and Copelata, as well as meroplanktonic larvae of Polychaeta, Mollusca, and Cirripedia. We also present here the checklist of meso- and macrozooplankton species that inhabit the open areas and coastal waters of the Baltic Sea.

Precise species identification of zooplankton organisms is necessary for the evaluation of their functional roles, bio-indication, and production potential – the important species-specific ecological parameters. However, it is a tedious and time-consuming work, which requires certain taxonomic skills, understanding of the general principles of species identification, and knowledge of taxonomically-important morphological characteristics of zooplankters from different groups. On a regular basis, species determination should be performed with the help of the professionally compiled taxonomic identification keys. Additionally, illustrated atlas books with drawings and photos of live and preserved planktonic organisms are also helpful; however, they cannot substitute the classical taxonomic guides and the expertise of professional taxonomists.

Nowadays, it is a common problem worldwide that taxonomists become extinct. For the Baltic Sea region, taxonomic training of the staff in hydrobiological laboratories that store their results in joint databases is of exceptional importance for acquiring and maintaining the quality assurance of the laboratories that participate in the international monitoring programmes in the Baltic Sea region. Unfortunately, such taxonomic training courses are rare nowadays.

Another important format for maintaining and advancing the taxonomic qualification of researchers is the zooplankton taxonomic training cources in the frames of the international conferences "Frontiers in Plankton Research" organized by the Russian Hydrobiological Society (http://gboran.ru/) every three years since 2012 and traditionally held in Kaliningrad Region, Russian Federation (Telesh, 2022). Other events like the International Rotifer Symposia (the recent one was held in Zagreb, Croatia, in September 2022; https://www.rotiferaxvi.biol.pmf.hr/) or specialized conferences on other groups of planktonic organisms also stimulate researchers to improve their taxonomic skills.

The information given in this publication provides the primary knowledge on zooplankton characteristics, which is essential for the identification and study of zooplankton. This information largely bases on the series of research papers and four Baltic Sea zooplankton atlas books (Telesh & Heerkloss, 2002, 2004; Telesh et al., 2008b, 2009).

The description of zooplankton is preceded by brief introduction into the vast field of knowledge about the environmental characteristics and peculiarities of the community structure and distribution patterns of mesozooplankton in the Baltic Sea. These sections allow mentioning only the basic features, facts and regularities that are specific to the Baltic Sea. Basing on this information, the interested reader will easily find a number of recent books, reviews, and research papers for further reading and getting more in-depth knowledge, which is necessary to study the zooplankton of the Baltic Sea. For example, for a detailed description of the historic data on oceanography of the Baltic Sea see Matthäus (1995) and Feistel et al. (2008), for ecology of the Baltic Sea see Schiewer (2008). And, of course, the most recent comprehensive description of all aspects of the Baltic Sea biology is presented in the book "Biological Oceanography of the Baltic Sea" edited by Pauline Snoeijs-Leijonmalm, Hendrik Schubert and Teresa Radziejewska (Snoeijs-Leijonmalm et al., 2017).

The authors of the current edition hope that the new, updated version of "Zooplankton of the Baltic Sea: General Aspects and Identification Hints" will make the zooplankton species identification easier and thus contribute to better usage of the zooplankton data for water quality assessment in the Baltic Sea and dissemination of knowledge on marine biodiversity.

Rostock, February 2023

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CHAPTER 1

The Baltic Sea environment: introductory remarks

The Baltic Sea is the world's largest semi-closed brackish water body. It is a temperate shelf sea with permanent salinity stratification, a unique horizontal salinity gradient, and low water turnover of 25–35 years. It is a shallow sea with a mean depth of 62.1 m, the greatest depth 459 m, an area of 415,266 km^2 (Baltic proper itself is 211,069 km^2), and a volume of ca. 22,000 km^3 (HELCOM, 2001; Wulff et al., 2001; Schiewer, 2008). The Baltic Sea catchment area covers 1,671,000 km^2 (Kortum, 1996). The presence of shallow sills at the western inlets causes stable water stratification. Climate is humid in the Baltic Sea area. The Baltic can be best compared to a stratified fiord with a rich supply of fresh water from the rivers. There is an estuarine circulation with outflow of low-saline water above the halocline and powerful periodic injections of North Sea water below the halocline that greatly affect the salinity and oxygen regimes in the deep water layers.

In the history of the Baltic Sea, periods of freshwater, marine water and brackish water predominance succeeded gradually, being sometimes interrupted by complete freezing of the whole region. The postglacial history of the Baltic region started with the melting of the glacial ice shield. As the ice shield barred the melting water from the open sea, this Baltic Ice-Lake contained fresh water. About 10,000 years ago, a first connection to the ocean was opened through mid-Sweden surface, and the brackish Yoldia Sea emerged. It was probably exposed to large gradients and fluctuations of salinity, as a second connection to the White Sea was opened during several periods. The first connection closed about 9,250 years ago due to the uplift processes, resulting in a freshwater lake. This so-called Ancylus Lake existed between 9,250 and 7,100 years ago.

The Baltic Sea, as we know it now, is a brackish water system, existing as such since approximately 7,100 years ago. But even this geologically relatively short time span cannot be considered as a stable period. Between 7,100 and 4,000 years ago, the main Baltic fossile was *Littorina littorea*, giving its name to this period. During the recent 4,000 years, the Baltic Sea has gradually become less saline, and *Littorina* was first replaced by the freshwater mollusc *Limnea ovata* (Limnea period) and later, about 1,500 years ago – by *Mya arenaria* (Mya period), which still characterises the system. With respect to this variability, fluctuations in species composition and high numbers of invaders (the non-indigenous, or alien organisms) are neither surprising nor alarming events, but rather an expected pattern in a system exposed to an ever-changing abiotic background.

The recent Baltic Sea is connected with the North Sea via the Belt Sea, the Kattegat and the Skagerrak; it stretches for 1,200 km in the west-east direction from the Kattegat to the Gulf of Finland and for 1,300 km in the south-north direction from the Odra Bight up to the Bothnian Bay, close to the polar circle (Figure 1.1).

Figure 1.1: Regions of the Baltic Sea. Shown is the division of the Baltic Sea into "natural regions" according to Wattenberg (1949). The Bornholm Sea and the eastern and western Gotland Sea are often considered jointly and termed the "Baltic proper".

The hydromorphology of the Baltic Sea is rather complicated (Köster & Lemke, 1996). Several underwater barriers and deep basins follow each other, subdividing the Baltic Sea into certain districts, as indicated in Figure 1.1. The Bothnian Bay is the outermost northern part of the Baltic Sea; its adjacent southern region is the Gulf of Bothnia (the Bothnian Sea). The easternmost part between Finland, Russia and Estonia is called the Gulf of Finland; the large semi-enclosed part between the island of Saaremaa and the city of Riga is called the Gulf of Riga. The main water body, called the Baltic proper, stretches from westernmost Finland to the Bornholm Island. The shallow region around the Danish Islands is called the Belt Sea, it is connected to the Kattegat north of the Danish Islands. The Kattegat, irrespective of being covered by Baltic-wide regulations, e.g. the Helsinki Commission (HELCOM), is not an integral part of the Baltic Sea; it is the transition area between the North Sea and the Baltic Sea.

Wattenberg (1949) gives a more detailed, “natural” subdivision of the sea. He identifies the Åland Sea west of the Åland Islands, and the Archipelago Sea east of the Island of Åland as separate regions; the Baltic proper becomes splitted into Bornholm Sea and the Eastern and Western Gotland Sea (Figure 1.1). Another region often cited by several authors is the Quark (not shown in Figure 1.1), the area between the Bothnian Sea and the Bothnian Bay.

The maximum depths of the major regions are: the Arkona Basin – about 45 m, the Bornholm Basin – about 100 m, the Eastern and Western Gotland Basins – about 250 and 460 m, respectively, the Gulf of Finland – about 120 m; the Bothnian Sea and the Bothnian Bay are characterised by depths of 120 and 80 m, respectively (Feistel et al., 2008).

However, as any attempt to classify the natural aquatic systems, the subdivision of the Baltic Sea is largely conventional when water masses and their biota are considered, and the real borders between the areas mentioned above do not exist. This is especially relevant to the pelagic communities of living organisms (the plankton) that are mixed extensively, drift within large water masses, and may be driven by those water masses to significant distances (Telesh et al., 2009).

Irrespective of the fact that different division schemes mainly focus on morphology of the Baltic Sea, they also reflect changes in the abiotic conditions, especially salinity, which are of vital importance for the biota of this water body. That is due to the hydrological regime of the Baltic, which has only one narrow connection to the entirely marine habitat of the North Sea and is located in a humid climate zone. Fennel (1996) calculated the water budget of the entire Baltic Sea. River runoff was measured as ca. 483 km³ a^{-1}, whereby the Neva River with 77 km³ a^{-1}, located in the outermost eastern part of the Gulf of Finland, was by far the largest fresh water contributor to the Baltic Sea, followed by the Vistula River with its 34 km³ a^{-1}. The precipitation was estimated to be 266 km³ a^{-1}, and evaporation amounted to 207 km³ a^{-1}, resulting in a freshwater input of approx. 60 km³ a^{-1}. The total freshwater input therefore added up to 540 km³ a^{-1}. This surplus of freshwater input gets counteracted by the inflow of marine water via the Skagerrak and the Kattegat.

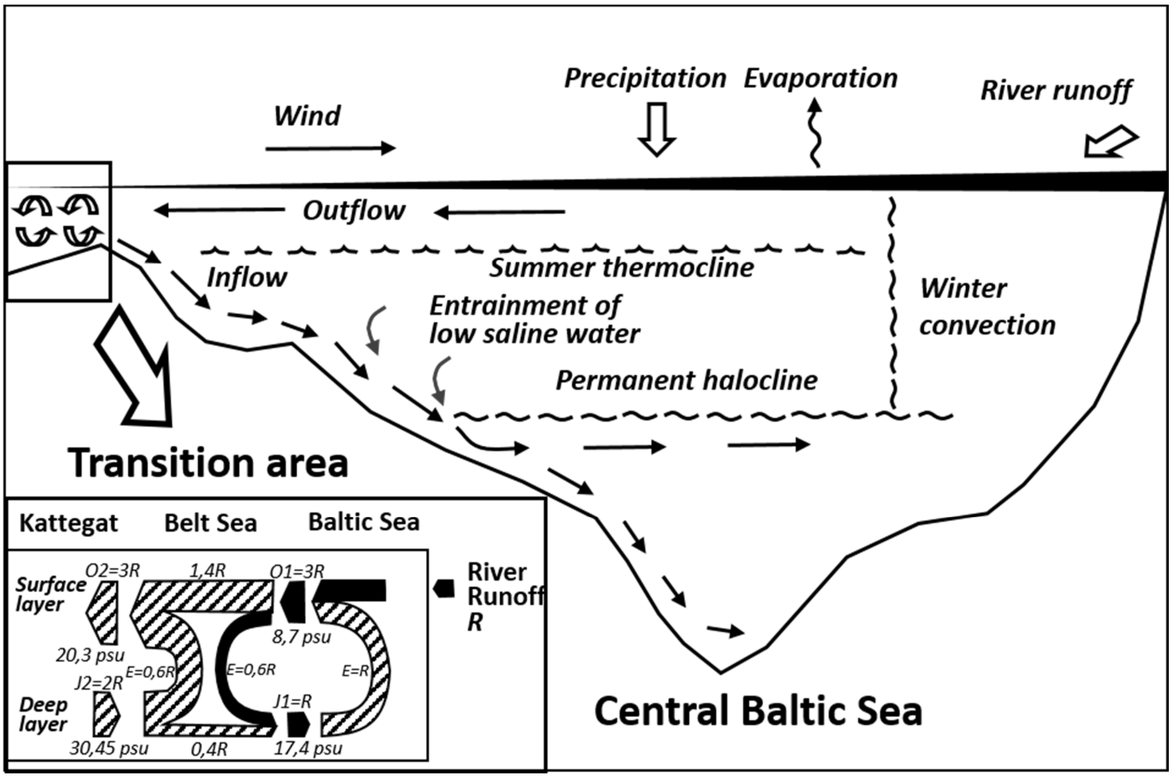

Figure 1.2: Water balance and water circulation of the Baltic Sea. Bottom left: water exchange with the North Sea in river runoff units (R): O1, O2 – outflow in the surface layer; J1, J2 – inflow compensation current in the deep layer; E – entrainment of water from the deep layer into the surface layer and vice versa (from Lass & Matthäus, 2008).

The mechanisms of water exchange between the Baltic Sea and the North Sea are very intricate. The positive water balance of the Baltic Sea determines the estuarine circulation, which is driven by the outflow of brackish surface water through the Kattegat. Due to a lower density of the brackish water compared to the Kattegat water, a deep-water compensation current is transporting saline water from the North Sea into the Baltic Sea. The compensation current is even more pronounced, the stronger the outflow at the surface layer is. These fundamental processes together with upwelling and vertical mixing processes determine the special hydrographic conditions of the Baltic Sea.

The brackish water originating from the Baltic Sea has a lower density and, therefore, moves at the surface relatively unhampered. It is driven by gravity because of the positive water budget mentioned above. Salt water inflow from the North Sea is influenced by numerous underwater barriers and sills. The most important ones are the Drogden Sill (Öresound) and the Darss Sill (Arkona Sea) reaching down to 7 m and 18 m underneath the surface, respectively. As a result, there is a steep salinity gradient along the Baltic Sea. From almost marine conditions in the Kattegat region, salinity drops within a short distance of ca. 300 km down to <10 psu in the Baltic proper. Further east, salinity declines more slowly until it reaches values of less than 2 psu in the Bothnian Bay and the easternmost parts of the Gulf of Finland. In general, salinity regime in the Baltic Sea ranges between oligohaline (0.5 psu) and mesohaline (18 psu) conditions, with an average of 7–8 psu in the major open Baltic waters (HELCOM, 2001). However, climate change and decadal scale variability of these parameters modify the hydrographic characteristics accordingly (BACC, 2008; Feistel et al., 2008).

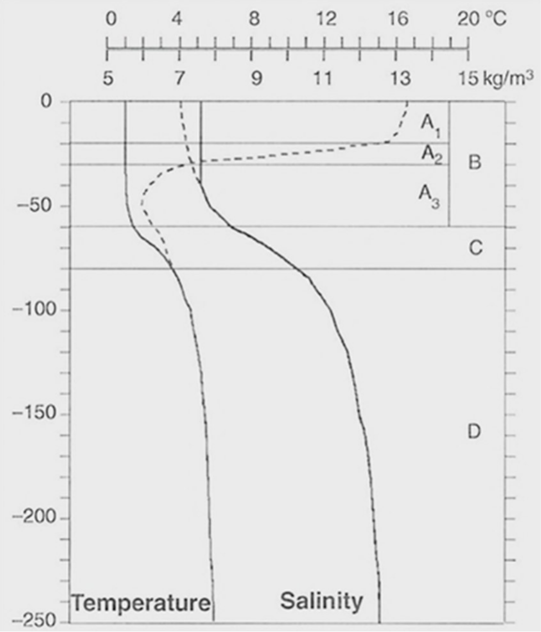

Figure 1.3: Typical thermocline stratification of the central Baltic Sea during winter (solid line) and summer (brocken line). A1 = summer upper layer; A2 = summer thermocline; A3 = cold intermediate water layer; B = cold winter water layer; C = permanent discontinuity layer; D = deep water layer (from Lass & Matthäus, 2008).

Depending on air temperature, a thermocline forms seasonally due to the warming of the surface water layer in spring and summer at a depth of 25–30 m (Figure 1.3). The thermohaline stratification is subject to spatial and temporal variations throughout a year. In winter, the permanent thermohalocline separates low saline cold winter water from higher saline warmer deep-water (Figure 1.3). During spring, the surface water is warming up and a thermocline develops, separating warm surface water from cold intermediate water. In consequence, the vertical mixing of the surface water and the intermediate water is inhibited until autumn. A stable halocline and a seasonally existing thermocline prevent vertical circulation and, consequently, ventilation of the bottom water.

The general picture of the average salinity in the open waters, however, is superimposed by different ranges of irregular fluctuations of salinity at a certain location. Sheltered lagoons and bays are influenced by freshwater runoff and therefore their average salinities differ largely from that of the adjacent Baltic Sea. The actual salinity in such locations therefore depends on (a) the current freshwater runoff, fluctuating seasonally according to the precipitation regime (which is not uniform all around the Baltic), (b) the actual water exchange with the Baltic Sea, and (c) the salinity of the adjacent Baltic Sea water. The latter can play a major role, because large changes of the salinity of the Baltic Sea water are common.

The saline inflows from the North Sea are the main source of new oxygen for bottom water of the deep Baltic Sea basins. Major saline water inflows occur most frequently between October and February whereas they have never been recorded between May and August. They either occur in clusters of several subsequent years or as isolated events. Between 1880 and 1980, major saline water inflows into the Baltic Sea occurred quite regularly with only 2 or 3 years in between. Since the middle 1980s, the situation changed dramatically. The frequency of major saline water inflows decreased significantly, with about 10 years between two major inflow events (Figure 1.4). The decreased frequency and intensity of inflow events caused important consequences for the chemical and biological conditions below the permanent halocline. During long stagnation periods, the salinity and oxygen concentration in the deep water layer decreases. Oxygen deficiency areas develop at the sediment and in the bottom water layer, especially in deep Baltic Sea basins.

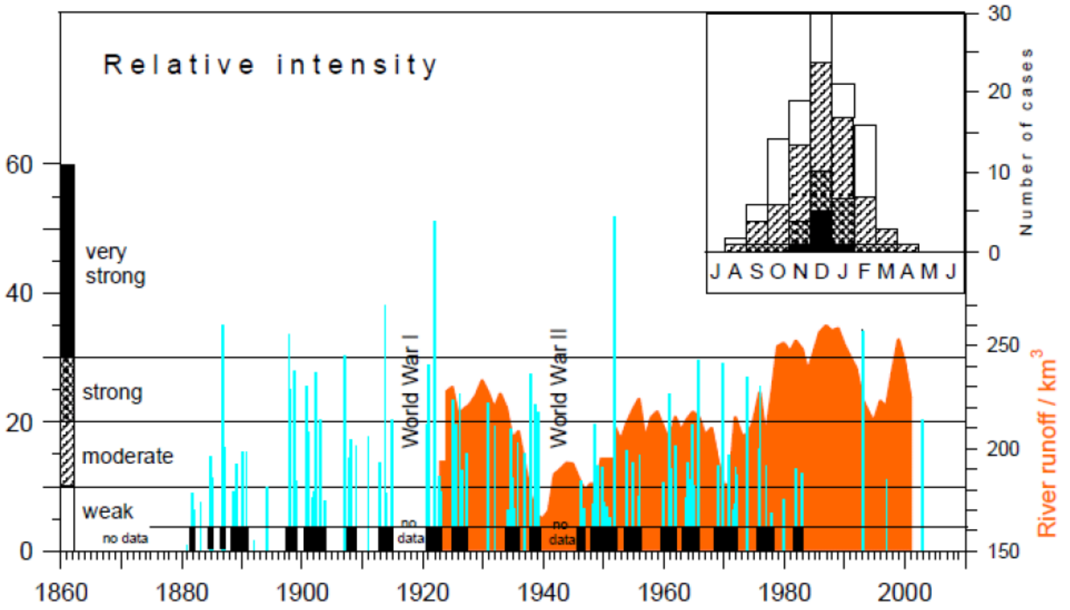

Figure 1.4: Major Baltic inflows between 1880 and 2007 and their seasonal distribution (upper right) shown in terms of their relative intensity and five year running means of river runoff to the Baltic Sea (inside the entrance sills) averaged from September to March (shaded). Black boxes on the time axis: major inflows arranged in clusters. Intensities: 0 equals an inflow of 5 days duration with S = 17 psu, 100 equals an inflow of 30 days duration with S = 24 psu (from Matthäus et al., 2008).

Major Baltic inflows cause a renewal process in the deepwater of the central Baltic Sea. Salinity and oxygen concentrations increase, especially when the inflow events take place during the cold season (January to April). Immediately after the deep water renewal, a new stagnation period begins, due to an increased stability of the salinity stratification. During stagnation period, the salinity decreases slowly in the deep water caused by vertical and horizontal mixing. Oxygen concentration decreases rapidly due to microbial consumption processes with the consequence of hydrogen formation.

The Baltic Sea is also characterised by a strong climatic gradient, as it stretches over 20 degrees of longitude and 12 degrees of latitude. Maritime temperate conditions predominate in the southern and western parts, whereas continental conditions prevail in the eastern and northern parts, becoming more arctic-influenced in the Bothnian Bay.

Due to the large north-south expansion of the Baltic Sea, the insolation and temperature regimes in this water basin vary greatly. To illustrate these differences, a southernmost location at 54° N was compared with a northernmost one at 65° N in terms of insolation (Figure 1.5; original data of H. Schubert). All data are based on potential insolation, irrespective of actual weather conditions. As shown in Figure 1.5, daily irradiance on June 22, the longest day of the year, differs only slightly between the locations. In the northern location, maximum irradiance is ca. 13% lower, but day length is prolonged by 4 h. Therefore, the overall difference in daily light dose is small between the locations. On December 22, the shortest day in the northern hemisphere, a large difference between the two locations can be observed with almost no irradiance at the northern station and still some irradiance in the southern location.

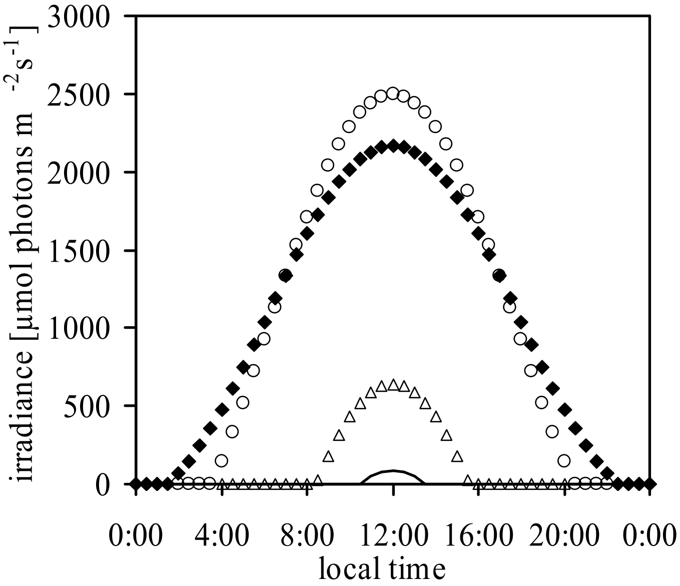

Figure 1.5: Daily irradiance curve. Shown are the daily irradiance curves at a northernmost location (65°N) and at a southernmost location (54°N) of the Baltic Sea. Calculations were made irrespective of actual weather conditions and thus show potential insolation (original data of H. Schubert).
Symbols used: open circles - 54°N, June 22; open triangles - 54°N, December 22; filled rhombs - 65°N, June 22; solid line - 65°N, December 22.

The temperature regime is related to the insolation regime and thus exhibits large differences across the Baltic Sea. The average water temperature is about 8.4 °C at the southern Baltic coast (Warnemünde), but in St. Petersburg and in Helsinki, located on the eastern Baltic coast, the average temperature only amounts to 4.5 °C. Furthermore, the annual temperature amplitude (monthly means) forms a gradient across the Baltic Sea, reaching only 18 °C in the south-western regions and 28 °C in the north-eastern regions (Heyer, 1977).

The great variation in the temperature amplitude mentioned above results in the differences in probability and duration of ice cover across the Baltic Sea (Figure 1.6). The Bothnian Bay and some parts of the innermost Gulf of Finland have the highest probability of ice cover formation and are covered with ice completely every winter. Sheltered lagoons and coastal enclosures around the Baltic are covered with ice during most winters, but large differences can be observed in thickness and duration of the ice cover. As shown in Figure 1.6, other regions of the Baltic Sea are not covered by ice every winter. In some years, almost the whole Baltic Sea is frozen and only small areas of the Baltic proper are kept open, whereas in other winters ice cover is restricted to the northern and eastern parts of the sea. The probability of ice formation ranges from about 30% in exposed locations of the Baltic proper and Kattegat to about 70% along the Baltic proper coastline and 100% along the coastlines of Finland, Russia and northern Sweden. A corresponding gradient in the duration of ice cover can be observed. Average duration of ice cover, in the caces when ice-forming conditions are present, is about 30 days in the exposed regions of the Baltic proper and in the Kattegat, about 60 days along the coastline of the Baltic proper, and more than 180 days in the Bothnian Bay (Strübing, 1996).

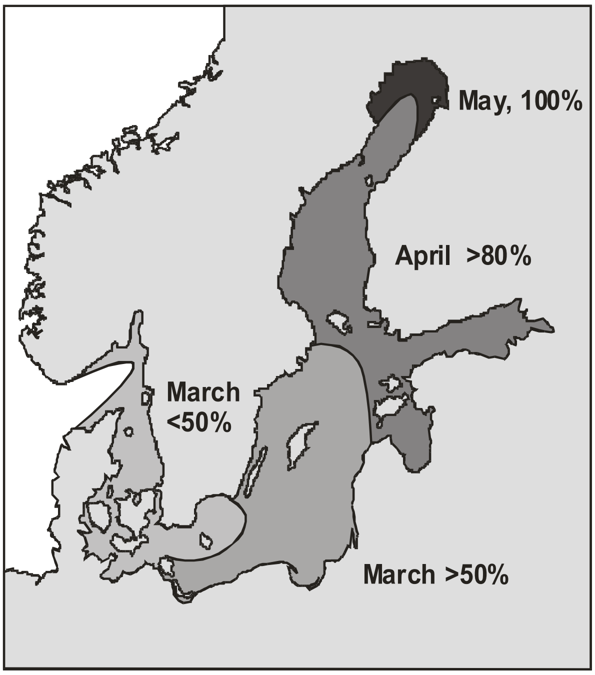

Figure 1.6: End of ice cover period and probability of ice cover formation. Shown are the month of average ice break-up and the percentual probability of ice cover formation. Data are taken from Strübing (1996).

The Baltic Sea is a so-called microtidal system, exhibiting less than 15 cm amplitude of the daily tidal component, except for the Kattegat, which is influenced by the tides of the North Sea. Despite several details, dealing with resonance effects of the individual regions etc., tidal changes of the water level are generally of minor importance in the whole Baltic Sea. Of higher importance are wind-driven changes of the water level that are usually less than 1 m in amplitude, but sometimes reach maximum values of –2.5 m below and +3 m above average water level. Such great differences occur only rarely and in most of the cases they last just a few hours. In shallow lagoons and enclosures, however, already minor changes of 0.5 m, which are common events, can cause flooding and drying of large areas. In these habitats, such minor changes can have a major impact, even if they prevail only for a short time, as they are always accompanied by drastic changes in salinity. Within a few hours, inflow of salt water can cause an increase in salinity of more than 100% and thus lead to massive hyperosmotic stress. This effect can be amplified further by dry conditions occurring a few hours or a day later, or by hypoosmotic stress in the case of rain.

The above mentioned water level changes of 0.5 m can be caused just by air pressure differences across the Baltic region, solely or in combination with wind. Tiesel (1996) described a typical seasonal pattern of air pressure gradients across the Baltic Sea. Strong pressure gradients across the whole Baltic Sea are present in winter (October–February) and can also be expected during May. During summer, mainly the south-western part of the Baltic Sea is influenced by strong air pressure gradients, leading to remarkable water level changes, whereas the northern part is less influenced. During the growth period, especially the south-western part is thus exposed to high water level changes and considerable fluctuations in salinity, as described above.

The ion composition of the brackish water in the Baltic Sea is also of pronounced ecological importance. While the ion composition of water is more or less constant in oceanic systems, this assumption may fail for brackish water systems due to the following reasons: (1) large impact of freshwater runoff with different chemical composition, (2) lower total amount of ions and, therefore, higher probability of influencing their concentrations by biological processes, (3) possibility of stagnation of the water body, leading to accumulation of compounds in the stagnant deep water where the ions can be reduced under anoxia, and (4) incomplete mixing of water bodies of different origin. Additionally, strong local anomalies occur in regions of low salinity for, e.g., the SO_4^{2-}/Cl^- ratio, reflecting the high contribution of riverine runoff to the SO_4^{2-} pool of the Baltic Sea (Kremling, 1996). Regarding those anomalies, at least on a small scale, differences between the trace element composition of the Baltic Sea and oceanic systems can be expected. Especially in the anoxic systems and regions heavily influenced by fresh water, significant deviations for numerous elements can be registered (HELCOM, 1990).

At least some of these elements are further influenced by the high concentration of dissolved organic matter in the Baltic Sea, particularly the so-called chromophoric dissolved organic matter (cDOM), which originates from incomplete lignin metabolisation. Freshwater runoff is the main source of cDOM but, unfortunately, little is known about its Baltic Sea-wide distribution in relation to salinity. The few investigations (Scheer, 1998; Blümel et al., 2002) showed a significant dependency of cDOM on salinity in coastal enclosures, but also indicated potential non-terrestrial sources of cDOM and complex changes in its composition during transport in brackish water systems. These cDOM's are of interest for two reasons. First, they are strongly attenuated by short wavelengths of photosynthetically active radiation and, therefore, limit the depth distribution of autotrophs (Schubert et al., 2001). Second, they are able to form stable complexes with many transition metals, such as copper, iron, and nickel. The first effect is well investigated and can be quantified by attenuation measurements. The second effect, however, is difficult to quantify so far, because the currently used analytical methods can hardly distinguish the complex-bound and free metals. Schlungbaum (1979) as well as Nessim (1980) assumed that most of the iron determined in the water is bound in complexes with cDOM and, therefore, is of diminished biological availability.

Largely impacted, or even driven by the abiotic factors of the environment, the biotic components of the ecosystem differ significantly in their diversity, structural features and functional characteristics throughout the Baltic Sea.

Early investigations of macrozoobenthic diversity by Remane (1934) revealed the existence of a salinity-dependent gradient in species number, which was decreasing from marine conditions to "critical salinities" of about 5−8 psu (Khlebovich, 1968), the so-called horohalinicum (Kinne, 1971). At salinity of about 8 psu, only few brackish-water species that can perform hypertonic as well as hypotonic regulation are present. When salinity decreases further, the benthic species' number increases again because of numerous freshwater species which are able to tolerate low salinities.

Later surveys of macrophytobenthos diversity confirmed the decrease in species number during the transition from marine to brackish conditions. However, the lowest species numbers were found at salinities far below 8 psu (Nielsen et al., 1995; Schubert et al., 2011). The reasons are still being investigated; however, the effect itself points to a reduced interspecific competition within phytobenthos at low salinities.

For planktonic organisms, including phytoplankton and zooplankton, but mostly for protists, Telesh et al. (2011a) discovered the opposite rule: a species maximum at the horohalinicum. There exists a number of possible explanations of this astonishing finding; Telesh et al. (2013, 2015) especially highlight the effects of environmental variability, size of organisms, evolution rate and planktonic lifestyle to explain the above salinity vs. species number pattern in a broader context. For example, it is known that aquatic bacteria, including the Cyanobacteria, and the eukaryotic, mostly single-celled Protista (algae, fungi and protozoa) demonstrate high physiological adaptability to changes in salinity. These taxa show extensive adaptive radiation. Members of the Protista have retained a considerable evolutionary euryhalinity and are, therefore, widely distributed in different aquatic environments. This is reflected in high bacterial and maximal protistan species richness in brackish waters, especially at critical salinities 5−8 psu (Herlemann et al., 2011; Telesh et al., 2011a, 2011b, 2013).

Recently, the cell size minimum was shown to back up the protistan species maximum concept, proving statistically that the smallest unicellular eukaryotic plankton are particularly diverse under the conditions of the brackish Baltic Sea waters that are stressful for larger, sessile organisms (Telesh et al., 2015).

The shallowness and the consequently vast area occupied by the coastal ecosystems in the Baltic Sea are the major reasons for the pronounced mixture of the coastal and open-water plankton communities and for the penetration of brackish, euryhaline and even freshwater species of zooplankton with the wide salinity tolerance range far into the open Baltic waters (Telesh et al., 2009). For this reason, the strict definition of the "open Baltic Sea" and its discrimination from the "coastal waters" in respect to the pelagic algoflora and fauna can hardly be given.

To summarise, we can state that for the Baltic Sea, as well as for other brackishwater systems, high variability of almost all environmental parameters in time and space is typical. Salinity fluctuation is an important factor for biodiversity formation. Due to peculiarities of the salinity regime, the pelagic ecosystem component in the Baltic Sea consists mainly of plankton communities dominated by euryhaline species. The planktonic organisms in the Baltic Sea are well adapted to the brackish water environment; however, only a few true brackish water species have evolved there. The present-day species composition of the Baltic Sea is a result of the selection process, where the organisms with a high osmotic resistance have been able to survive. The community structure and spatial distribution of zooplankton in the Baltic Sea are governed largely by the patterns and fluctuations of the environmental conditions. Meanwhile, recent studies showed that stability of major abiotic characteristics in the Baltic coastal ecosystems can be high during rather long period of 1–5 weeks, and that abiotic stability (but not just the absolute critical values of environmental parameters!) can act as one of the major promoters of water stagnation, oxygen depletion and other devastating events like harmful algal blooms (Telesh et al., 2021).

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CHAPTER 2

Zooplankton of the Baltic Sea

2.1 General characteristics of the Baltic Sea zooplankton

The Baltic Sea as a brackish water system with a horizontal salinity gradient from south-west to north-east and a permanent vertical salinity stratification of the central basins is a unique pelagic ecosystem with limited distribution ranges of marine and freshwater species. The location of the Baltic Sea in the temperate climatic zone with oceanic impact in the south-western part and continental impact in the north-eastern areas affects the whole ecosystem through seasonality by causing a pronounced seasonal succession of plankton populations.

Zooplankton in the Baltic Sea has been described routinely in terms of dominant species of certain groups (mainly copepods) and/or size fractions (mesozooplankton) that are identified and counted for monitoring purposes. Therefore, the mixoplankton (Flynn et al., 2019) that embrace the unicellular organisms capable of combining autotrophy and phagotrophy as their feeding modes, usually are not considered in these studies. Meanwhile, precise assessment of zooplankton species diversity provides important information on the marine ecosystem structure, functions, trophic webs and their natural and human-induced alterations. In many zooplankton groups, major functional characteristics responsible for the animals' behaviour and the interactions within communities are species-specific; therefore, the importance of the correct taxonomic identification of zooplankton, especially of key species, indicators of water quality, and non-indigenous species can hardly be overestimated.

Zooplankton of the Baltic Sea is a mixture of marine species and diverse brackish water and limnetic faunas typical for the vast estuarine and coastal areas located mainly in the southern and north-eastern parts of the Baltic. Some genuine brackish water zooplankton species are also known in the Baltic Sea (Remane, 1934). In addition to native species, there are several nonindigenous mesozooplankton species occurring temporarily or even establishing the permanent populations in the Baltic Sea (Gollasch & Nehring, 2006).

Since the publication of the "species minimum curve" by Remane (1934, 1940), it has been generally accepted that "the number of species in the Baltic is small" (Jansson, 1972, p. 12). This conclusion commonly was applied to and supported mainly by the data on benthic macrofauna (Zenkewitch, 1963). Meanwhile, already in the 1960-s Hans Ackefors proposed that "if the microfauna in the water and at the bottom are included the number of species will be much higher" (Ackefors, 1969, p. 5). In other words, according to an exceptionally evocative affirmation of Jansson (1972), "the diversity is there but it is found on a microscale" (p. 14). Thus, already in the second half of the XX century scientists around the Baltic were admitting that the real diversity of microscopic invertebrates in plankton might happen to be much higher when special biodiversity investigations are performed.

This idea was later supported by the results of the long-term plankton diversity research in the open and coastal Baltic waters that demonstrated high species richness of pelagic communities (for details see the review publications: Telesh, 1987, 1988, 2001, 2004, 2006a, 2006b, 2008; Telesh & Heerkloss, 2002, 2004; Telesh et al., 2008, 2009, 2011a, 2011b, 2013, 2015; Telesh & Skarlato, 2009; Mironova et al., 2009, 2012, 2013, 2014). Based on these and other published data we can conclude that the earlier existing conception of the low species diversity of planktonic communities in the Baltic Sea had resulted from the insufficient knowledge on the species composition of zooplankton, particularly its small-size fraction. Specifically, the new biodiversity concept was developed: the protistan species maximum concept for the horohalinicum (Figure 2.1), which substantiates high species richness of planktonic auto- and heterotrophic protists in the brackish Baltic waters, with maximum at the critical salinities of 5–8 psu (Telesh et al., 2011a, 2011b, 2013, 2015). The applicability of Remane´s species minimum concept for the biodiversity of mesozooplankton in the Baltic Sea is currently a challenging issue of the ongoing discussion (Cognetti & Maltagliati, 2000; Ptacnik et al., 2011; Telesh et al., 2011a, 2011b; Postel, 2012; Whitfield et al., 2012).

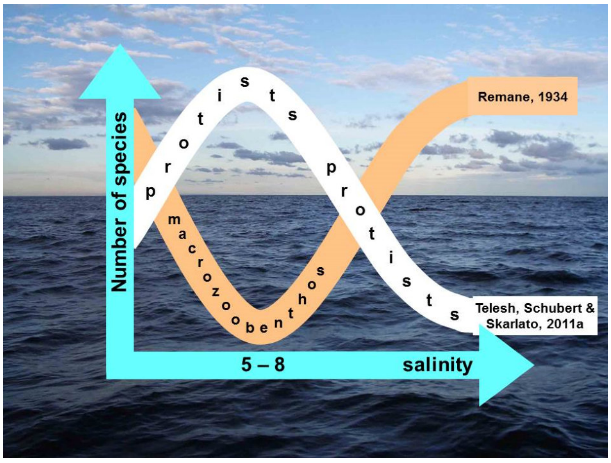

Figure 2.1: The protistan species-maximum concept (Telesh et al., 2011a) describes high diversity of photo- and heterotrophic protists in plankton of the Baltic Sea, with maximum at the critical salinities of 5 to 8 psu, which mirrors the *Artenminimum* curve for macrozoobenthos (Remane, 1934).

In general, zooplankton organisms range in size from few micrometers to meters. It is commonly accepted that a marine zooplankton community is formed by the following size fractions: picoplankton (size of organisms 0.2–2.0 µm, mainly heterotrophic bacteria), nanoplankton (2.0–20.0 µm, heterotrophic nanoflagellates, nanociliates), microplankton (20–200 µm, ciliates and a large part of rotifer species), mesozooplankton (0.2–20.0 mm, larger rotifers, mainly planktonic crustaceans, meroplanktonic larvae of some benthic invertebrates, etc.), and macrozooplankton (organisms larger than 20 mm: Cnidaria, Ctenophora, Chaetognatha, Mysidacea, Euphausiacea, Decapoda, Polychaeta and others) (Lenz, 2000).

Since the present publication is focused on mesozooplankton species that are most common in the Baltic Sea, we skip the information about macrozooplankton, as well as nano- and microzooplankters, major part of which are ciliates. However, it is important to mention that ciliates of the Baltic Sea are represented by more than 740 species (Mironova et al., 2014), they can be very abundant, and their functional role in planktonic communities has been substantially underestimated so far (Figure 2.2). Unlike the dominant mesozooplankters, microplanktonic ciliates usually are not considered in the regional monitoring programs; nevertheless, they are good indicators of water quality. They contribute significantly to energy fluxes (for example, through the microbial loop or due to mixotrophy) and water purification in the Baltic Sea ecosystem. The most recent data on species composition, diversity, spatial distribution, seasonality, abundance, biomass and productivity of ciliates in the Baltic Sea can be found elsewhere (Mironova et al., 2009, 2012, 2013, 2014, and references therein).

Mesozooplankton (0.2–20 mm) is the dominating group in the Baltic Sea in terms of biomass. It may constitute up to 76% (i.e. >1000 kg C/m²) of the average annual carbon mass, as measured in the western Gdańsk Bay during the 1980s (Witek, 1995). The remaining 18% and 6% were contributions of protozoans and macrozooplankton, respectively. The percentage of the average annual production of mesozooplankton in this region reaches 39%. Within the mesozooplankton fraction, copepods *Pseudocalanus* spp. (Figure 2.3), *Temora longicornis*[1], *Acartia* spp. (Figure 2.4), rotifers *Synchaeta* spp., and cladocerans *Evadne nordmanni* (Figure 2.5) are the most important taxa in terms of biomass and production. The ctenophore *Pleurobrachia pileus*, the copepod *Eurytemora affinis* (Figure 2.6) and rotifers *Keratella* spp. (Figures 2.5, 2.7) play a minor role, while the appendicularian *Fritillaria borealis* (Figure 2.8), Polychaeta larvae (Figure 2.9), the cladocerans *Bosmina* spp. (Figure 2.10), *Podon* spp. (Figure 2.5), the copepods *Centropages hamatus* (Figure 2.11), and Bivalvia larvae (Figure 2.8) range in between (Figure 2.12).

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[1] Authors of the Latin species names are mentioned in the zooplankton checklist (Table 5.1 in Chapter 5).

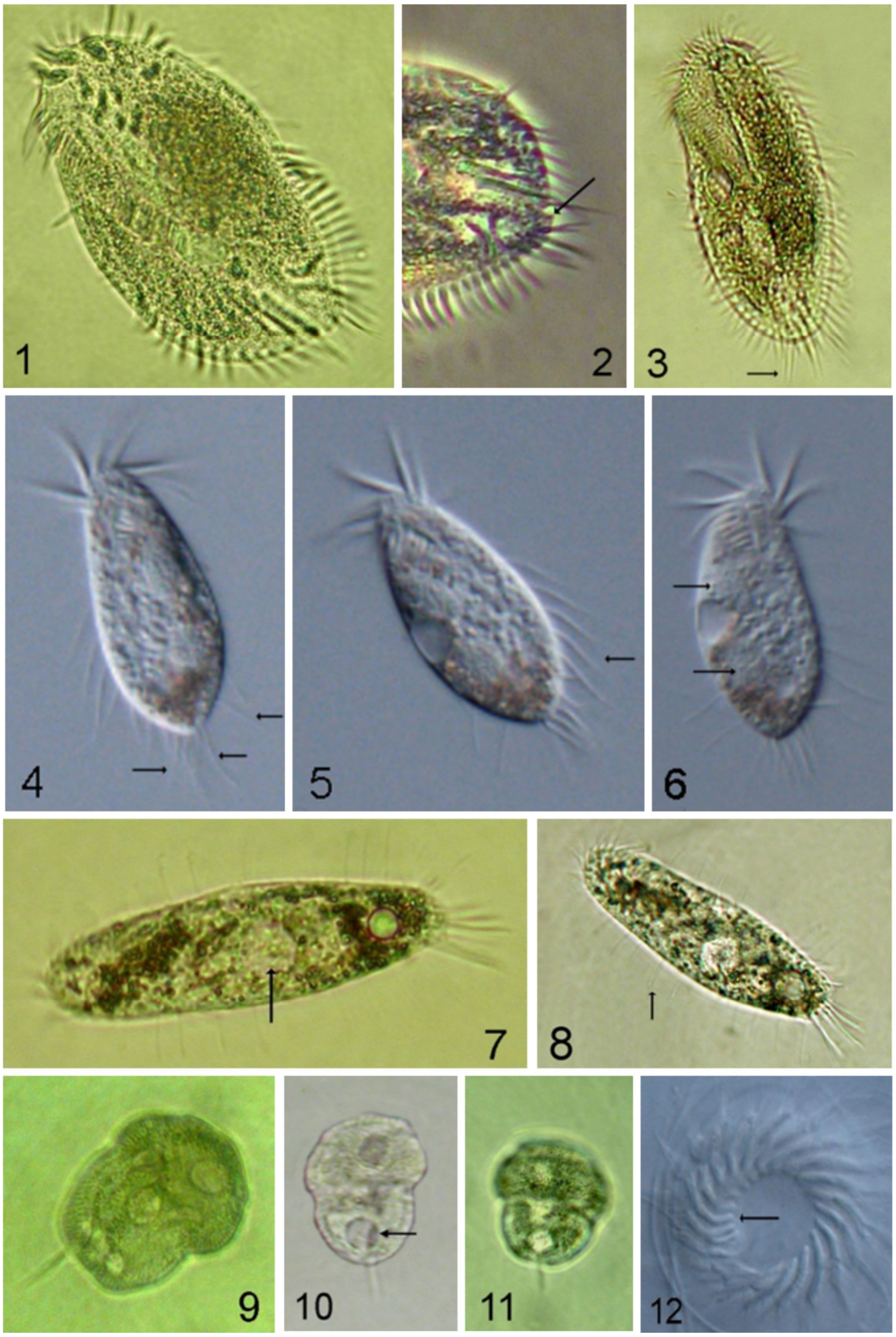

Figure 2.2: **Ciliates** (Ciliophora). **1**, Histriculus vorax, with large adoral zone of membranelles and two macronuclear nodules, body length 210 µm; **2**, Histriculus vorax, posterior body end is broadly rounded and notched (arrow); **3**, Sterkiella histriomuscorum, with short inconspicuous caudal cirri (arrow) and contractile vacuole located in the mid-body, body length 105 µm; **4**, **5**, **6**, Oxytricha setigera, with inconspicuous caudal cirri (**4**, arrows), dorsal cilia (**5**, arrow) and contractile vacuole located in mid-body between two macronuclear nodules (**6**, arrows), body length 38 µm; **7**, **8**, Tachysoma pellionellum, with contractile vacuole located in mid-body (**7**, arrow) and stiff dorsal cilia (**8**, arrow), body length 65 µm; **9**, **10**, **11**, Urocentrum turbo, dumbbell-shaped ciliate, with a tuft of caudal cilia and a single contractile vacuole located posteriorly (**10**, arrow), body length 55 µm; **12**, Strobilidium caudatum, top view of adoral zone, with prominent external and internal (arrow) adoral membranelles, live, differential interference contrast (DIC); photos E. Mironova (from Telesh et al., 2009).

Figure 2.3: **Copepoda**. **1,** *Pseudocalanus elongatus*, female, abdomen, lateral view, vertical arrow shows genital segment, horizontal arrow shows spermatophores; **2**, *P. elongatus*, P5 of male, lateral view; **3**, *P. elongatus*, copepodite C4, lateral view, length 716.9 ± 24.4 µm (Postel et al., 2007), red inclusions – lipids stocked for diapausing; **4**, *P. elongatus*, nauplius ventrally, length 306.9 ± 14.0 µm (Postel et al., 2007); **5**, *P. elongatus*, nauplii at different stages in the sample (**1, 2, 4, 5**, photos H. Sandberg; **3**, photo courtesy of P. Snoeijs-Leijonmalm).

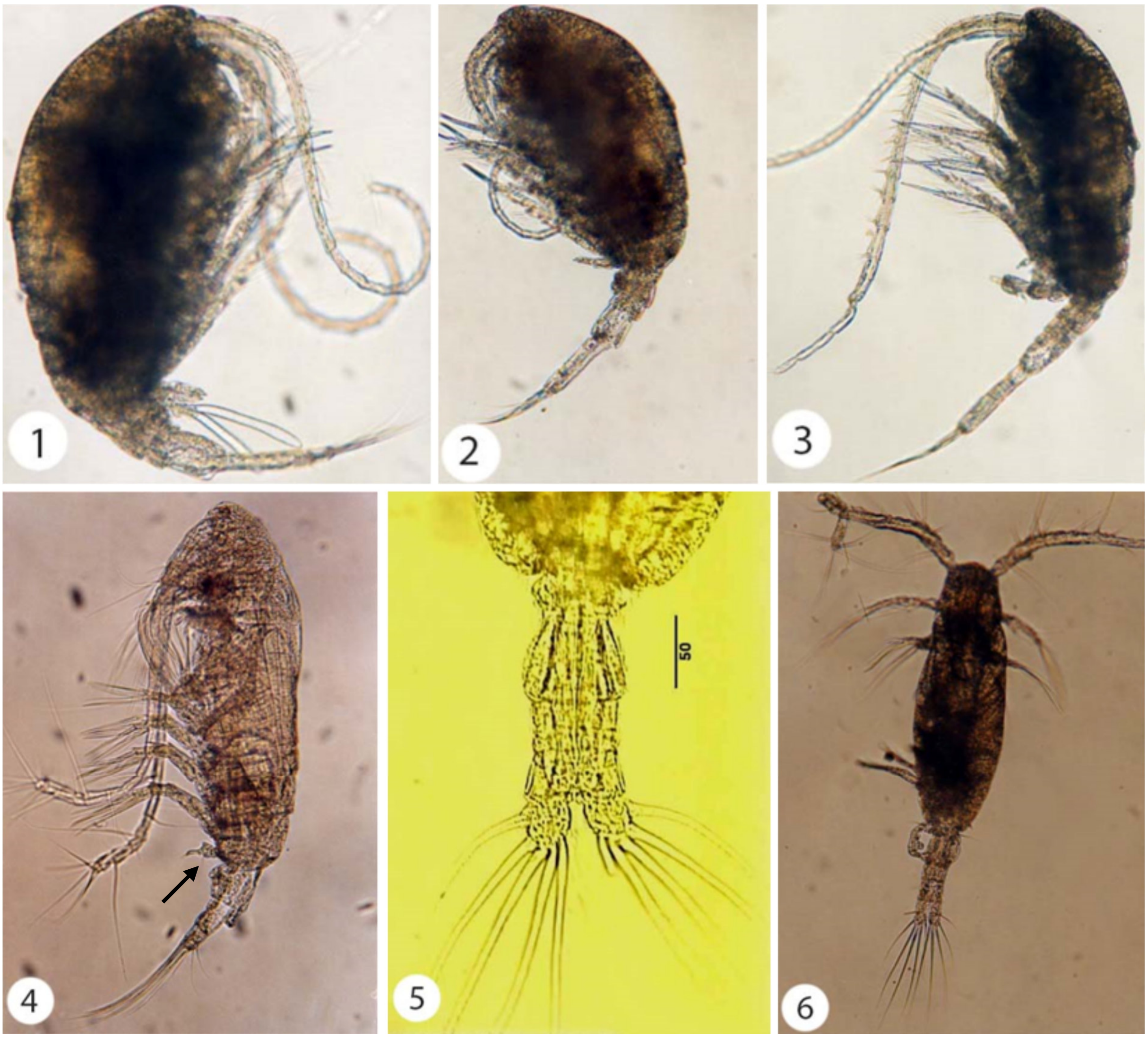

Figure 2.4. Copepoda. **1, 2,** *Temora longicornis*, female, lateral view, prosome length 709.3 ± 6.7 µm (Postel et al., 2007); **3**, *T. longicornis*, male, lateral view, prosome length 690.8 ± 6.0 µm (Postel et al., 2007) (photo courtesy of P. Snoeijs-Leijonmalm); **4**, *Acartia tonsa*, female laterally, prosome length ca. 620 µm, arrow shows P5 (photo H. Sandberg); **5**, *A. tonsa*, male urosome (after Telesh & Heerkloss, 2004); **6**, *Acartia longiremis,* male, ventral view, prosome length ca. 600 µm (photo H. Sandberg).

About forty mesozooplankton species are regularly occurring in the Baltic Sea in significantly high abundances. Ten to twelve of them are dominating taxa. Their spatial occurrence is explained mainly by the salinity patterns. According to hydrographic regime with prevailing outflow of low saline water in the upper layer and temporary inflows of higher saline water below the halocline, species with relevant salinity preferences inhabit the western and the eastern parts and the open Baltic Sea, respectively.

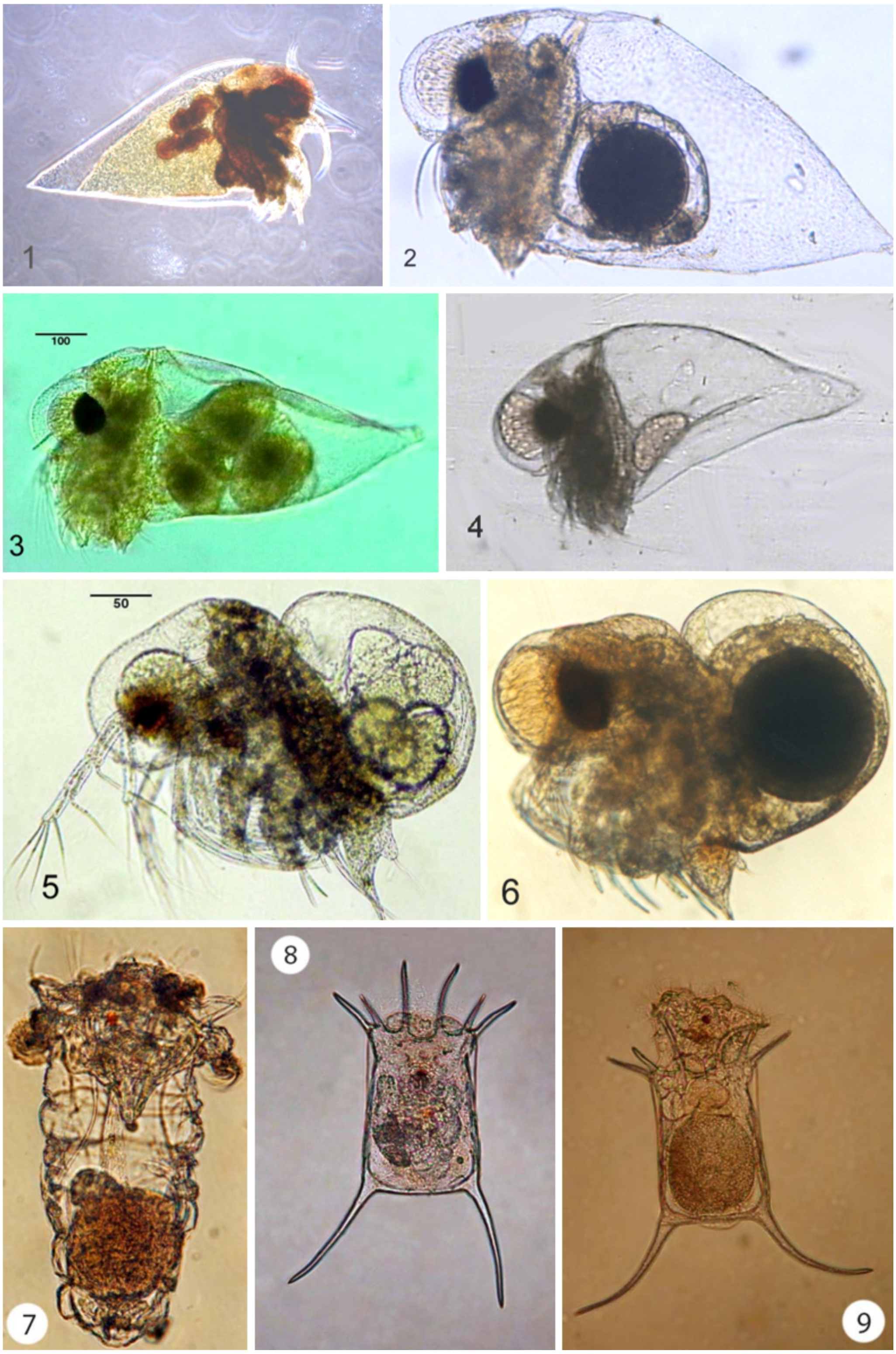

Figure 2.5: **Cladocera**. **1**, *Evadne nordmanni*, young female, lateral view (photo courtesy of P. Snoeijs-Leijonmalm); **2**, *E. nordmanni*, female with resting egg, lateral view, body length ca. 700 µm (photo H. Sandberg); **3**, *E. nordmanni*, female with embryos, lateral view; **4**, *E. nordmanni*, male, body length ca. 500 µm, lateral view (photo H. Sandberg); **5**, *Podon leuckartii*, female with eggs, lateral view; **6**, *Podon leuckartii*, female with resting egg, lateral view (**3, 5, 6** after Telesh & Heerkloss, 2004). **Rotifera**: **7**, *Synchaeta* sp., live female, semi-contracted, body length up to 6oo µm (photo H. Sandberg); **8, 9**, *Keratella quadrata platei*, female, dorsal view, body length up to 350 µm (photo courtesy of P. Snoeijs-Leijonmalm).

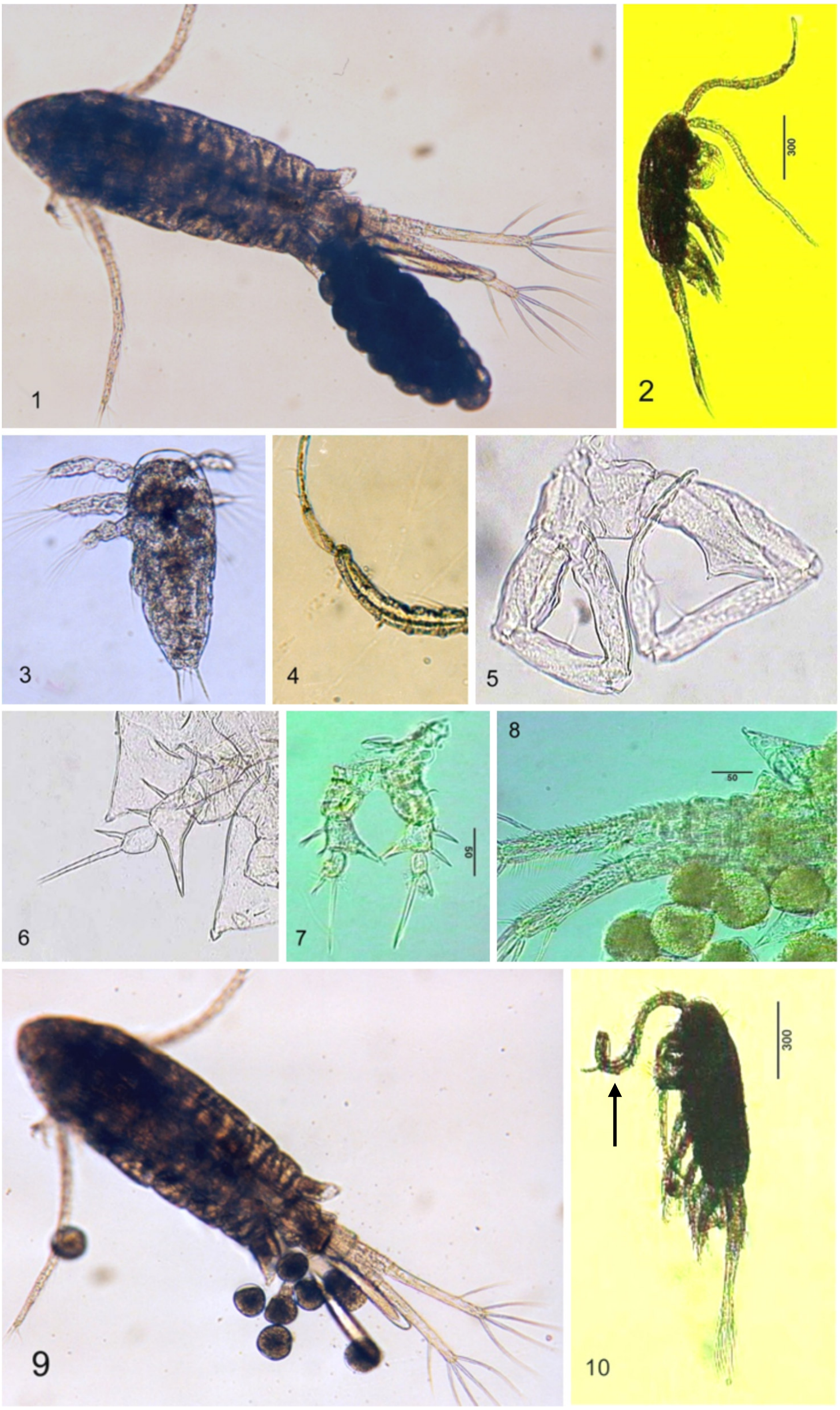

Figure 2.6: **Copepoda**. **1**, *Eurytemora affinis*, female with egg sack, ventral view, prosome length ca. 650 µm; **2**, *E. affinis*, male, lateral view; **3**, *E. affinis*, nauplius N6 ventrally, body length 260 µm; **4**, *E. affinis*, male, articulation of the antenna; **5**, *E. affinis*, P5 of male; **6**, **7**, *E. affinis*, P5 of female; **8**, *E. affinis*, posterior end of female, with eggs; **9**, *E. affinis*, female with few loose eggs; **10**, *E. affinis*, male, lateral view, arrow shows the articulated antenna (after Telesh & Heerkloss, 2004; **1, 3, 4, 9**, photos H. Sandberg).

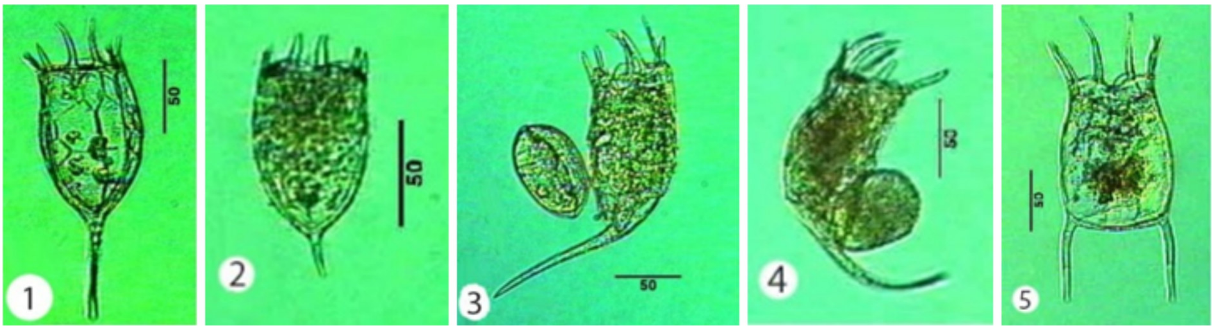

Figure 2.7: **Rotifera**. **1**, *Keratella cochlearis typica*, female, lorica with long spine, dorsal view; **2**, *K. cochlearis typica*, female, lorica with short spine, dorsal view; **3, 4**, *Keratella cochlearis baltica,* female, lateral view, with egg; **5**, *K. quadrata*, live female, dorsal view (after Telesh & Heerkloss, 2002).

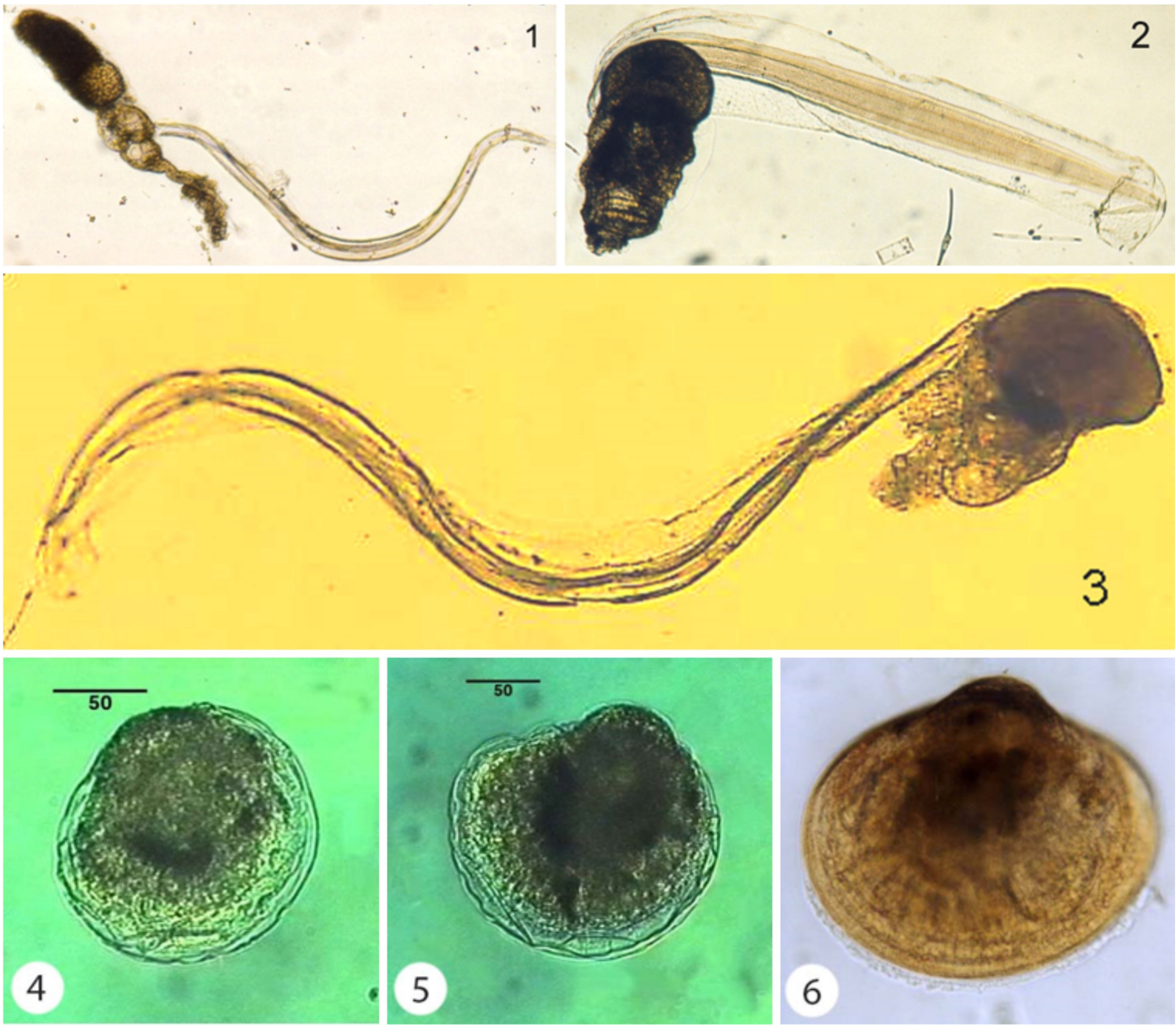

Figure 2.8: **Copelata**. **1,** *Fritillaria borealis*, body length 758.5 ± 59.1 µm (Postel et al., 2007); **2**, **3**, *Oikopleura dioica*, adult with fertile gonad, total length ca. 1200 µm, body length ca. 700 µm (photos H. Sandberg). **Larvae of bivalve molluscs: 4–6**, different larval stages of Bivalvia (**4, 5**, larvae of *Dreissena polymorpha*, after Telesh & Heerkloss, 2004).

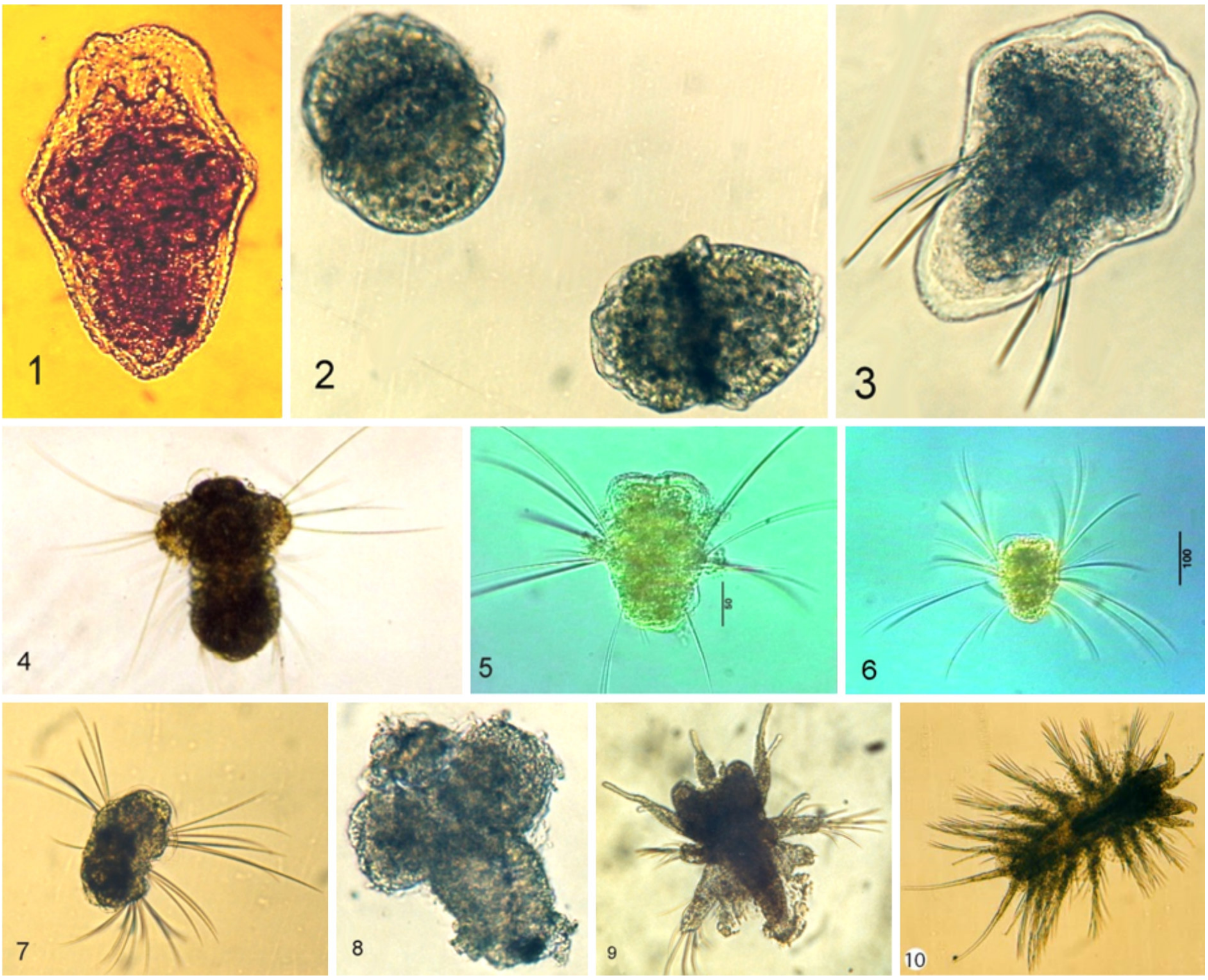

Figure 2.9: **Polychaeta, larvae** at different stages of development. **1**, **2**, Trochophore, length ca. 200 µm; **3–7**, nectochaete of different species (**5**, **6**, *Marenzelleria viridis*, after Telesh & Heerkloss, 2004); **8, 9**, larvae of unidentified polychaete species; **10,** *Harmothoe* sp., young specimen, length ca. 800 µm (photos H. Sandberg).

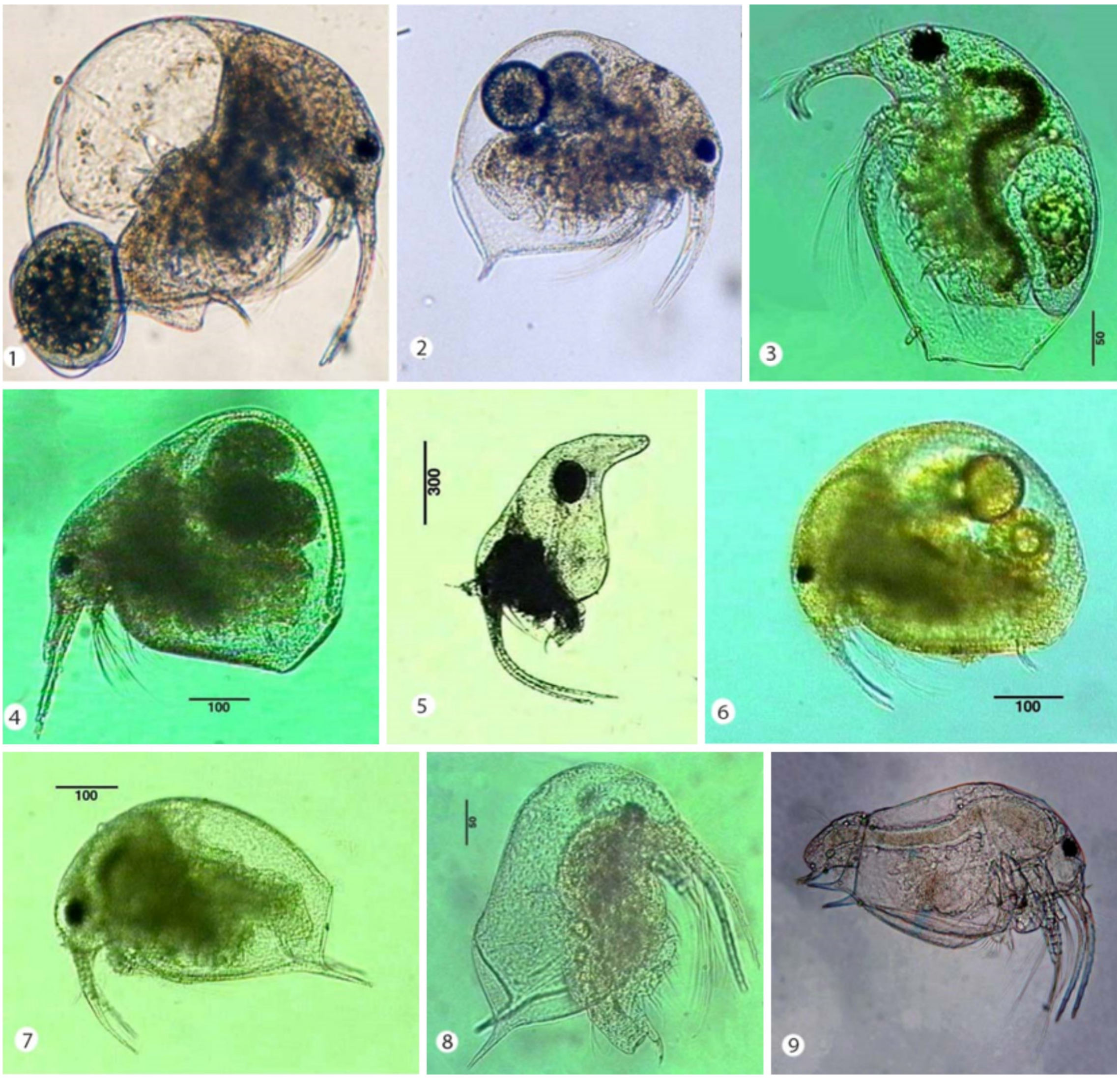

Figure 2.10: Cladocera. **1**, *Eubosmina maritima*, female with an embryo, lateral view, body length 250−620 µm; **2**, *E. maritima*, female with eggs, lateral view (**1, 2** photo courtesy of H. Sandberg); **3**, *Bosmina longirostris curvirostris*, female with an embryo in the brood chamber, lateral view; **4**, *Eubosmina coregoni gibbera*, female with embryos, lateral view; **5**, *Eubosmina coregoni thersites*, female with resting egg, lateral view; **6**, *Bosmina crassicornis*, female with eggs, lateral view; **7**, *Eubosmina longispina*, young female, lateral view; **8**, *E. longispina*, juvenile, lateral view; **9**, *E. longispina*, male, lateral view, body length 400−600 µm, photo courtesy of P. Snoeijs-Leijonmalm (**3−8** after Telesh & Heerkloss, 2004).

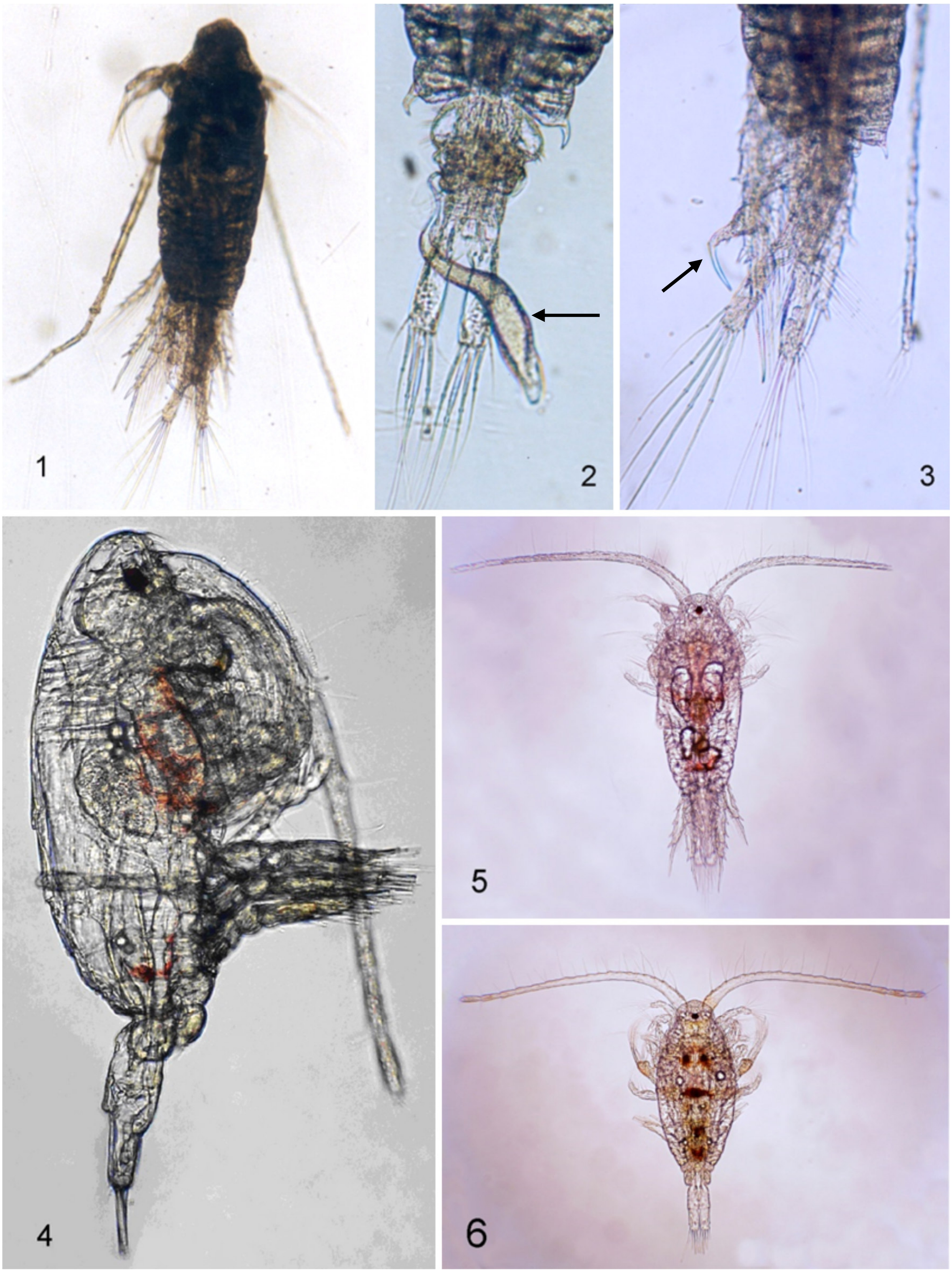

Figure 2.11: Copepoda. **1**, *Centropages hamatus*, male, dorsal view, total length ca. 1400 µm, cephalothorax length 802.8 ± 8.6 µm (Postel et al., 2007); **2**, *C. hamatus*, abdomen of female, with spermatophore (arrow); **3**, *C. hamatus*, abdomen of male, P5 seen at left side (arrow); **4**, *C. hamatus*, copepodite C4, lateral view, length of prosome 655.8 ± 12.1 µm (Postel et al., 2007); **5**, **6**, *C. hamatus*, copepodite C2, ventral view, length of prosome 478.4 ± 16.4 µm (Postel et al., 2007) (**1–3**, photos H. Sandberg; **4–6**, photo courtesy of P. Snoeijs-Leijonmalm).

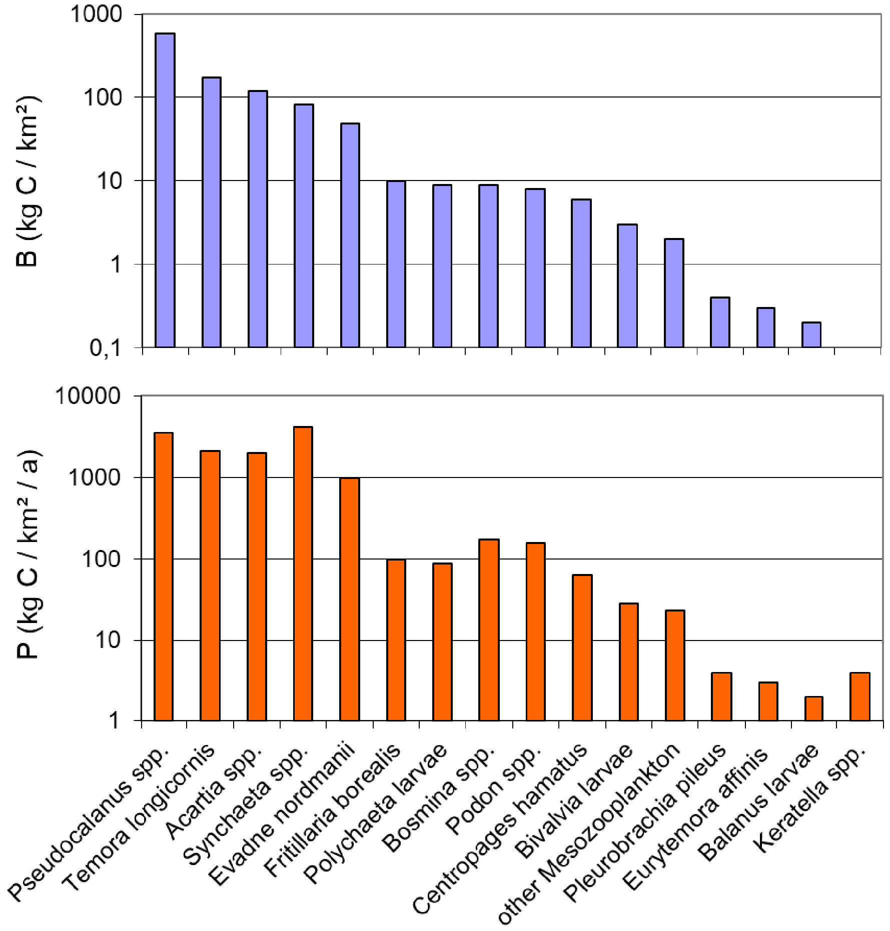

Figure 2.12: Contribution of various taxa to zooplankton biomass (B, above) and annual production (P, below) in Gdańsk Bay during the 1980s (after Witek, 1995).

Additionally, there is a remarkable shift in the dominating taxonomic groups throughout the Baltic Sea. Thus, *Paracalanus parvus*, *Pseudocalanus* spp. (Figure 2.13) and *Oithona similis* (Figure 2.14) dominantly occur in the entire water column of the western Kattegat, while *Calanus finmarchicus* and *Centropages typicus* occasionally appear there. Predominant cladocerans are the carnivorous *Evadne nordmanni*, *Podon* spp. (Figure 2.5) and *Pleopsis polyphemoides* in this area. The brackishwater filter feeding cladocerans from the genera *Eubosmina* and *Bosmina* (Figure 2.10) are dominant in the Baltic proper during summer.

Partly in the eastern Kattegat and especially in the Sound, the zooplankton species composition demonstrates similarities to that in the near-surface waters of the Arkona Sea, for example, by the occurrence of *Acartia* species, which is a result of the Baltic Sea water outflow. Copepods *Acartia bifilosa* that tolerate a salinity of 0.30 psu (Sewell, 1948), and *Eurytemora affinis* (Figure 2.6), which survives at 0.50 psu (Busch & Brenning, 1992), are the key species in the Gulf of Finland and the Bothnian Sea. Behrends et al. (1990) described a two-layer distribution of zooplankton in the Bay of Bothnia. While the glacial relict copepods *Limnocalanus macrurus* (Figure 2.15) inhabit the cooler and low-saline deep waters, *Daphnia* (Figure 2.16) species appear in the surface layers, in nearly freshwater conditions. *Centropages hamatus* (Figure 2.11) is a subdominant; it occurs at maximum population densities from Kattegat to the Arkona Sea. The Baltic proper is the area where *Acartia* species, *Temora longicornis* and *Bosmina* spp. (in summer) are dominating.

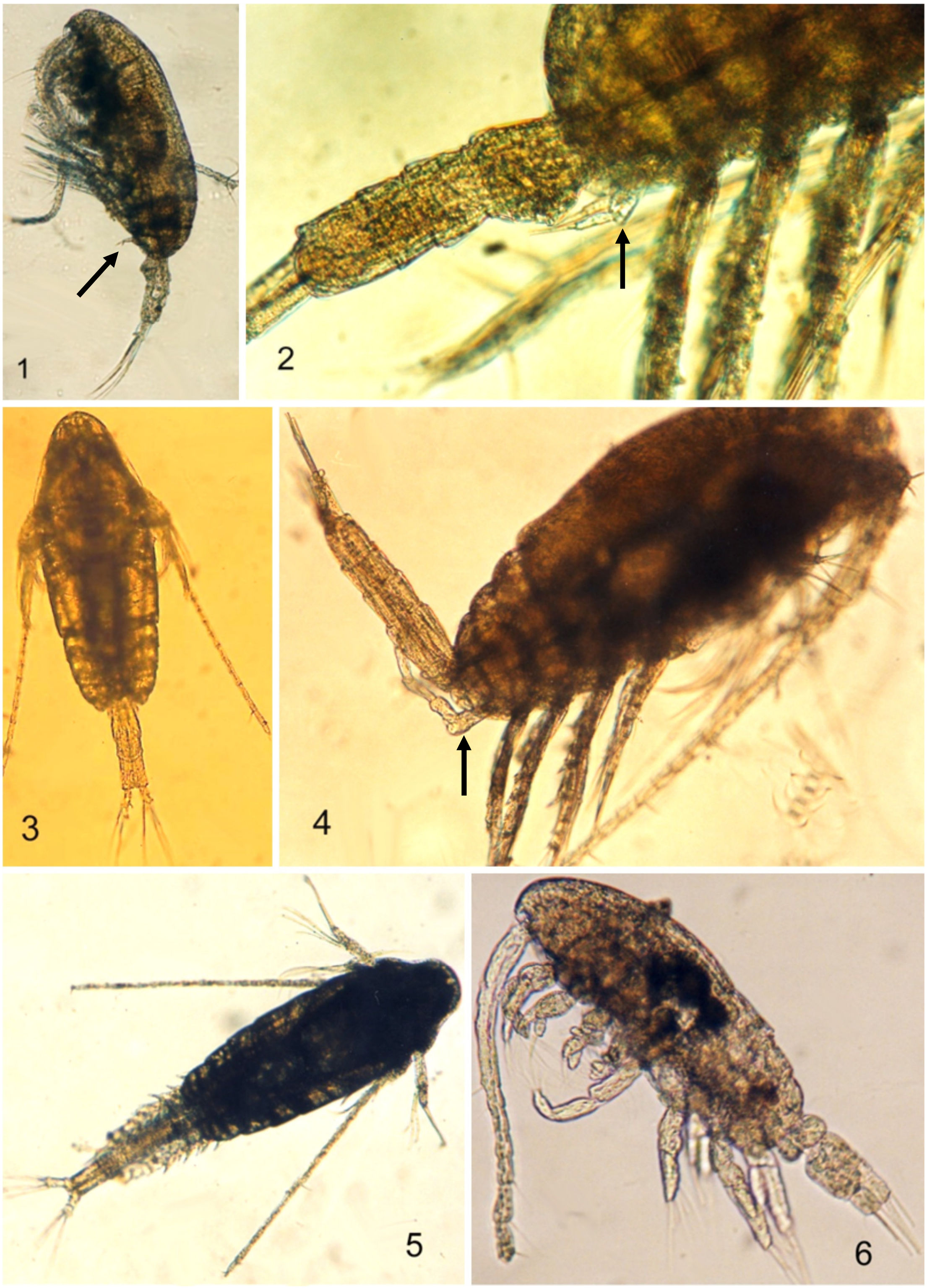

Figure 2.13: Copepoda. 1, 2, *Paracalanus parvus*, female, lateral, body length ca. 1000 µm, arrow shows P5; **3**, *P. parvus*, male, ventral view, prosome length 789.8 ± 10.4 µm (Postel et al., 2007); **4**, *P. parvus*, male, lateral view, arrow shows P5; **5**, *Pseudocalanus elongatus*, female, dorsal view, prosome length 887.0 ± 9.5 µm (Postel et al., 2007); **6**, *P. elongatus*, copepodite C3, lateral view, prosome length 573.5 ± 41.9 µm (Postel et al., 2007) (photos H. Sandberg).

The seasonality is a pronounced reason for structural variability in plankton communities of temperate regions like the Baltic Sea. It is exposed in the reproduction cycles that are linked with the species' demands for food availability and for certain temperature. Rotifers typically dominate in May (*Synchaeta* spp.) and in August (*Keratella* spp.) when their parthenogenetic reproduction mode allows for utilizing optimal food conditions within a short period of time. Cladocerans proceed in the same way. *Bosmina* spp. peak using a small temporal “window” in summer, when temperature rises above 15 °C (Ackefors, 1969).

There are two species of appendicularians in the Baltic Sea, *Oikopleura dioica* and *Fritillaria borealis* (Figure 2.8). The first one prefers the higher salinity in the western Baltic Sea. Its reproduction maximum is in autumn while *F. borealis* inhabit all regions of the Baltic proper, mainly in spring. Bivalvia larvae (Figure 2.8) also peak in a bimodal way, probably depending on different reproduction periods of various species, which is likely, because two of four co-occurring species are more abundant (Ackefors, 1969) and have their reproduction time span from May to August (*Macoma balthica*) or from August to October (*Mytilus edulis*) (Hernroth & Ackefors, 1979).

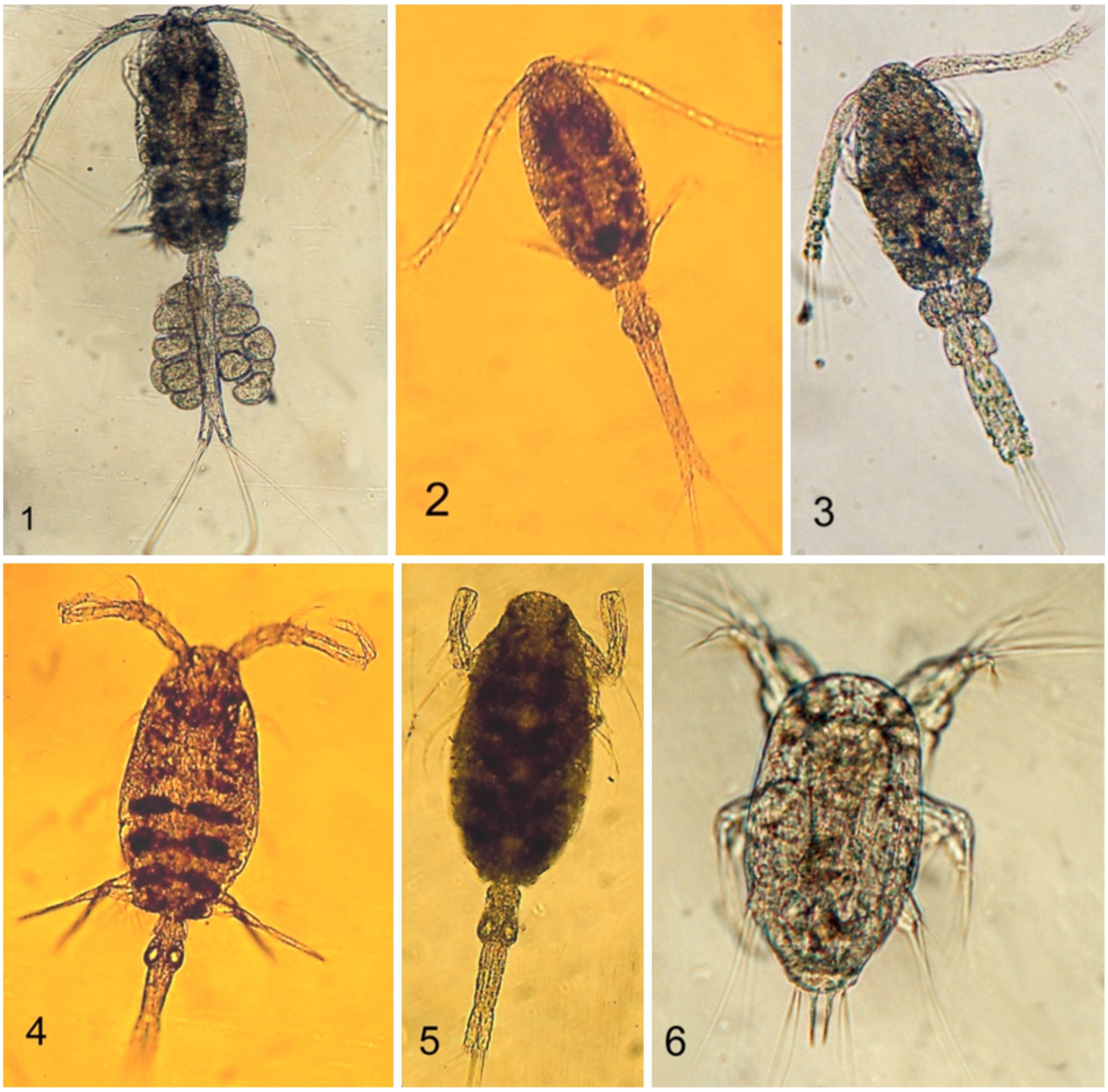

Figure 2.14: Copepoda. 1, 2, *Oithona similis*, female ventrally, total length ca. 800 mm, CPHT length 432.3 ± 10.0 µm (Postel et al., 2007); **3**, *O. similis*, young copepodite, CPHT length 293.8 ± 26.6 µm (Postel et al., 2007); **4**, *O. similis*, male ventrally, total length ca. 600 µm; **5**, *O. similis*, male dorsally; **6**, *O. similis*, nauplius dorsally, length 235.4 ± 1.4 µm (Postel et al., 2007) (photos H. Sandberg).

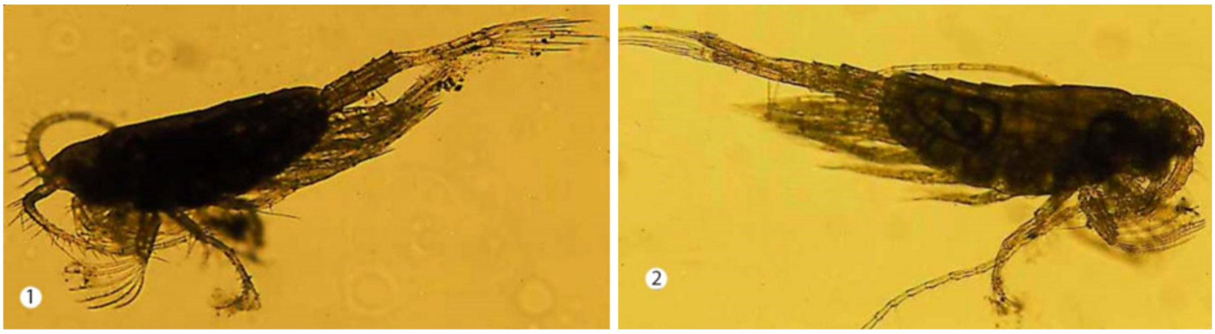

Figure 2.15: Copepoda. 1, *Limnocalanus macrurus*, male, dorso-lateral view, prosome length 1.7–1.8 mm (Hernroth, 1985); **2**, *L. macrurus*, female, lateral view, total length 2.4–2.9 mm, prosome length 1.7–1.9 mm (Czaika, 1982; Balcer et al., 1984; Hernroth, 1985) (photos H. Sandberg).

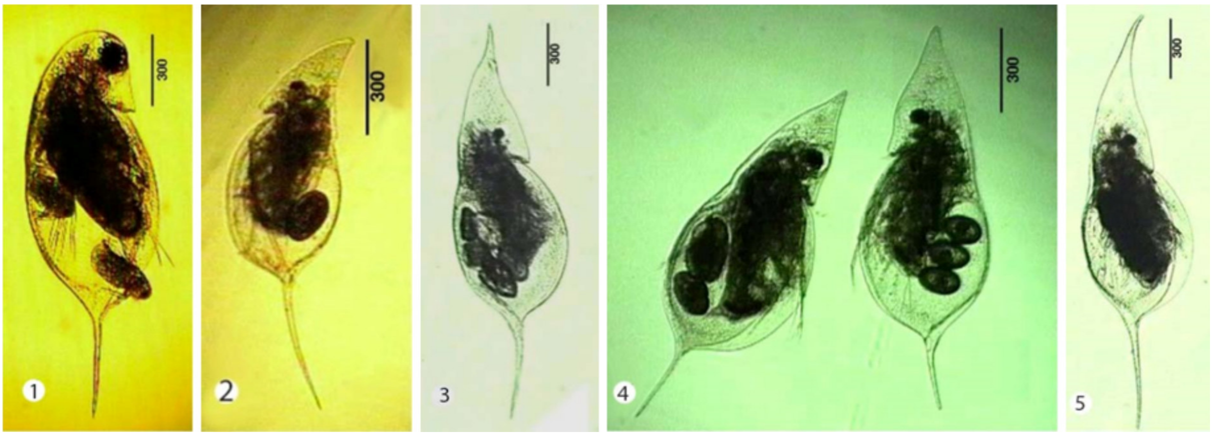

Figure 2.16: Cladocera. 1, *Daphnia longispina*, female with embryos, lateral view; **2**, *Daphnia cristata,* female with egg, lateral view; **3**, **4**, *Daphnia cucullata*, females with eggs, lateral view, difference in helmet morphology is due to cyclomorphosis; **5**, *Daphnia cucullata procurva*, female, lateral view (after Telesh & Heerkloss, 2004).

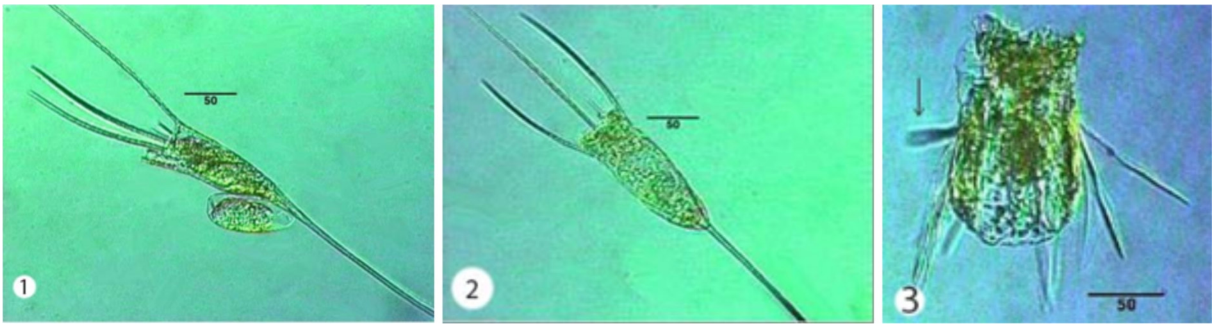

Figure 2.17: Rotifera: **1**, *Kellicottia longispina*, female, lateral view, with egg; **2**, *K. longispina*, female, ventral view; **3**, *Polyarthra vulgaris*, female, lateral view, arrow shows ventral finlet (after Telesh & Heerkloss, 2002).

The amount of co-occurring *Cardium* species and *Mya arenaria* is normally negligible (Ackefors, 1969). Polychaeta larvae are more abundant during the phytoplankton spring bloom than in the remaining time of the year. Finally, the seasonal patterns of the adult calanoid copepods density demonstrate one peak in March and another period of higher abundances during several months in summer and autumn.

Taking the key species with maximal abundance of several thousand individuals per cubic meter separately, the seasonal pattern of calanoids is more differentiated and explains the annual course of the total zooplankton abundance. *Pseudocalanus* spp. (Figure 2.13) become mature in March, April and May; they are followed by *Acartia bifilosa* in May, July and August, *Eurytemora affinis* (Figure 2.6) in July and August, *Temora longicornis* (Figure 2.4) in July and August, and finally, by *Acartia longiremis* (Figure 2.4) – mainly in August. Copepods *Pseudocalanus* spp. are probably responsible for the total zooplankton peak in May, while the majority of calanoids become adult in summer. This could be explained by different temperatures in the habitats. Meridional shifts in seasonality are possible.

Decadal and multi-decadal variability in the atmospheric and consequently in the hydrographic regime also causes changes in mesozooplankton abundances and sometimes in species composition. Salinity and temperature changes are the main driving forces here. For example, the longer period of missing salt-water inflows and rising river runoff in the Northern Baltic proper and the Gulf of Finland in the late 1980s corresponded to the appearance of eight *Keratella* species and other rotifers, e.g. *Polyarthra* spp. and *Kellicotia longispina* (Figure 2.17), as well as the cladocerans *Bythotrepes longimanus* (Postel et al., 1996). Consequently, the number of taxonomic groups increased. At the same time, the key species changed in the Central Baltic proper. The former dominant halophilic representatives of the cold-water genus *Pseudocalanus* were substituted by the *Acartia* species. In the northern parts of the Baltic proper, the former dominance of *Acartia* spp. was replaced by the brackish water species *Eurytemora affinis*. These results based on the HELCOM data set for the entire Baltic Sea were in accordance with the reports on the regional shifts published by Vuorinen and Ranta (1987), Viitasalo et al. (1990), Lumberg and Ojaveer (1991), Flinkman et al. (1998), Ojaveer et al. (1998), Vuorinen et al. (1998), Dippner et al. (2000, 2001) and Möllmann et al. (2000, 2003).

2.2 Dominant species and mesozooplankton community composition

The most abundant mesozooplankton species that dominate in the Baltic proper in terms of biomass belong to the calanoid copepods (*Acartia*, *Temora*, *Pseudocalanus*, *Centropages*, *Eurytemora*). Marine copepods found in the Baltic Sea are small-sized, compared to those occurring in the fully marine environments, and they are able to adapt to mesohaline or oligohaline conditions. Thus, truly marine species such as representatives of the genus *Calanus* do only occur sporadically in the most western part of the Baltic Sea, as a consequence of saltwater intrusions from the North Sea. The occurrence and reproduction success of the marine copepods *Pseudocalanus* sp. depend strongly on high salinity and oxygen content in the water system. This species is the most important and energy-rich food source for zooplanktivorous fish such as herring (Flinkmann et al., 1998; Möllmann et al., 2003). Holmborn et al. (2010) confirmed by the genetic analyses that *Pseudocalanus acuspes* is the only species of this genus with a resident population in the Baltic Sea. Copepods from the other above mentioned genera are less sensitive to salinity changes and brackish water conditions. Especially *Acartia* spp. and *Eurytemora affinis* are the coastal and estuarine marine species with high capacity of adaptation to oligohaline or even freshwater environments. A truly freshwater copepod, distributed in low-salinity habitats such as the Gulf of Finland, the Åland Sea and the Bothnian Bay, is *Limnocalanus macrurus* (HELCOM, 2009).

The circumglobally distributed marine cyclopoid copepod *Oithona similis* has been described as a eurythermal, euryhaline, omnivorous species since it can be adapted to a wide range of habitats (Fransz et al., 1991). In the Baltic Sea, the distribution range of this small-sized species is mainly restricted by salinity conditions.

The cosmopolitan marine tunicates *Fritillaria borealis* and *Oikopleura dioica* are common members of the zooplankton communities in temperate climate zones, although the distribution range of the former extends to the Polar Regions whereas the latter is rather adapted to warm and even subtropical habitats (Fenaux et al., 1998; Schulz & Hirche, 2007). Both species are euryhaline and able to conform to salinities as low as 6 psu (*Fritillaria*) and >11 psu (*Oikolpeura*) (Ackefors, 1969).

Most Cladocera are of freshwater origin, such as the family Bosminidae, which is represented by a variety of species in the Baltic Sea, some of which can hardly be distinguished morphologically. In the central Baltic Sea, *Bosmina (Eubosmina) coregoni maritima* is registered very often (e.g. Ackefors, 1971; Möllmann et al., 2005; Schulz et al., 2012), although other authors determine this species as *Bosmina longispina maritima* (e.g. Kankaala, 1983; Rudstam et al., 1992; Telesh & Heerkloss, 2004). In coastal waters, other Bosminidae are also known: *Bosmina longirostris*, *Eubosmina coregoni*, *Bosmina coregoni typica* (Wiktor, 1964; Arndt, 1989; Telesh & Heerkloss, 2004; Semenova, 2011). The cladocerans *Evadne nordmanni*, *Podon intermedius*, *Podon leuckarti*, *Pleopsis polyphemoides* and *Penilia avirostris*, belonging to the family Podonidae, are the marine taxa occurring regularly in the coastal waters of the Baltic Sea (e.g. Hällfors et al., 1981; Viitasalo et al., 1995; Durbin et al., 2008). The Ponto-Caspian invader *Cercopagis pengoi* is a brackish-water species, which invaded the Baltic Sea during the late 1980s–early 1990s (Ojaveer & Lumberg, 1995; Panov et al., 1996). Since the mid-1990s, it established permanent populations in the Gulf of Finland and the Gulf of Riga (Avinski, 1997; Krylov et al., 1999; Uitto et al., 1999) and is still further expanding its distribution range southwards (Bielka et al., 2000; Litvinchuk & Telesh, 2006). For more information about the invasive species in plankton of the Baltic Sea, see Section 2.7 below.

Rotifers are especially diverse and abundant in the Baltic coastal ecosystems (Telesh & Heerkloss, 2002; Telesh, 2004). Rotifers decrease in diversity and in numbers with increasing water salinity, due to the freshwater origin of this group. The most species-rich rotifer families in the Baltic Sea are Synchaetidae (*Synchaeta* spp., *Polyarthra* spp.) and Brachionidae (*Brachionus* spp., *Keratella* spp.). These rotifers contribute significantly to the total zooplankton biomass and production, also in the open Baltic waters (Ojaveer et al., 2010). It is very difficult to discriminate between the species of *Synchaeta* in the preserved samples; therefore, they are often lumped together as *Synchaeta* spp. Common species in coastal and offshore waters of the Baltic Sea are *Synchaeta baltica* and *Synchaeta monopus* (Johansson, 1992; Viitasalo et al., 1995; Telesh & Heerkloss, 2002; Telesh et al., 2009). The second most abundant rotifer genus in the coastal waters of the Baltic Sea is *Keratella*, occurring with several species. Identification of these species is based on the characteristics of the lorica. The most common species of this genus are *Keratella quadrata*, *Keratella cochlearis* and *Keratella cruciformis* (Johansson, 1992; Viitasalo et al., 1995; Telesh & Heerkloss, 2002; Telesh et al., 2009). Relative abundance of different forms from the *Keratella cochlearis*-group can be converted into eutrophication index (the *Keratella*-index, KIN), which is a convenient tool for evaluation of the trophic state in coastal waters of the Baltic Sea (Gopko & Telesh, 2013).

2.3 Why zooplankton composition varies spatially?

The variable salinity conditions in the Baltic Sea, with horizontal and vertical gradients as well as intensive mixing processes, affect the physiological functions of zooplankton organisms by causing osmotic stress. Depending on their origin, species live in a hypo- or hyper-osmotic milieu. These organisms are either osmoregulators, maintaining a certain internal ion concentration, or they are osmoconformers and adapt their intracellular osmolarity to the surrounding medium. The regulation of the osmolarity of euryhaline marine organisms is often facilitated by low water temperatures. In any case, acclimatization to variable salinities is energy consuming and thus shapes the distribution ranges of zooplankton species differently, depending on their specific physiological performance.

2.4 Horizontal distribution patterns

The salinity gradient from the south-western (mesohaline) to the north-eastern Baltic Sea (oligohaline) is an important factor regulating the horizontal distribution range of zooplankton species and the biodiversity of the zooplankton community (Figure 2.18).

Figure 2.18: The mesozooplankton community composition in the western Baltic Sea above the halocline changes from west to east. MDS-plot of zooplankton community of four geographical areas in July 2009; blue squares: Great Belt; green triangles: Fehmarnbelt; red rhomb: Mecklenburg Bight; grey triangle: Darss Sill (from FEMA-FEHY, 2013).

In the most south-western part of the Baltic Sea, the Belt Sea, the zooplankton community composition is strongly influenced by the saline water inflow from the North Sea and outflow of low saline water in the surface layer. Key species of saltwater inflows are, for instance, the marine copepods *Calanus helgolandicus* and *Calanus* *finmarchicus,* as well as the marine cladocerans *Penilia avirostris,* which can reach the Kiel Bight and the Mecklenburg Bight by the advection of organisms with water masses from the North Sea but do not establish reproducing populations there because of the mesohaline conditions in the Belt Sea (Postel, 1995). In the western Baltic Sea, the prevalent marine calanoid copepod is *Pseudocalanus acuspes*. The abundance of this species shows a strongly decreasing trend east of the Darss Sill, which is known as a faunistic distribution limit for the marine species in the Baltic Sea (Flinkmann et al., 2007).

Marine taxa, such as Tunicata (mainly *Oikopleura dioica*) and the cyclopoid copepod *Oithona similis*, are quite abundant in the Belt Sea where they frequently account for up to a half of the total biomass in summer and autumn, but occur only rarely east of the Darss Sill (Figure 2.19). In contrast, the brackish-water Cladocera from the family Bosminidae increase in their abundance from the west to the east and account for up to a half of the total zooplankton biomass in summer at Darss Sill (Figure 2.19).

East of the Darss Sill, brackish-water species dominate the mesozooplankton community. Rotifera such as *Synchaeta* spp. and *Keratella* spp. as well as Copepoda such as *Acartia bifilosa*, *Acartia longiremis*, *Eurytemora affinis* and Cladocera of the family Bosminidae occur in high abundances in the surface water layer of the central Baltic Sea and further north-east (Viitasalo, 1992; Postel, 1995). In estuaries and in the most north-eastern coastal areas, the Bothnian Bay and the Gulf of Finland, the freshwater copepod *Limnocalanus macrurus* as well as freshwater species of the genera *Cyclops* and *Daphnia* are regular members of the zooplankton community (Hällfors et al., 1981; Telesh & Heerkloss, 2004).

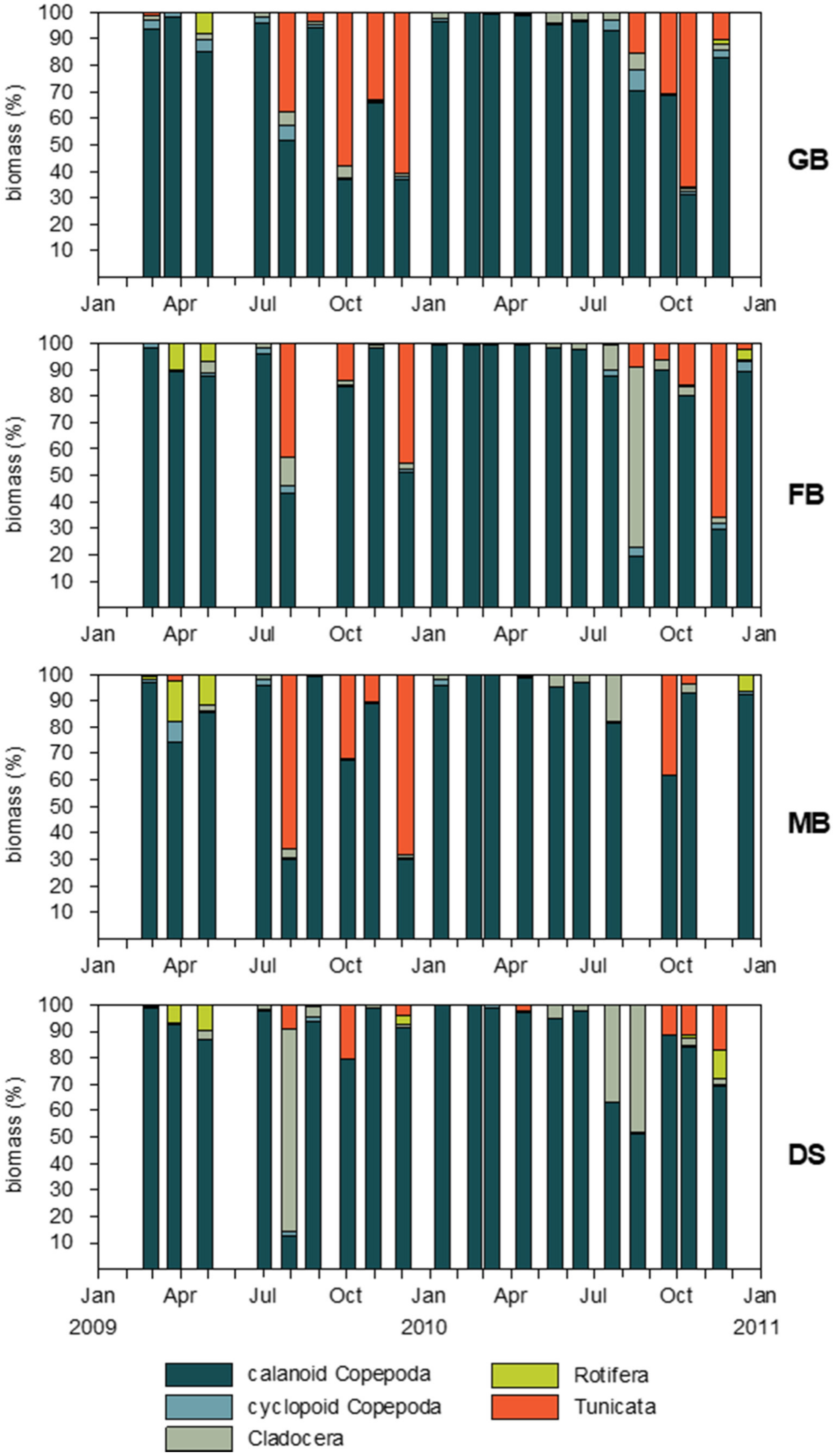

Figure 2.19: Proportion of biomass (%) of zooplankton taxonomic groups in the south-western Baltic Sea in 2009 and 2010; arranged from west (top) to east (bottom). GB: Great Belt; FB: Fehmarnbelt; MB: Mecklenburg Bight; DS: Darss Sill (from FEMA-FEHY, 2013).

2.5 Vertical distribution patterns

The vertical distribution of mesozooplankton species in the Baltic Sea is greatly affected by the abiotic factors: salinity, temperature, oxygen and light. Varying conditions regarding food and the occurrence of predators at different depths are of high importance as well.

One of the most influential factors regulating the vertical distribution patterns of the zooplankton community is the vertical salinity stratification and presence of the halocline (Figure 1.3). The mesozooplankton community shows significant differences between the water layers above and below the halocline, especially during the stagnation periods (in summer and early autumn). In stratified brackish-water systems, marine species can extend their distribution ranges by inhabiting saline deep water layers below the halocline as long as oxygen concentration is sufficient ("brackish water submergence"; Remane, 1940). In the central Baltic Sea, the suitable habitat for marine species is thus limited from above by low salinity and from below – by low oxygen concentration. This phenomenon is confirmed by the spatial distribution patterns of several marine zooplankton species in the Baltic Sea such as the copepods *Pseudocalanus acuspes* and *Oithona similis* that do occur in the water layer between the halocline at salinities >11 psu and the hypoxic zone (<1 ml l^{-1}) as far east as the Bornholm and Gotland Basins (Postel, 1995; Hansen et al., 2004; Renz & Hirche, 2006; Schulz et al., 2007; Schulz & Hirche, 2007; Figure 2.20).

Copepods with a high physiological tolerance of salinity fluctuations, such as *Temora longicornis* and *Centropages hamatus*, show generally a broad vertical distribution range within the whole water column (Hällfors et al., 1981). *Acartia bifilosa* and *Acartia longiremis* are brackish-water species and, therefore, they are well adapted to low salinities. They can inhabit the upper part of the water column, where growth conditions due to food availability are assumed to be better, if compared to the deeper regions (Fransz et al., 1991; Hansen et al., 2006).

Besides the impact of salinity on vertical distribution patterns of zooplankton, the thermal stratification shapes the distribution ranges of certain species as well. As a consequence of its adaptation to low temperatures, the Baltic glacial relict species *Fritillaria borealis* shows, for instance, a seasonal submergence to avoid warm surface water layers in summer (Ackefors, 1969; Ojaveer et al., 1998). In contrast, the production of the surface zooplankton community of the central Baltic Sea, consisting generally of small species such as cladocerans (*Bosmina* spp., *Podon intermedius*) and rotifers *(Synchaeta* spp., *Keratella* spp.), depends mainly on the seasonally high water temperatures and favorable feeding conditions in the surface water layer (Viitasalo et al., 1995; Schulz et al., 2007; Figure 2.21).

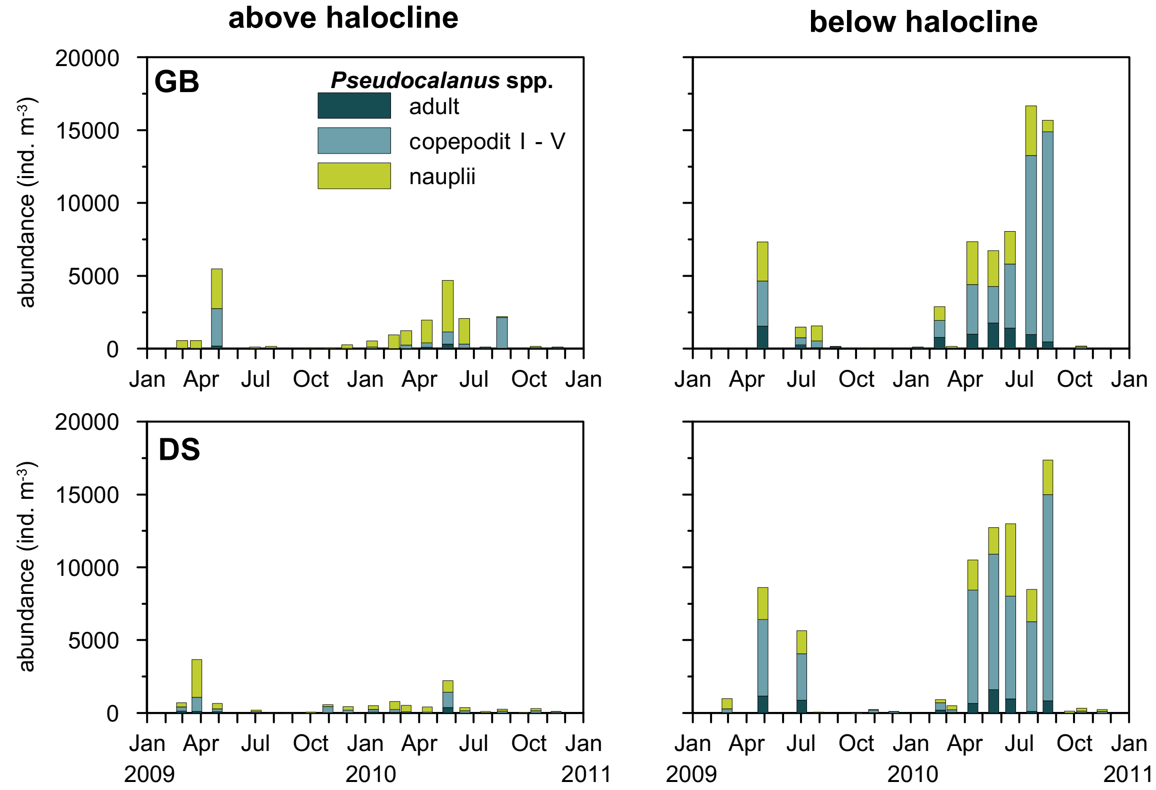

Figure 2.20: Abundance of *Pseudocalanus* spp. developmental stages and adults in 2009 and 2010 above and below the halocline in the Great Belt area (above, GB) and the Darss Sill area (below, DS) (from FEMA-FEHY, 2013).

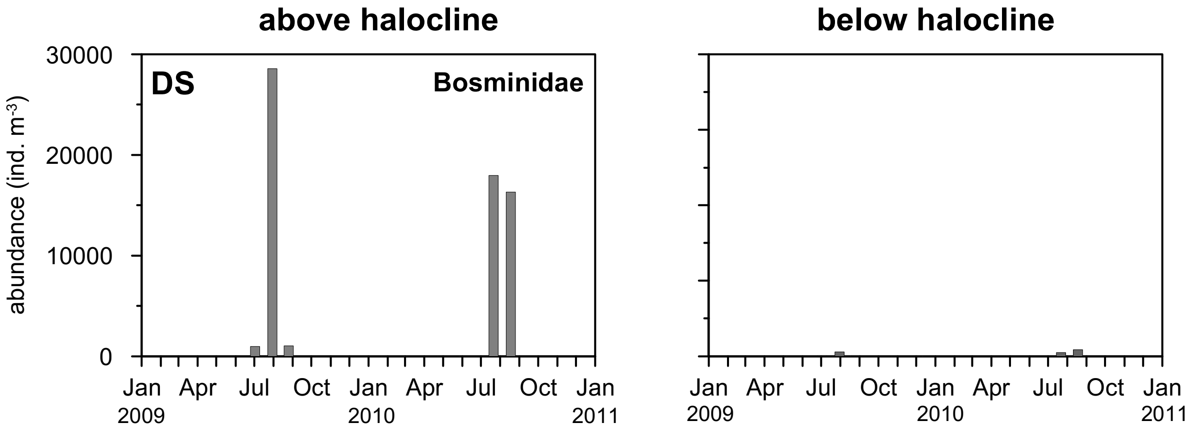

Figure 2.21: Abundance of Bosminidae in 2009 and 2010 above and below the halocline in the Darss Sill area (DS) (from FEMA-FEHY, 2013).

Many species of planktonic crustaceans, especially the adult forms of copepods, conduct diurnal vertical migrations through the water column. Vertical migrations are mainly affected by the environmental factors. The ultimate reason for vertical migrations is diminishing mortality through predator avoidance. Therefore, the general migration pattern involves rising to the surface at dusk and grazing on phytoplankton during the night, prior to descending to deeper water layers before dawn to avoid visually feeding predators. Due to the strong relationship between the migration behavior and light conditions, the zooplankton migration patterns change seasonally.

When comparing vertical distribution patterns of zooplankton during the day and at night, obvious differences can be observed. Considering, for instance, the Eastern Gotland Basin with its stable salinity stratification and a pronounced thermal stratification during summer, diurnal migration is expected for certain species (Hällfors et al., 1981). In midsummer, the euryhaline copepods *Centropages hamatus* and *Temora longicornis* accumulate within the thermocline or below the thermocline in daytime but occur mainly in surface waters above the thermocline at night. *Pseudocolanus acuspes* generally prefers deeper water layers because of their higher salinity. Nevertheless, an upwards movement and accumulation in the mid-water layer between the halocline and the thermocline can be observed during the night. Other species such as the cladocerans *Pleopsis polyphemoides* and *Evadne nordmanni* likely do not perform a pronounced diurnal migration; they stay generally in the surface water layers within or above the thermocline (Hällfors et al., 1981). Observations in the Arkona Sea in summer showed that the biomass of mesozooplankton, mainly consisting of the cladocerans *Bosmina* spp., doubled at midnight if compared with the mid-day values in the uppermost 25 m water layer (Postel, 1995).

Vertical migration is not restricted only to deep and stable stratified Baltic Sea basins but occurs also in shallow coastal waters. Diurnal migration patterns were, for example, observed in the nearshore waters of the Mecklenburg Bight at depths of only 12 m. After sunset, especially the adult specimens of the copepods *Acartia* spp., *Pseudocalanus* sp. and *Temora longicornis* were migrating to higher water levels (Böckmann, 2013).

The migration behavior of certain zooplankton species is also affected by their body size, the ontogenetic developmental stage, and sex (Titelman & Fiksen, 2004). For the common calanoid copepods *Eurytemora affinis* and *Acartia* spp. it was shown that the migration activity intensified with the increasing body size and older developmental stage, and it was the greatest in adult males (Holliland et al., 2012). However, adult females of *Eurytemora affinis* remained at deeper water layers with only slight upward movement at night, especially in spring. This phenomenon is attributed to the predator-avoidance effect due to high vulnerability of egg-carrying females to predation (Vuorinen, 1987; Flinkman et al., 1992; Holliland et al., 2012).

2.6 Seasonal variations in zooplankton

In temperate climatic zones, pelagic ecosystems are strongly influenced by the seasonality in temperature and light conditions, which regulates primary production and therewith the length of the growing period of the organisms at higher trophic levels, such as zooplankton. To some extent, the biomass and production of zooplankton is directly regulated by temperature conditions. As a consequence, mesozooplankton species of the Baltic Sea show specific annual developmental cycles, causing a pronounced seasonal succession of the composition of the zooplankton community. The annual duration of the growing season of zooplankton in the Baltic Sea depends on the geographic latitude. In the south-western Baltic Sea, the duration of the growing season is from March to October. In the northern Gotland Basin, the season starts one month later and ends one month earlier. Further to the north, in the Gulf of Bothnia, the growing period is reduced to 4 months and lasts from May through August (Postel, 1995). Depending on the length of the growing season, the biomass of zooplankton shows one or two annual maxima that develop subsequently to the spring and autumn phytoplankton blooms (Figure 2.22).

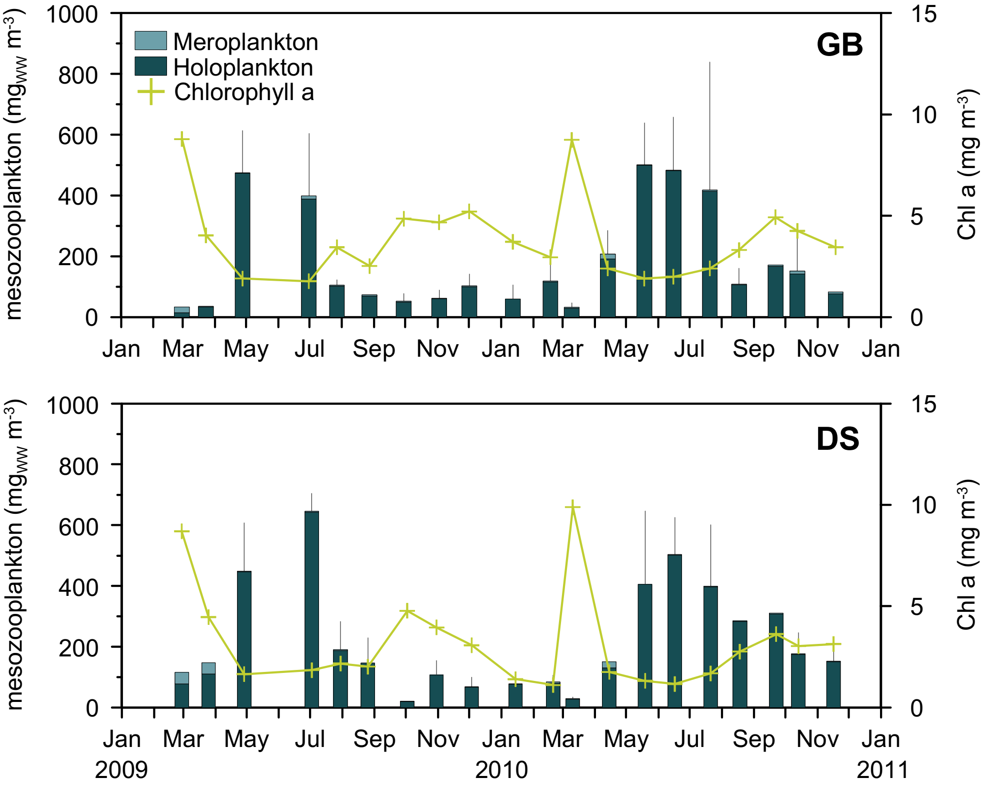

Figure 2.22: Mesozooplankton biomass and chl-*a* concentration in the south-western Baltic Sea in 2009 and 2010. GB: Great Belt; DS: Darss Sill. Mesozooplankton biomasses are calculated for the whole water column, while chl-*a* concentrations represent the upper 10 m of the water column (from FEMA-FEHY, 2013).

Besides the annual cycle of the mesozooplankton biomass, the composition of the zooplankton community changes throughout the year. A pronounced succession of the community structure can be recognized from April to September as a consequence of seasonal recruitment and community succession of the dominating taxa (Figure 2.23). In contrast, the winter/early spring community (October to March) appears to be more stable.

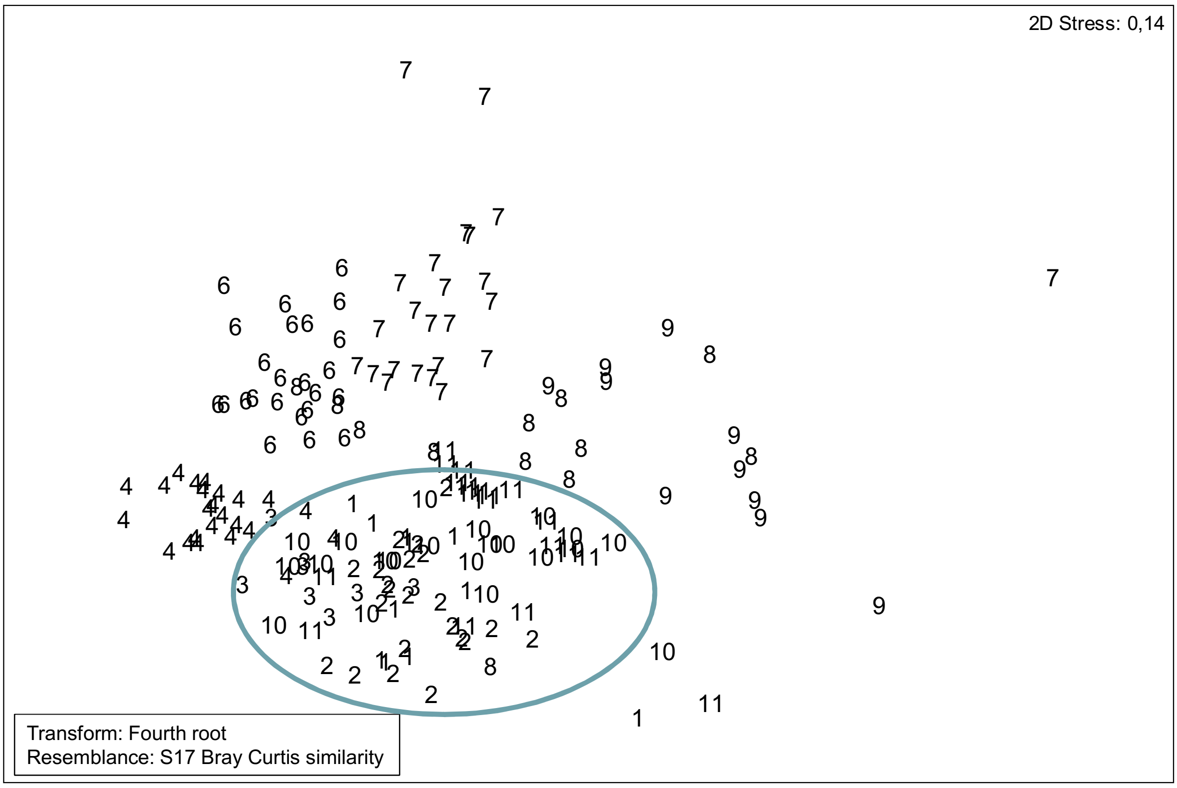

Figure 2.23: The zooplankton community composition in the western Baltic Sea changes throughout the year. MDS-plot of mesozooplankton community in 2009. Data were obtained monthly at 12 stations in the south-western Baltic Sea. Numbers indicate months. The blue ellipse indicates late autumn to early spring season (from FEMA-FEHY, 2013).

The seasonal cycle of the zooplankton community is mainly structured by the developmental cycle of the dominant calanoid copepods. The start of the spawning period with significant number of nauplii is correlated with increasing temperature during spring and early summer: *Acartia* spp. at 0–4 °C, *Pseudocalanus* sp. at 4–8 °C, *Temora longicornis* at 6–10 °C, *Centropages hamatus* and *Eurytemora* sp. at 8–10 °C (Hällfors et al., 1981). A seasonal increase in abundance is also typical for the cyclopoid *Oithona similis*, which shows the annual abundance peaks in late summer/autumn in the central Baltic Sea (Hansen et al., 2004).

Cladocerans reproduce very rapidly by parthenogenesis, developing high population densities very fast in summer when environmental conditions are optimal (Figures 2.24, 2.25). A variety of investigations demonstrate clearly that high temperatures have positive effects on the population dynamics of theses crustaceans (Kankaala, 1983; Viitasalo et al., 1995; Möllmann et al., 2002). The dominant species in summer are *Bosmina* spp., whereas the marine cladocerans *Evadne nordmanni* and *Podon* spp. reach population peaks already in spring (Poggensee & Lenz, 1981; Viitasalo et al., 1995; Möllmann et al., 2002).

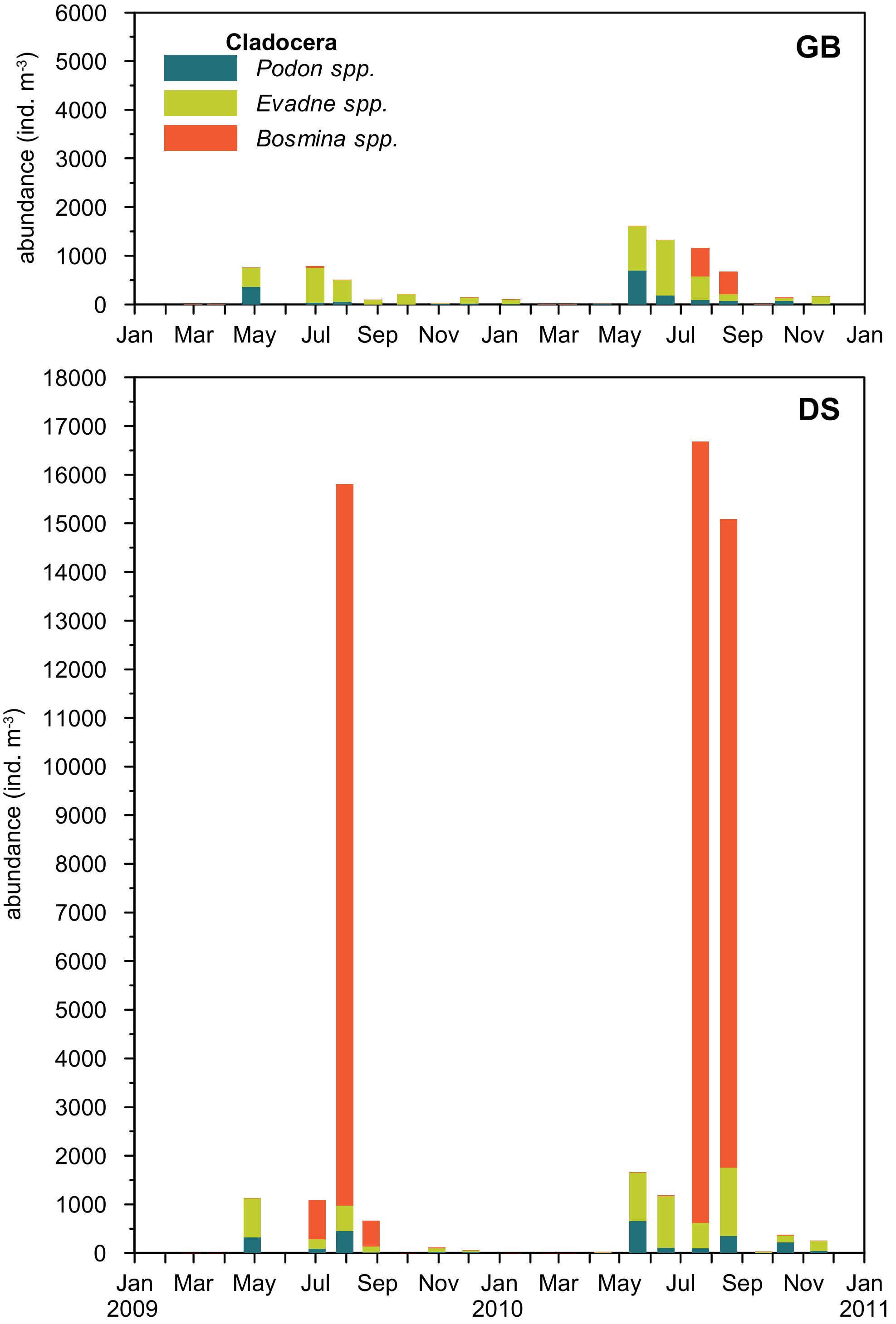

Figure 2.24: Abundance of Cladocera in 2009 and 2010 in Great Belt (GB) and Darss Sill (DS) (from FEMA-FEHY, 2013).

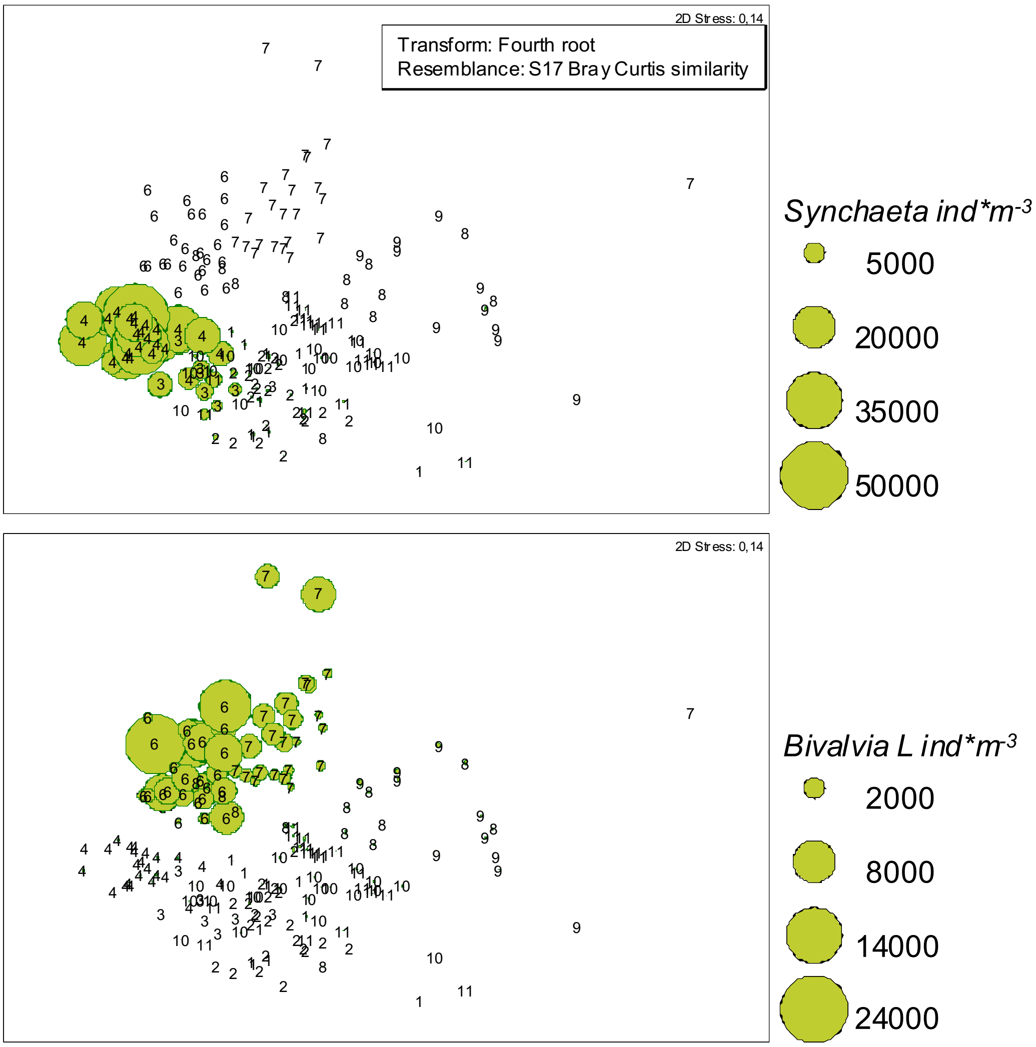

Figure 2.25: Example for the seasonal occurrence of two mesozooplankton taxonomic groups in the south-western Baltic Sea. MDS-plot of mesozooplankton community in 2009. Data were obtained monthly at 12 stations in the south-western Baltic Sea, numbers indicate months. The green bubbles show the seasonal distribution of *Synchaeta* (above) and larvae of Bivalvia (below) (from FEMA-FEHY, 2013).

Rotifers are seasonally dominating components of the zooplankton community in offshore and coastal habitats of the Baltic Sea. In the south-western and central Baltic Sea, mass development of the rotifers *Synchaeta* spp. is common in April and May following the phytoplankton spring bloom. Another abundance peak, although smaller, is occasionally observed in autumn. The inter-annual variations are quite high (Dippner et al., 2000). Due to parthenogenetic reproduction, rotifer populations increase fast as soon as the environmental conditions are suitable. The optimum temperature for *Synchaeta* spp. is 4–10 °C. Corresponding to the shifted vegetation period in the northern part of the Baltic Sea, abundance peaks of *Synchaeta* spp. and *Keratella* spp. occur in June (Viitasalo et al., 1995).

The seasonal occurrence of a range of less abundant taxa also contributes to the intra-annual zooplankton community succession. The thermophile Tunicata *Oikopleura dioica* occurs annually in summer (Schulz & Hirche; 2007). Besides the holoplanktonic species, meroplanktonic larvae of benthic invertebrates occur strongly seasonally, correlated with the abundance peaks of Polychaeta larvae in March/April, larvae of the common starfish *Asterias* in June, Bivalvia and Gastropoda larvae in June/July (Figure 2.25), and Gymnolaemata (Bryozoa) larvae in December–February (FEMA-FEHY, 2013).

2.7 Invasive species

Number of the invasive (nonindigenous or alien) zooplankton species in the Baltic Sea has increased during the recent decades (Leppäkoski & Olenin, 2000; Ojaveer et al., 2010, 2021). Currently, a number of cladoceran species from the Ponto-Caspian area, e.g. *Cercopagis pengoi* (Figure 2.26), *Evadne anonyx* and *Cornigerius maeoticus*, and a ctenophore from the American east coast *Mnemiopsis leidyi* (Figure 2.27) are the examples of alien zooplankters in the Baltic Sea. As obligatory or facultative planktonic predators, they can affect the Baltic pelagic ecosystem (Telesh & Naumenko, 2021). Therefore, such introductions must be monitored very carefully.

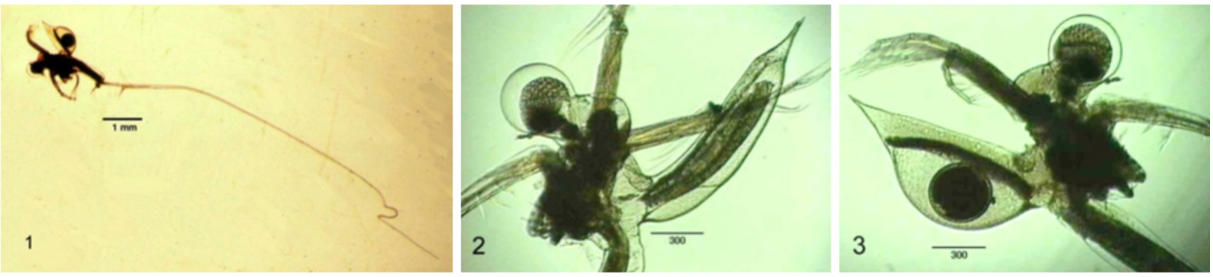

Figure 2.26: Cladocera. 1, *Cercopagis pengoi*, general view of a female at stage II (with 2 claws) with resting egg, lateral view; **2**, *C. pengoi*, body of a female with embryos in brood chamber, lateral view; **3**, *C. pengoi*, body of a female with resting egg, lateral view (after Telesh & Heerkloss, 2004).

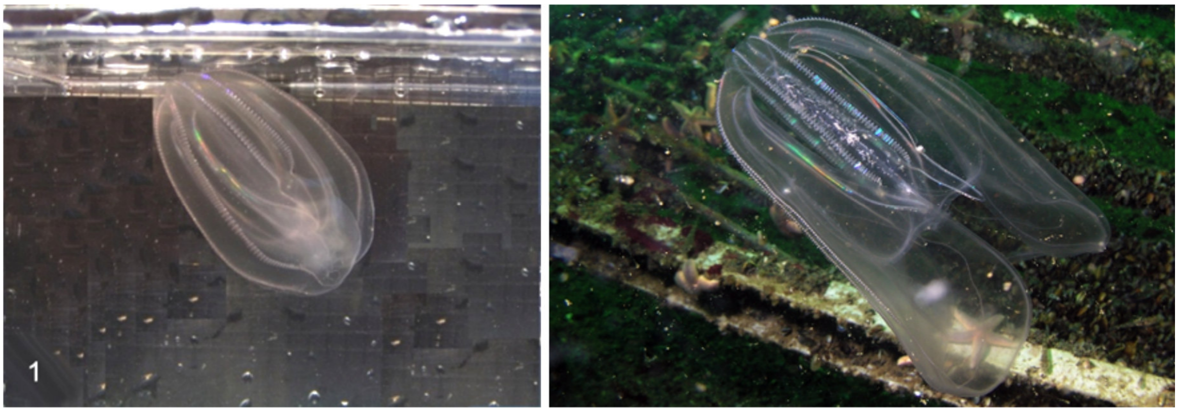

Figure 2.27: Ctenophora. *Mnemiopsis leidyi*, adult, average body length 4–6 cm (**1**, in aquarium, photo L. Postel, 2006); **2**, in the sea (photo G. Niedzwiedz, 2008).

By now, the population of fishhook water flea *C. pengoi* has been established in the greater part of the Baltic Sea. *C. pengoi* occurs more often in coastal waters, but it is also present in the open Baltic Sea (Uitto et al., 1999; Telesh & Ojaveer, 2002; Karasiova et al, 2004; Litvinchuk & Telesh, 2006; Olszewska, 2006; Naumenko & Telesh, 2019; Telesh & Naumenko, 2021). This predatory cladoceran causes a significant impact on the native zooplankton community by feeding on dominant native species such as *Eurytemora affinis*, their nauplii and eggs (Lehtiniemi & Gorokhova, 2008; Naumenko & Telesh, 2019). They consume also *Bosmina* spp. (Pollumäe &

Väljataga, 2004; Gorokhova et al., 2005) and other planktonic filtrating crustaceans (Laxson et al., 2003) that are normally dominant in the central Baltic Sea during summer. Finally, due to elimination of other crustaceans by *C. pengoi*, panktivorous pelagic fishes often feed on *Cercopagis* (Antsulevich & Välipakka, 2000). The predation impact of *C. pengoi* can be numerically evaluated (Telesh et al., 2001) and used for monitoring of this successful invasion and its effect on the natural zooplankton community in the Baltic Sea (Telesh & Naumenko, 2021). The predatory planktonic invaders make the food chain longer by one level, which allows expecting additional energy losses during the general energy flow through the pelagic ecosystem of the Baltic Sea. This phenomenon can affect energy balance in general and the size of pelagic fish stocks in particular (Naumenko & Telesh, 2019).

The influence of the most recent invader – the alien ctenophore *Mnemiopsis leidyi* on the pelagic food web of the Baltic Sea is likely limited so far due to its low abundances in the Baltic proper and the northern regions (Kube et al., 2007a, 2007b; Lehtiniemi & Flinkman, 2007). Certain danger to the ecosystem might be expected from a spatial and temporal overlap between a potential mass occurrence of *M. leidyi* and cod eggs below the halocline of the Bornholm Basin (Haslob et al., 2007). This case requires further attention of the researchers (for more details see Section 6.2).

Another invader, formerly known as *Eurytemora affinis* (Poppe, 1880), has happened to be a group of sibling species (Alekseev et al., 2009; Sukhikh et al., 2013). *Eurytemora affinis*, which is originally native to the Ponto-Caspian region, is an important example of the invasive zooplankter in the Baltic Sea. It is the euryhaline copepod species that has been reported from the western European coast, parts of Asia, and within North America from the Atlantic coast, including the Gulf of Mexico, to the Pacific coast (Kipp & Benson, 2010). This species represents a set of cryptic species in the northern hemisphere (Lee, 1999) and was recently defined as a sibling species among copepods in the Baltic Sea (Alekseev et al., 2009). One of the cryptic species of this group inhabiting North America was recently described as the new species *Eurytemora carolleeae* Alekseev and Souissi, 2011 (Sukhikh et al., 2013).

The sibling species are a special group of invaders: they are hardly distinguishable morphologically from the local species, but they can be influential for the stability of aquatic ecosystems (Gelembiuk et al., 2006). At the beginning of the invasion, the sibling species can cause an unidentifiable change in the biological diversity, further followed by a rearrangement of the aquatic communities. Sympatric sibling species often exhibit distinct habitat preferences defined by depth, salinity or exposure (Sukhikh et al., 2013). Successional differences between sibling species, reflecting temporal partitioning of resources in response to seasonal change or disturbance, were also documented (Knowlton, 1993). For the North American and European *Eurytemora* species, there are some differences in egg production rate and the reproductive lifespan (Beyrend-Dur et al., 2009). Hence, the *Eurytemora* species complex needs to be studied in a detailed and precise way with monitoring programs that may allow conservationists to combat the invasion (Sukhikh et al., 2013, 2020).

Molecular genetic diagnosis is the most efficient way to identify or confirm the sibling species' penetration to new habitat (Goetze, 2003). Morphological differences among sibling species can also be found but they have to be preceded by the molecular confirmation. In the recent studies, the results of the molecular genetic diagnosis based on the analysis of mitochondrial DNA nucleotide sequence (barcoding) in the populations of a common circumpolar species *Eurytemora affinis* (Poppe, 1880) and *Eurytemora carolleeae* Alekseev and Souissi, 2011, as well as their comparison with the morphological data have revealed the co-occurrence of both species in the Gulf of Finland, the Baltic Sea (Sukhikh et al., 2013). Interestingly, the proportion of the North-American invader *E. carolleeae* in the Gulf of Finland was ca. 20% of the entire *Eurytemora* abundance, while in the Vistula Lagoon and the Gulf of Riga, the native European *E. affinis* dominated (Sukhikh et al., 2013). Thus, we can conclude that at present the Baltic Sea hosts two genetically divergent clades (now species) of *Eurytemora*: the Atlantic *E. carolleeae* (possibly invasive) and the European *E. affinis* (native) that overlap in their distribution (Alekseev et al., 2009; Sukhikh et al., 2013).

In the Baltic Sea, invasions are registered also in microplankton. There, a vast functional group of microscopically small organisms, the protists, is currently categorized as “mixoplankton”, or mixotrophic plankton, due their mixotrophic feeding mode, i.e. the combination of autotrophic feeding (phototrophy) and phagotrophy (Flynn et al., 2019, and references therein). These organisms can be attributed to both phyto- and zooplankton because they combine the morphological and functional features of an alga (presence of chloroplasts and photosynthetic activity) and a „perfect beast“, feeding phagotrophically (Flynn & Mitra, 2009). At the microplankton level, the invasions of alien species may seem “invisible”; however, microplankton introductions also can have evident (and fast) nuisance ecosystem consequences (Telesh & Skarlato, 2022). A good example of the delayed though devastating effects of a protistan alien is the peculiar history of invasion of the Baltic Sea by the bloom-forming potentially toxic dinoflagellates *Prorocentrum cordatum* (Ostenfeld) J.D.Dodge, 1975 (Telesh et al., 2016). Nowadays, these unicellular planktonic protists form harmful blooms (red tides) in the marine coastal waters globally (Skarlato et al., 2018b; Glibert, 2020).

In the brackish-water Baltic Sea, which is the area of intensively ongoing invasion processes (Olenin et al., 2017), the mixotrophic dinoflagellate *P. cordatum* is generally accepted as the only one truly invasive protistan species because the dynamics and importance of only this unicellular alien meets the major established requirements of the ‘‘invader’’ (Olenina et al., 2010).

The mixotrophic dinoflagellates *P. cordatum* form an important component of pelagic ecosystems since they are involved in a variety of trophic interactions in plankton food webs. These interactions, food sources, and major grazers of *P. cordatum* in the trophic network were summarized recently using the Black Sea case studies (Khanaychenko et al., 2019); they are represented schematically in Figure 2.28.

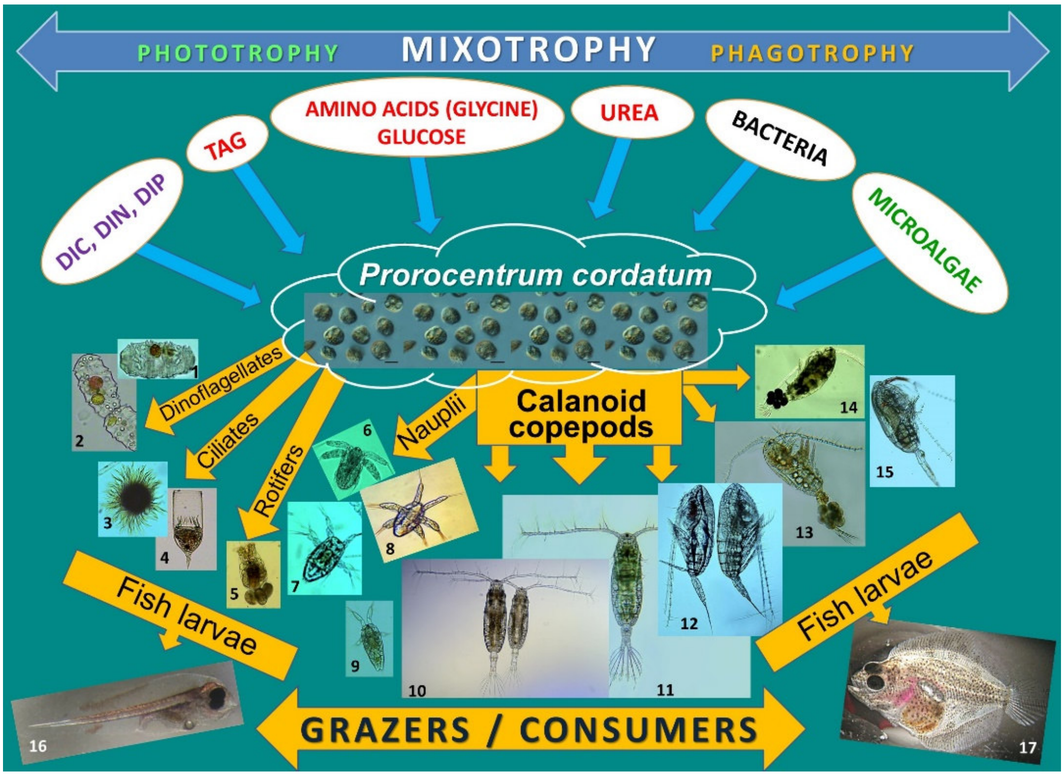

Figure 2.28: Mixotrophic dinoflagellates *Prorocentrum cordatum* in the pelagic food web: their feeding substrates/sources and major grazers/consumers. Heterotrophic dinoflagellates: 1, 2, *Polykrikos kofoidii*. Ciliates: 3, *Strombidium* sp.; 4, *Favella ehrenbergii*. Rotifers: 5, *Brachionus plicatilis*. Larvae of calanoid copepods: 6, 7, *Acartia tonsa*, nauplii; 8, *Calanus helgolandicus*, nauplius; 9, *Calanipeda aquaedulcis*, nauplius. Adult calanoid copepods: 10, *Acartia clausi* (left – female, right – male); 11, *Acartia tonsa*, female; 12, *Calanus helgolandicus* (left – male, right – female); 13, *Calanipeda aquaedulcis*, female with egg sac; 14, *Arctodiaptomus salinus*, female with egg sac; 15, *Pseudocalanus elongatus*, female. Fish larvae: 16, *Scophthalmus maximus* var. maeoticus, early larvae (4 days); 17, *Scophthalmus maximus* var. *maeoticus*, metamorphosing larvae. Photo courtesy of N.A. Gavrilova (1, 2, 4), T.V. Rauen (5), and L.S. Svetlichny (7, 10–14). Photo A.N. Khanaychenko (3, 6, 8, 9, 15–17). *Prorocentrum cordatum*, live cells in culture (photo courtesy of M.A. Berdieva). DIC, dissolved inorganic carbon; DIN, dissolved inorganic nitrogen; DIP, dissolved inorganic phosphorus; TAG, triacylglycerides. From Khanaychenko et al., 2019, with modifications.

Recent studies discuss the possible interplay of planktonic invaders in the Baltic Sea. One of the examples is a probability of the cases when harmful blooms of the potentially toxic dinoflagellates *Prorocentrum cordatum* might be downregulated by the neritic copepods *Acartia tonsa* – another alien species in the region (Telesh et al., 2020, and references therein). The preliminary analysis of the available published data revealed that in the Baltic Sea, the populations of both invaders, the protist *P. cordatum* and the copepod *A. tonsa*, are currently increasing in abundance. At present, the major ecological requirements of *P. cordatum* and *A. tonsa* in the Baltic Sea coastal waters partially juxtapose. However, with the on-going eutrophication and global warming, the population of the invasive copepods *A. tonsa* will likely proliferate in the Baltic Sea in the near future and can react positively to the possible shifts in phytoplankton community structure and dynamics, particularly to those changes caused by the enhancing water temperature and/or decreasing salinity. The related shifts in the dominant mixoplankton in favor of the bloom-forming species and the projected enhanced magnitude of blooms could likewise affect their grazers and cause the overall plankton community restructuring in the Baltic Sea (Telesh et al., 2020).

Currently, the multiple negative ecosystem effects of red tides caused by *P. cordatum* are well identifiable: those are displacement of the native *Prorocentrum* species from the dominants due to effective competition for food, oxygen depletion in water due to high concentrations of metabolites after the bloom decay, water quality deterioration, etc. The ecological niche dimensions of this invader in the Baltic Sea were determined since they are largely responsible for the species' range expansion (Telesh et al., 2016). Moreover, fine mechanisms of the invasive success of *P. cordatum* such as mixotrophic feeding, high adaptability of cells to external stresses, and intra-population heterogeneity in the uptake of different nutrient substrates have been largely unveiled in recent years (Matantseva et al., 2016, 2018; Skarlato et al., 2018a, 2018b; Pechkovskaya et al., 2020; Telesh et al., 2020, 2021). However, linkage of this knowledge with predictive invasion theories and forecasts of nuisance ecosystem effects is still in its natural infancy because the integration of microplankton biology into invasion science has been insufficient so far (Ricciardi et al., 2021). Moreover, a large array of studies attempted at finding traits to predict invasiveness, i.e. establishment and spread of new aliens (e.g., see Dickey et al., 2020). Many of those, however, have failed to robustly predict ecological impact of alien species spanning diverse habitats, taxonomic categories and trophic groups, and no correlations between invasiveness and ecological impact were detected so far (Ricciardi et al., 2021, and references therein).

2.8 Long-term trends

Zooplankton diversity, distribution and abundance are closely related to hydrographic conditions in the Baltic Sea, salinity and temperature being the most pronounced driving forces. Hydrological conditions are controlled by climate through the combined effect of river-runoff and occasional intrusions of saline water from the North Sea. Although hydrographic effects are considered as the key factors to the long-term dynamics of zooplankton, the long term changes of the food web with bottom-up effects (eutrophication and food availability; HELCOM, 2009) and top-down effects (changes in fish stocks, e.g. sprat, Möllmann & Köster, 2002) are crucial for the inter-annual variability as well. Changes of the whole entity of these environmental constraints are reflected by the structure and dynamics of zooplankton communities on different timescales.

The biomass of dominant calanoid copepods changed pronouncedly during the last decades in the central Baltic Sea. Namely, *Pseudocalanus acuspes* was reported as the most abundant calanoid copepod during the 1980s in the Baltic proper south of Gotland (Witek, 1995; Postel et al., 1996). Since then, the abundance of this species decreased significantly, most likely as a result of decreasing salinity due to less frequent saltwater inflows (Lass & Matthäus, 2008; HELCOM, 2009). At the same time, warmer thermal conditions during the 1990s have positively affected the thermophile calanoid copepods *Temora longicornis* and *Acartia* spp., which increased in their abundance in the central and northern Baltic Sea (Dippner et al., 2000; Möllmann et al., 2000; Aleksandrov et al., 2009; HELCOM, 2009).

The negative trend of salinity and the positive trend of water temperature in the Baltic Sea since the 1980s have also affected the long-term dynamics of cladocerans, even though these trends for the latter zooplankters were less significant than for copepods. In the 1990s through the 2000s, the density and biomass of cladocerans increased, for instance, in the south-eastern Baltic Sea. Higher water temperatures create favorable conditions for the development of the thermophile *Bosmina* spp. in summer and the eurytherm *Evadne nordmanni* in spring (Aleksandrov et al., 2009). Further to the north, in the Gotland Basin, these trends are less pronounced. A slight rise in the summerly abundances of *Bosmina* spp. were reported between the 1960s and 1980s. However, this trend did not continue in later decades (Möllmann et al., 2002). Similarly, spring abundances of *E. nordmanni* and *Podon* spp. increased between the 1960s and 1990s (Möllmann et al., 2002).

Recent investigations show that currently an area of about 65% of the Baltic Sea surface water (including the Gulf of Bothnia) has sea surface salinity of less than seven. However, according to the projected models, virtually the whole Baltic Sea surface layer will have the salinity of horohalinicum after some decades with proceeding climate change, while species distribution will change accordingly (Rajasilta et al., 2014; Vuorinen et al., 2015). Considering this trend, it is especially important to obtain the precise data on the actual zooplankton species composition, abundance, biomass and productivity, which is essential for the prognostic modelling of the future biological diversity and the ecosystem stability in the Baltic Sea.

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CHAPTER 3

Methods of collecting and processing samples, microscopic study, counts and determination of zooplankton biomass

3.1 Sampling: general aspects

Zooplankton composition, abundance, and distribution patterns depend on type and geographical location of the water body, season, time (considering daily vertical migrations), trophic status and a large number of other internal characteristics of the water body as well as numerous environmental (external) factors influencing the aquatic biota. Therefore, adequate sampling design should be developed prior to collecting zooplankton samples, relevant sampling methods should be selected, and appropriate sampling intervals chosen (for details see Telesh et al., 2009).

Zooplankton sampling techniques depend on the aim of the study and the targeted zooplankton fraction. For example, the *taxonomic survey* would benefit from the sample size: the larger the volume of water analyzed the more zooplankton species can be found in the sample; for this research, qualitative samples can be collected. Meanwhile, *numerical estimation* of zooplankton density, biomass and production can be performed only if quantitative samples are available.

For collecting various target groups of zooplankton, different sets of equipment are necessary. For example, ciliates are sampled by water bottles, meanwhile the larger organisms are only occasionally captured during such sampling; they must be caught by plankton nets with different mesh sizes depending on the size of the organisms.

3.2 Routine sampling, identification and counts of meso- and macrozooplankton

Mesozooplankton in the sea is best sampled by the WP-2 UNESCO Standard net (UNESCO, 1968). It is a closing net suitable for vertical tows and stratified sampling. For effective sampling of the smaller mesozooplankton in the Baltic Sea, this net (Figure 3.1a) is recommended for the HELCOM Monitoring and Assessment program with a mesh size of 100 µm (HELCOM, 1988, 2005). In shallow coastal areas, the use of horizontally or oblique towed nets of a similar shape is suitable, like Bongo or Multiple nets (Figure 3.1b, c).

Macrozooplankton is collected by nets with larger openings and mesh sizes (Wiebe & Benfield, 2003, and references therein). Fractionation strategies of sampling and examples of estimating the total plankton concentration can be found in Witek and Krajewska-Soltys (1989), Quinones et al. (2003), Postel et al. (2007).

The exact amount of water filtered by the net during towing should be determined by a flow meter. For the details of recommended flow meter types, their position, functioning, and efficiency calculation see Telesh et al. (2009).

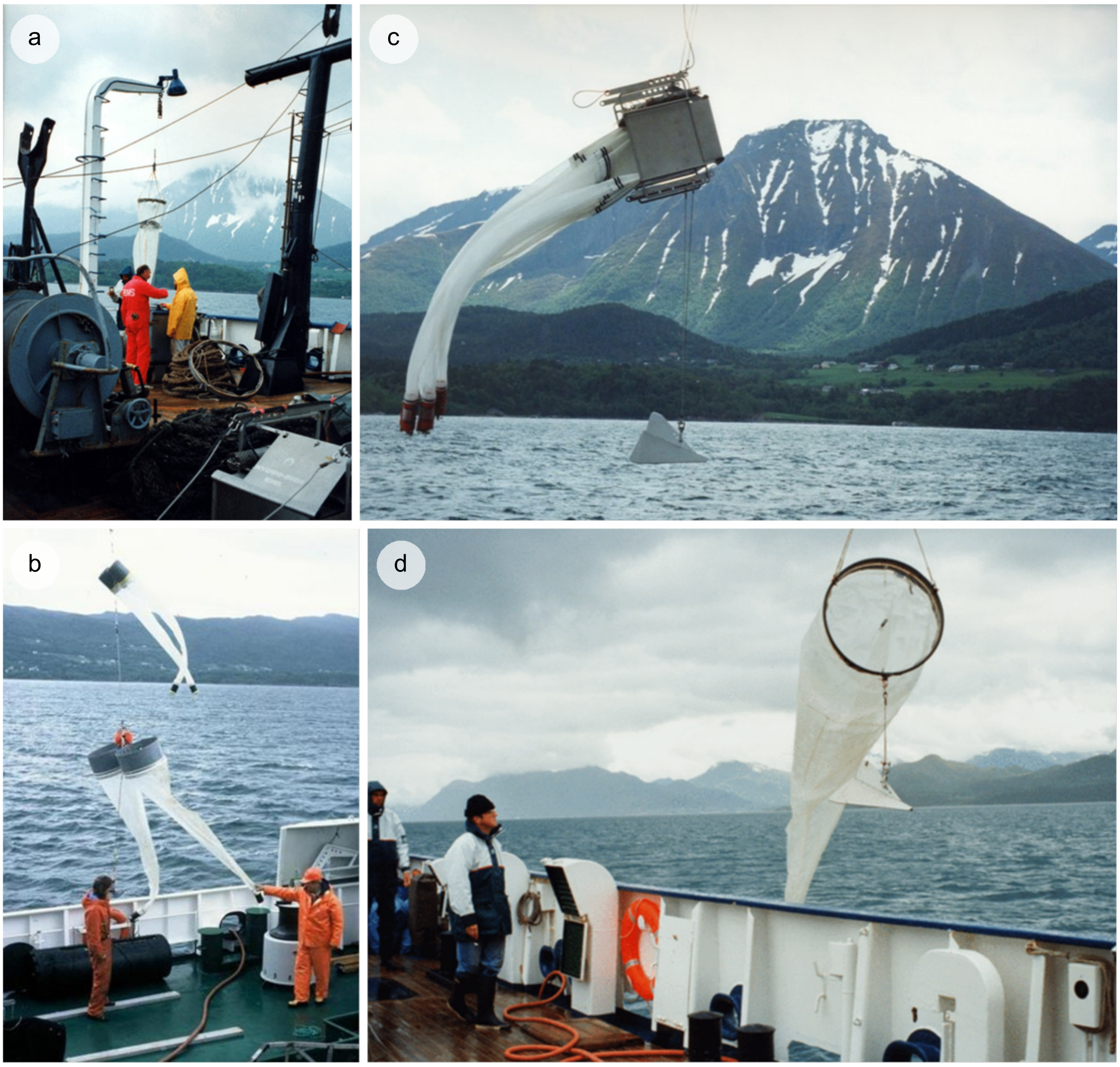

Figure 3.1: **a,** The WP-2 UNESCO Standard net being deployed aboard the R/V A. v. Humboldt; **b,** Twenty cm and 60 cm Bongo nets ready for deployment from the R/V Johan Hjort; **c,** The Multinet rigged for horizontal towing from aboard the R/V A. v. Humboldt; **d,** Deployment of a CalCOFI net from the R/V A. v. Humboldt. All photos stem from an ICES/GLOBEC Sea-going workshop for inter-calibration of plankton samplers at Storfjorden, Norway, June 1993 (ICES, 2002) (after Telesh et al., 2009).

After the net sample is taken out of the water, the net must be carefully rinsed *from the outside* with seawater. The sample, which is concentrated in the cod end of the net, must be transferred to a sample jar and preserved by buffered formalin with a final concentration of 4%. Labeling of the sample jar inside and outside by station number, date, time, and sampling depth interval is mandatory.

Species identification and counting are the basics of any zooplankton community analysis. These procedures are time-consuming and require considerable professional skills and experience. This fact often restricts the number of samples that can be analyzed with an acceptable effort within a reasonable time span. Attempts to overcome these difficulties by the automatic counting methods may help to solve the problem of under-sampling (Wiebe & Benfield, 2003). However, application of the automatic methods is limited to relatively uniform samples (e.g., laboratory cultures), certain size-class-specific analyses, or a coarse separation of organisms from higher taxonomic groups with significant differences in general body morphology. Coupling of such procedures with computerized image analysis may be helpful; however, it requires sophisticated technical equipment and special software.

Routinely, for monitoring purposes, counting is performed for the dominant organisms from easily identifiable taxonomic groups and their developmental stages. More taxonomic skills are required for the identification of certain species using the appropriate guidebooks. The species names should be used according to the *International Code of Zoological Nomenclature* (http://www.iczn.org). Information on the validity of names and actual taxonomic classification can be given, for example, following the Integrated Taxonomic Information System (http://www.itis.gov) and The European Register of Marine Species (http://www.marbef.org/data/erms.php).

The laboratory procedure of sorting mesozooplankton starts with removing the redundant formalin from the sample by its filtration through the mesh with size smaller than the mesh size of the sampling gear. (The filtrated preservative can be used again after the analysis for any further storage). The organisms are suspended in filtered tap water or distilled water for the analysis. The procedure should be carried out under a fume-hood. The sample is often so densely concentrated that it requires sub-sampling into aliquots. For example, 1/32 ± 1/8 of the sample were analyzed within the monitoring program of the Leibniz Institute for Baltic Sea Research, Warnemünde, in 2005 (Wasmund et al., 2006).

The volume of the total sample, measured in a graduated cylinder, is noted as the reference amount. The sample then is poured into a beaker to allow a thorough mixing until the organisms are distributed randomly before taking an aliquot. Repeated sub-sampling by the Stempel pipette (Hensen, 1887) produces a coefficient of variation of 7–9%, applying a bulb pipette 14–15%, and a Folsom splitter 5–18%. The variability between total counts amounts to 0.3–2.5% (Guelpen et al., 1982). The use of pipettes is 5 to 8 times faster than the splitter technique. Its limitation is inapplicability to sub-sample zooplankters which size is larger than the pipette's diameter. The Kott splitter (Kott, 1953) is more convenient in comparison to the Folsom splitter (Sell & Evans, 1982; Griffiths et al., 1984). The Kott splitter produces 8 sub-samples at the same time, while the Folsom device splits samples into halves and increases the error from one step to another (Behrends & Korshenko, pers. comm.).

For routine sorting of larger zooplankton, a dissecting stereomicroscope is used (Figure 3.2). It makes manipulation of the specimen during the identification procedure possible. For the smaller mesozooplankton, such as rotifers, cladocerans, copepods and their developmental stages, an inverted microscope accomplishes the same role. It allows routine survey with the 50× magnification and the analysis of details with a magnification factor of 80× to 125× as well. For more specific investigations of certain taxonomic features, like the examination of the fifth leg of copepods, a compound microscope with achromatic condenser and 10× to 70× objectives is the preferred instrument. For looking into the details of rotifer morphology, 100× oil immersion objective is needed.

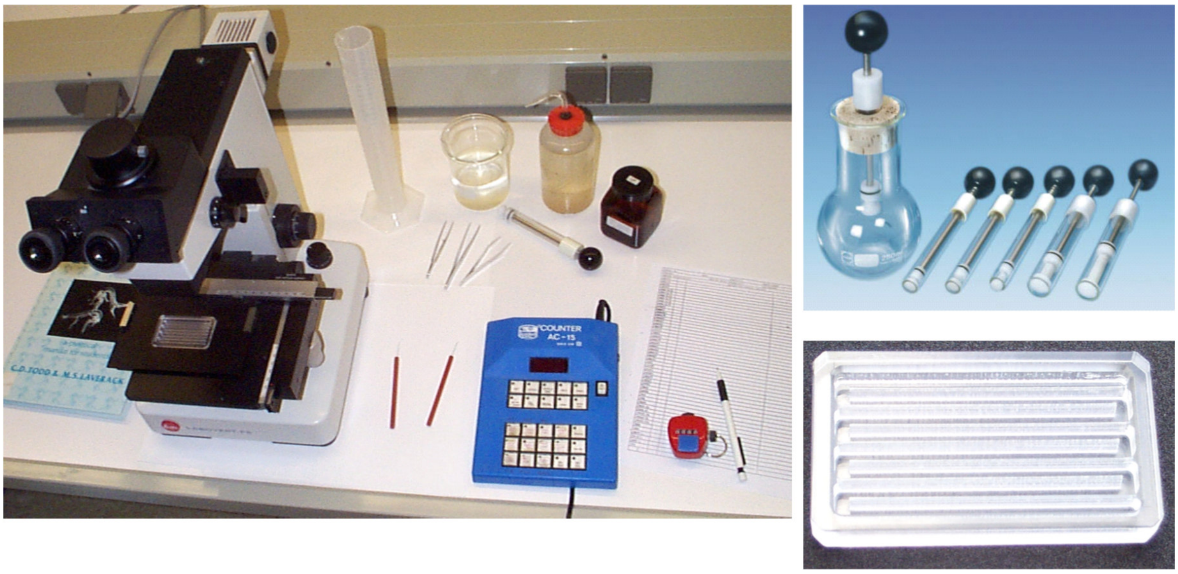

Figure 3.2: Working place for counting and identification of smaller mesozooplankton with an inverted microscope (Labovert, Leica Microsystems GmbH, Wetzlar, Germany) and accessory equipment like Stempel pipette (Hydrobios GmbH, Kiel, Germany), and Mini-Bogorov chamber (Postel et al., 2000, modified after Arndt, 1985).

For an inverted microscope, an open Plexiglas counting chamber of high transparency like the Mini-Bogorov chamber (modified after Arndt, 1985) is necessary. Closed types of counting chambers are preferably used in microzooplankton studies. The trays are provided with sections to allow a better orientation and to avoid a repeated counting of the same organism. One counting strip is fully covered with the 50× magnification. The Mini-Bogorov chamber (Figure 3.2) is easy to produce in a workshop. It has the following dimensions: the length, width, and height are 40, 70, and 8 mm, respectively. The counting paths are 6 mm deep, their width amounts to 3 mm, the section walls are 1 mm wide, and their height is 4.5 mm. The sides and walls are tapered sloping at top. The tray is made of clear plastic and needs to be polished to high quality (Postel et al., 2000). The table of the microscope has to be adapted to carry the tray (Figure 3.2). The Mini-Bogorov tray is filled with a known aliquot (e.g., 0.5 or 1 ml, which has to be considered for calculation of abundance) and finally made up to the top (10 ml) with filtered tap water or distilled water. The surface must be level to avoid any reflections. Therefore, the outer walls are 1.5 mm higher than those of the counting paths are.

Some organisms, for example, cladocerans, tend to float in the surface film. Addition of detergents or cetyl alcohol [$CH_3(CH_2)_{14}CH_2OH$] (Desmarias, 1997) reduces their surface tension and promotes sinking to bottom. This makes it easier to focus on all animals in the same way. Other sorting media are glycerol and propylene glycol, or lactic acid used for clearing tissues of small crustaceans (Omori & Ikeda, 1984). Contamination of a zooplankton sample by large quantities of phytoplankton makes the analysis more difficult. In this case, staining of animals by adding Eosin Y is a helpful tool. A few drops are enough for a 100 ml sample volume; several hours should be allowed for staining (Edmondson, 1971).

Lund et al. (1958), Cassie (1971) and others have considered the statistical aspects of counting errors, which allow identifying how many organisms have to be counted in order to obtain adequate estimation of abundance. The required accuracy of results depends on the purpose of the work. To detect differences between total zooplankton abundance in space or time of 100%, an accuracy of 50% is adequate, and any time spent in making more accurate estimates is largely wasted. Generally, an error of ±20% is acceptable. If all organisms are randomly distributed, following the Poisson distribution, the accuracy of a sample and the precision of a single count depends only on the number of specimens counted. The 95% confidence limits ($C.L._{95}$) are calculated from the number of counts (n) and the significance level of the Poisson distribution at the 5% probability error of 1.96:

$$C.L._{95}[\%] = \pm 1.96 \cdot \left(\frac{100}{\sqrt{n}}\right)$$

In practice, one or more counting chambers (aliquots) with the same concentration should be analysed until 100 specimens of the most abundant taxonomic groups are counted in a sample (HELCOM, 2005).

The estimations of abundances of the remaining (less common) zooplankton groups are of lower precision. If the counting procedure is continued until 100 specimens of the other groups are reached, neglecting the more abundant groups, the different sub-sample sizes must be considered in the successive calculations. Finally, the remaining part of the total sample can be surveyed for rare species.

The number of individuals per unit volume of water is defined as abundance (N). Its calculation (e.g., as ind./m^3) needs to consider the number of counts (n), the fraction of the sample counted (k, i.e. the proportion of total volume to sub-sample volume), and the amount (volume) of water filtered by the sampling net (V, m^3):

$$N = \frac{n \cdot k}{V}$$

The abundance values for certain zooplankton species are further used for calculation of other structural (e.g. biomass) and functional (productivity, feeding rates, decomposition of organic matters, etc.) characteristics of populations of single species as well as entire zooplankton community. Information on methods for determining functional characteristics of zooplankton can be found elsewhere (see the List of references).

3.3 Biomass determination

The knowledge about body mass of zooplankton organisms is essential for the analyses of their productivity, energy balance calculations, and estimation of zooplankters' role in the trophic webs. Therefore, the calculation of biomass is a next step in zooplankton community analysis. For the adequate biomass calculation, the suitable individual body mass values or proper morphometric approaches are applied (for reviews see: Table 4.12 in Postel et al., 2000; Telesh & Heerkloss, 2002, 2004). Such biomass determination is zooplankton species-specific, in contrast to quantifying the biovolume or the other sum biomass parameters of the entire sample by volumetric or other procedures (for details see Postel et al., 2000). The zooplankton biomass values obtained with the help of the individual mass values or length/mass correlations are advantageous because these results cannot be falsified by phytoplankton and detritus that sometimes are very abundant in the zooplankton samples.

For zooplankton monitoring purposes in the Baltic Sea, the individual body mass values suggested by Hernroth (1985) are recommended. This compilation includes individual wet mass values of six common copepod and three cladoceran taxa, determined based on the body volume calculations using the morphometric approaches (Chojnacki & Jankowski, 1982; Chojnacki, 1983, 1986), and the successive conversion to wet mass of the organisms. The compilation was supplemented by literature data for rotifers, chaetognaths, appendicularians and some other copepods. Seasonal and regional differences were considered; therefore, the amount of data was sufficient for precise determination of the individual mass values, which is important as rough body mass calculations may cause significant errors when multiplied by large individual numbers. Therefore, usage of individual body mass values and length to mass ratios based on direct measurements is strongly recommended. There are some of those available from the Northern Baltic Sea (Kankaala & Johansson, 1986; Kankaala, 1987; Tanskanen, 1994); they are based on the kryo-conservation technique (Latja & Salonen, 1978; Salonen, 1979). For rotifers, direct species-specific estimations of carbon mass of 13 species are available for biomass calculation (Telesh et al., 1998).

The Baltic Sea as a brackish water system with a horizontal salinity gradient from south-west to north-east and a permanent vertical salinity stratification of the central basins is a unique pelagic ecosystem with limited distribution ranges of marine and freshwater species. The location of the Baltic Sea in the temperate climatic zone with oceanic impact in the south-western part and continental impact in the north-eastern areas affects the whole ecosystem through seasonality by causing a pronounced seasonal succession of plankton populations.

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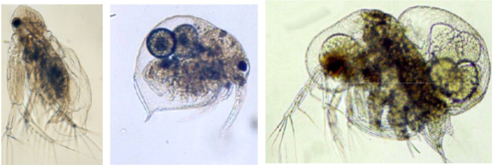
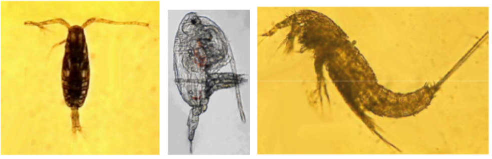
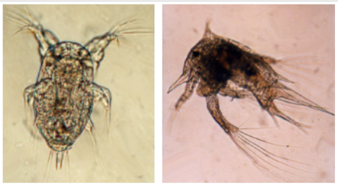
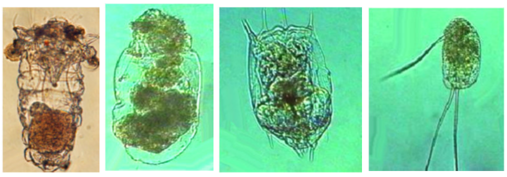
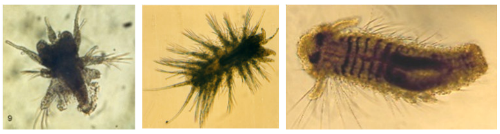
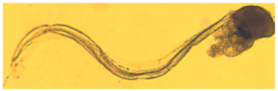
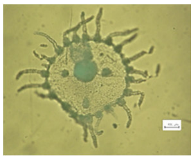
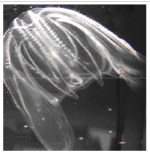
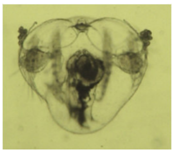
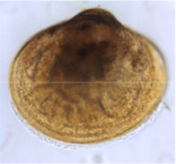
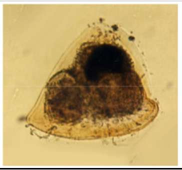
CHAPTER 4

Picture key for major zooplankton taxa

No	Character	Taxon	Examples
1	Unicellular	Ciliata	
1a	Multicellular		2
2	With obvious legs/antennae		3
2a	Without obvious legs/antennae		4
3	Large compound eye; body with carapace of bivalve appearance, segmentation unclear; large antennae	Cladocera	
3a	Eye small; body elongated or cylindrical, with clear segmentation; antennae usually large	Copepoda	
3b	Single minute eye spot; body small, unsegmented; with 3 pairs of appendages	Nauplia of Copepoda or Cirripedia	
4	Body cylindrical or sack-shaped, covered with cuticle or lorica, usually <200 µm; head with ciliated corona	Rotifera	
4a	Body > 200 µm		5
5	Body segmented, with parapodia and prominent bundles of chaetae	Polychaeta, larvae	
5a	Body not segmented; without spines		6

No	Character	Taxon	Examples
6	Body oval, elongated or arrow-like		7
6a	Other body shape		8
7	Oval or elongated trunk; long tail with notochord	Appendicularia	 
7a	Large arrow-like body (15-45 mm) with paired lateral fins	Chaetognatha	
8	Medusa-like		9
8a	Other shape		10
9	Medusa-like	Cnidaria	 
9a	Biradially-symmetric comb-jelly-like	Ctenophora	 
10	Snail-like	Gastropoda, larvae	
10a	Bivalve-like	Bivalvia, larvae	
10b	With large projections	Echinodermata, larvae	
10c	Bell-like	Bryozoa, larvae	

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CHAPTER 5

Checklist of meso- and macrozooplankton species of the Baltic Sea

Table 5.1: Meso- and macrozooplankton species in the Baltic Sea: **BP** – Baltic Proper; **WBS** – Western Baltic Sea; **NBS** – Northern Baltic Sea, **SBS** – Southern Baltic Sea; **EBS** – Eastern Baltic Sea (“+” present; no sign = species not found). After Telesh et al. (2009), with additions and modifications.

No	Taxa	BP[1]	WBS[2]	NBS[3]	SBS[4]	EBS[5]
	Cnidaria, Anthomedusae					
1	*Euphysa aurata* Forbes, 1848	+	+			
2	*Euphysa tentaculata* Linko, 1905	+	+			
3	*Halitholus cirratus* Hartlaub, 1913	+	+		+	
4	*Hybocodon prolifer* L. Agassiz, 1862	+	+			
5	*Rathkea octopunctata* (M. Sars, 1835)	+	+			
6	*Sarsia tubulosa* (M. Sars, 1835)	+	+			
	Cnidaria, Trachymedusae					
7	*Aglantha digitalis* (O.F. Müller, 1776)	+	+			
	Cnidaria, Scyphomedusae					
8	*Aurelia aurita* (Linnaeus, 1758)	+	+	+	+	
9	*Clytia hemisphaerica* (Linnaeus, 1767)	+				
10	*Cyanea capillata* (Linnaeus, 1758)		+			
11	*Haliclystus auricula* O. Fabricius, 1780		+			
12	*Lucernaria quadricornis* O.F. Müller, 1776		+			
13	*Rhizostoma octopus* (Mayer, 1910)		+			
	Cnidaria, Leptomedusae					
14	*Melicertum octocostatum* (M. Sars, 1835)	+	+		+	
15	*Obelia geniculata* (Linnaeus, 1758)	+	+		+	

No	Taxa	BP[1]	WBS[2]	NBS[3]	SBS[4]	EBS[5]
	Ctenophora					
16	*Beroe cucumis* Fabricius, 1780	+	+			
17	*Beroe gracilis* Künne, 1939	+	+			
18	*Bolinopsis infundibulum* O.F. Müller, 1776	+	+			
19	*Mnemiopsis leidyi* A. Agassiz, 1865	+	+	+	+	
20	*Pleurobrachia pileus* (O.F. Müller, 1776)	+	+	+	+	+
	Turbellaria					
21	*Alaurina composita* Metschnikow, 1865		+			
	Rotifera					
22	*Anuraeopsis fissa* (Gosse, 1851)			+		
23	*Asplanchna* sp.			+		
24	*Asplanchna brightwelli* Gosse, 1850		+			+
25	*Asplanchna priodonta* Gosse, 1850		+		+	+
26	*Asplanchna seiboldi* (Leydig, 1854)		+			
27	Bdelloidea indet.			+		+
28	*Brachionus* sp.			+	+	+
29	*Brachionus angularis* Gosse, 1851		+	+	+	+
30	*Brachionus calyciflorus* Pallas, 1766		+	+	+	+
31	*Brachionus plicatilis* O.F. Müller, 1786		+			
32	*Brachionus quadridentatus* Hermann, 1783		+	+		
33	*Brachionus rubens* Ehrenberg, 1838		+			
34	*Brachionus urceus* (Linnaeus, 1758)		+	+		
35	*Cephalodella catellina* (O.F. Müller, 1786))		+			
36	*Cephalodella megalocephala* (Glasscott, 1893)		+			
37	*Collotheca* sp.					+
38	*Collotheca mutabilis* (Hudson, 1885)		+			
39	*Collotheca ornata* (Ehrenberg, 1832)		+			
40	*Collotheca pelagica* (Rousselet, 1893)					+
41	*Colurella* sp.		+	+		+
42	*Conochilus unicornis* Rousselet, 1892				+	
43	*Dicranophorus* sp.				+	
44	*Encentrum pachypus* Remane, 1949		+			+
45	*Euchlanis* sp.					+
46	*Euchlanis dilatata* Ehrenberg, 1832		+	+	+	+
47	*Filinia brachiata* (Rousselet, 1901)			+		

No	Taxa	BP[1]	WBS[2]	NBS[3]	SBS[4]	EBS[5]
48	*Filinia longiseta* (Ehrenberg, 1834)		+	+	+	+
49	*Filinia terminalis* (Plate, 1886)		+	+	+	
50	*Hexarthra fennica* (Levander, 1892)		+			+
51	*Kellicottia longispina* (Kellicott, 1879)			+	+	+
52	*Keratella cochlearis* (Gosse, 1851)	+	+	+	+	+
53	*Keratella cochlearis baltica* (Sokolova, 1927)	+	+	+	+	+
54	*Keratella cochlearis recurvispina* (Jägerskiöld, 1894)	+		+		+
55	*Keratella cochlearis tecta* (Gosse, 1851)		+	+	+	+
56	*Keratella cruciformis eichwaldi* (Levander, 1894)	+	+	+	+	+
57	*Keratella quadrata* (O.F. Müller, 1786)	+	+	+	+	+
58	*Keratella quadrata platei* (Jägerskiöld, 1894)	+		+		+
59	*Lecane* sp.			+		+
60	*Lecane lamellata* (Daday, 1893)		+			
61	*Lecane luna* (O.F. Müller, 1776)					+
62	*Lecane lunaris* (Ehrenberg, 1832)		+			
63	*Lepadella* sp.			+		
64	*Monommata* sp.			+		
65	*Mytilina mucronata* (O.F. Müller, 1773)		+			
66	*Notholca* sp.				+	+
67	*Notholca caudata* Carlin, 1943			+		
68	*Notholca acuminata* (Ehrenberg, 1832)	+	+			+
69	*Notholca acuminata extensa* Oloffsson, 1918		+			
70	*Notholca acuminata marina* Focke, 1961		+			
71	*Notholca labis* Gosse, 1887					+
72	*Notholca squamula* (O.F. Müller, 1786)					+
73	*Notholca squamula salina* Focke, 1961		+			
74	*Notholca striata* (O.F. Müller, 1786)	+	+	+		
75	*Philodina* sp.			+		
76	*Ploesoma truncatum* (Levander, 1894)			+		+
77	*Polyarthra* sp.				+	+
78	*Polyarthra dolichoptera* Idelson, 1925	+	+	+	+	+
79	*Polyarthra major* Burckhardt, 1900			+		
80	*Polyarthra remata* Skorikov, 1896			+		
81	*Polyarthra vulgaris* Carlin, 1943		+	+		+
82	*Pompholyx sulcata* Hudson, 1885			+		
83	*Proales* sp.		+			+

No	Taxa	BP^{1}	WBS^{2}	NBS^{3}	SBS^{4}	EBS^{5}
84	*Proales reinhardti* (Ehrenberg, 1834)			+		
85	*Synchaeta* sp.	+		+	+	+
86	*Synchaeta baltica* Ehrenberg, 1834	+	+	+	+	+
87	*Synchaeta cecilia* Rousselet, 1902		+	+		
88	*Synchaeta curvata* Lie-Pettersen, 1905	+	+	+		+
89	*Synchaeta fennica* Rousselet, 1909	+	+		+	+
90	*Synchaeta grimpei* Remane, 1929		+			
91	*Synchaeta gyrina* Hood, 1887	+				+
92	*Synchaeta littoralis* Rousselet, 1902		+	+		+
93	*Synchaeta monopus* Plate, 1889	+	+	+	+	+
94	*Synchaeta pectinata* Ehrenberg, 1832		+			
95	*Synchaeta triophthalma* Lauterborn, 1894	+	+			
96	*Synchaeta vorax* Rousselet, 1902					+
97	*Testudinella clypeata* (O.F. Müller, 1786)		+			+
98	*Trichocerca* sp.		+	+	+	
99	*Trichocerca capucina* (Wierzejski et Zacharias, 1893)			+		+
100	*Trichocerca dixon-nutalli* Jennings, 1903		+			
101	*Trichocerca marina* (Daday, 1890)		+	+		+
102	*Trichocerca pusilla* (Lauterborn, 1898)					+
103	*Trichocerca (Diurella) similis* (Wierzejski, 1893)			+		
104	*Trichotria pocillum* (O.F. Müller, 1776)					+
	Cladocera					
105	Acroperus harpae (Baird, 1834) ^{c}				+	+
106	*Alona* sp.			+	+	
107	*Alona affinis* Leydig, 1860 ^{c}				+	+
108	*Alona costata* G.O. Sars, 1862 ^{c}				+	+
109	*Alona guttata* G.O. Sars, 1862 ^{c}				+	+
110	*Alona intermedia* G.O. Sars, 1862		+			+
111	*Alona quadrangularis* (O.F. Müller, 1776)				+	+
112	*Alona rectangula* Sars, 1861		+		+	+
113	*Alonella excisa* (Fischer, 1854) ^{c}				+	+
114	*Alonella exigua* (Lilljeborg, 1853) ^{c}				+	
115	*Alonella nana* (Baird, 1850) ^{c}					+
116	*Alonopsis elongata* Sars, 1862				+	+
117	*Bosmina crassicornis* P.E. Müller, 1867					+
118	*Bosmina longirostris* (O.F. Müller, 1776)	+	+	+	+	+

No	Taxa	BP^{1}	WBS^{2}	NBS^{3}	SBS^{4}	EBS^{5}
119	*Bythotrephes* sp.					+
120	*Camptocercus rectirostris* Schoedler, 1862 ^{c}				+	+
121	*Camptocercus lilljebborgii* Schoedler $^{**, c}$					+
122	*Cercopagis pengoi* (Ostroumov, 1891)	+		+	+	+
123	*Ceriodaphnia* sp.			+	+	+
124	*Ceriodaphnia laticaudata* P.E. Müller, 1867		+			
125	*Ceriodaphnia pulchella* G.O. Sars, 1862				+	+
126	*Ceriodaphnia quadrangula* (O.F. Müller, 1785)				+	+
127	*Ceriodaphnia reticulata* (Jurine, 1820)		+		+	
128	*Ceriodaphnia setosa* Matile $^{**, c}$				+	
129	*Chydorus latus* Sars, 1862 ^{c}					+
130	*Chydorus ovalis* Kurz, 1874 ^{c}				+	+
131	*Chydorus piger* G.O. Sars, 1862 ^{c}				+	
132	*Chydorus sphaericus* (O.F. Müller, 1785)		+	+	+	+
133	*Cornigerius maeoticus* Pengo, 1879					+
134	*Daphnia* sp.				+	+
135	*Daphnia cristata* G.O. Sars, 1861			+	+	+
136	*Daphnia cucullata* G.O. Sars, 1862	+		+	+	+
137	*Daphnia curvirostris* Eylman, 1887 ^{c}				+	
138	*Daphnia galeata* G.O. Sars, 1864		+			
139	*Daphnia longispina* (O.F. Müller, 1785)		+		+	+
140	*Daphnia magna* Straus, 1820		+			
141	*Daphnia pulex* Leydig, 1860 ^{c}				+	+
142	*Diaphanosoma brachyurum* (Liévin, 1848)		+	+	+	+
143	*Diaphanosoma mongolianum* Ueno, 1938		+			
144	*Disparalona rostrata* (Koch, 1841) ^{c}				+	+
145	*Eubosmina coregoni* Baird, 1857	+	+	+	+	+
146	*Eubosmina longispina* (Leidig, 1860) (Syn.*: *Bosmina longispina* Leidig, 1860; *Bosmina coregoni maritima* sensu Purasjoki, 1958)	+	+	+	+	+
147	*Eubosmina maritima* (P.E. Muller, 1867) (Syn.: *Bosmina maritima* P.E. Müller, 1867)	+	+	+	+	+
148	*Eurycercus lamellatus* (O.F. Müller, 1776)		+		+	+
149	*Evadne anonyx* G.O. Sars, 1897 [May be confused with *E. nordmanni*]				+	+
150	*Evadne nordmanni* Lovén, 1836	+	+	+	+	+
151	*Evadne spinifera* P.E. Müller, 1867		+			
152	*Graptoleberis testudinaria* (Fischer, 1848) ^{c}				+	+
153	*Holopedium gibberum* Zaddach, 1855 ^{c}					+

No	Taxa	BP[1]	WBS[2]	NBS[3]	SBS[4]	EBS[5]
154	*Ilyocryptus acutifrons* G. O. Sars, 1862 [c]				+	+
155	*Ilyocryptus agilis* Kurz, 1878 [c]					+
156	*Ilyocryptus sordidus* (Liévin, 1848) [c]					+
157	*Kurzia latissima* (Kurz, 1874) [c]					+
158	*Lathonura rectirostris* (O. F. Müller, 1776) [c]					+
159	*Latona setifera* (O. F. Müller, 1776) [c]				+	+
160	*Leptodora kindtii* (Focke, 1844)			+	+	+
161	*Leydigia leydigi* (Leydig, 1860) [c]				+	+
162	*Limnosida frontosa* Sars, ... [**, c]					+
163	*Macrothrix rosea* (Liéven, 1848) [c]					+
164	*Moina brachiata* (Jurine, 1820) [c]				+	+
165	*Monospilus dispar* G. O. Sars, 1861 [c]				+	+
166	*Ophryoxus gracilis* G. O. Sars, 1861 [c]					+
167	*Oxyurella tenuicaudis* (G. O. Sars, 1862) [c]				+	+
168	*Picripleuroxus laevis* (G. O. Sars, 1861) [c] (Syn.: *Pleuroxus laevis* G. O. Sars, 1861)					+
169	*Picripleuroxus striatus* (Schödler, 1863) [c] (Syn.: *Pleuroxus striatus* Schödler, 1863)					+
170	*Pleopsis polyphemoides* (Leuckart, 1859)	+	+	+	+	+
171	*Pleuroxus aduncus* (Jurine, 1820) [c]				+	+
172	*Pleuroxus trigonellus* (O. F. Müller, 1776) [c]				+	+
173	*Pleuroxus truncatus* (O. F. Müller, 1785) [c]				+	+
174	*Pleuroxus uncinatus* Baird, 1850 [c]				+	+
175	*Podon intermedius* Lilljeborg, 1853	+	+	+	+	+
176	*Podon leuckartii* (G.O. Sars, 1862)	+	+	+	+	+
177	*Polyphemus pediculus* (Linnaeus, 1761)					+
178	*Pseudochydorus globosus* (Baird, 1843) [c]				+	+
179	*Rhynchotalona falcata* (G. O. Sars, 1861) [c]				+	+
180	*Scapholeberis mucronata* (O. F. Müller, 1776) [c]				+	+
181	*Sida crystallina* (O.F. Müller, 1776)					+
182	*Simocephalus exspinosus* (DeGeer, 1778) [c]				+	+
183	*Simocephalus serrulatus* (Koch, 1841) [c]					+
184	*Simocephalus vetulus* (O. F. Müller, 1776) [c]				+	+
	Copepoda, Calanoida					
185	*Acanthodiaptomus denticornis* (Wierzejski, 1887) [c]					+
186	*Acartia bifilosa* (Giesbrecht, 1881)	+	+	+	+	+
187	*Acartia clausi* Giesbrecht, 1889	+	+	+	+	+

No	Taxa	BP[1]	WBS[2]	NBS[3]	SBS[4]	EBS[5]
188	*Acartia discaudata* (Giesbrecht, 1882)	+	+		+	
189	*Acartia longiremis* (Lilljeborg, 1853)	+	+	+	+	+
190	*Acartia tonsa* Dana, 1849	+	+	+	+	+
191	*Calanus finmarchicus* (Gunner, 1765)	+	+		+	+
192	*Calanus hyperboreus* Krøyer, 1838		+			
193	*Candacia armata* (Boeck, 1872)		+			
194	*Centropages chierchiae* Giesbrecht, 1889		+			
195	*Centropages hamatus* (Lilljeborg, 1853)	+	+	+	+	+
196	*Centropages typicus* Krøyer, 1849		+		+	
197	*Diaptomus graciloides* Lilljeborg, 1888 [c]				+	+
198	*Eudiaptomus gracilis* (G.O. Sars, 1862)		+		+	+
199	*Eurytemora affinis* (Poppe, 1880)	+	+	+	+	+
200	*Eurytemora carolleeae* Alekseev and Souissi, 2011 [Recently described as a sibling species of *E. affinis* in the Baltic Sea; in the earlier studies in the BP, WBS and NBS, might have been confused with its sibling (Alekseev et al. 2009; Sukhikh et al., 2013)]				+	+
201	*Eurytemora hirundoides* (Nordquist, 1888) (Syn.: *Eurytemora hirundo* Giesbrecht, 1881)	+	+	+	+	+
202	*Eurytemora lacustris* (Poppe, 1887)				+	+
203	*Eurytemora velox* (Lilljeborg, 1853)		+			+
204	*Heterocope appendiculata* Sars, 1863 [c]					+
205	*Limnocalanus grimaldii* (De Guerne, 1886)	+	+	+	+	+
206	*Limnocalanus macrurus* G.O. Sars, 1863	+	+	+	+	+
207	*Metridia lucens* Boeck, 1865		+			
208	*Microcalanus pusillus* G.O. Sars, 1903		+			
209	*Paracalanus parvus* (Claus, 1863)	+	+		+	+
210	*Paraeuchaeta norvegica* (Boeck, 1872)	+	+			
211	*Pareucalanus attenuatus* (Dana, 1849)		+			
212	*Pseudocalanus acuspes* (Giesbrecht, 1881) [The recent molecular data (RFLP results) confirm that *P. acuspes* is the only *Pseudocalanus* species with a resident population in the Baltic Sea (Holmborn et al., 2011). Earlier, two more species from this genus were also considered for this sea: *Pseudocalanus elongatus* (Boeck, 1865) and *P. minutus* (Krøyer, 1845)]	+	+	+	+	+
213	*Temora longicornis* (O.F. Müller, 1785)	+	+	+	+	+

No	Taxa	BP[1]	WBS[2]	NBS[3]	SBS[4]	EBS[5]
	Copepoda, Cyclopoida					
214	*Acanthocyclops robustus* (G.O. Sars, 1863)		+			
215	*Cyclopina gracilis* Claus, 1863		+			
216	*Cyclopina kieferi* Schäfer, 1936 **		+			
217	*Cyclopina norvegica* Boeck, 1864		+			
218	*Cyclops* sp.	+		+	+	+
219	*Cyclops americanus* Marsh, 1893					+
220	*Cyclops furcifer* Claus, 1857 [c]					+
221	*Cyclops kolensis* Lilljeborg, 1901 [c]					+
222	*Cyclops scutifer* G.O. Sars, 1863 [c]				+	+
223	*Cyclops strenuus* Fischer, 1851		+		+	+
224	*Cyclops vicinus* Ulyanin, 1875		+		+	+
225	*Diacyclops bicuspidatus* (Claus, 1857)		+		+	+
226	*Diacyclops bisetosus* (Rehberg, 1880)		+		+	+
227	*Ectocyclops phaleratus* (Koch, 1838) [c]					+
228	*Eucyclops graciloides* Lilljeborg, 1888		+			
229	*Eucyclops lilljeborgi* Sars, 1918 [c]					+
230	*Eucyclops macruroides* (Lilljeborg, 1901) [c]				+	+
231	*Eucyclops macrurus* (G.O. Sars, 1863)				+	+
232	*Eucyclops serrulatus* (Fischer, 1851)		+		+	+
233	*Eucyclops speratus* (Lilljeborg, 1901)		+			
234	*Halicyclops affinis* (G.O. Sars, 1863) **		+			
235	*Halicyclops magniceps* (Lilljeborg, 1853)		+		+	
236	*Halicyclops neglectus* Kiefer, 1935		+			
237	*Macrocyclops albidus* (Jurine, 1820)				+	+
238	*Macrocyclops fuscus* (Jurine, 1820) [c]				+	
239	*Megacyclops viridis* (Jurine, 1820)		+	+	+	+
240	*Megacyclops gigas* (Claus, 1857) [c]				+	
241	*Mesocyclops* sp.	+				
242	*Mesocyclops dybowskii* (Lande, 1890) [c]				+	
243	*Mesocyclops hyalinus* (Rehberg, 1880) **		+			
244	*Mesocyclops leuckarti* (Claus, 1857)		+	+	+	+
245	*Microcyclops bicolor* (Sars) **, [c]					+
246	*Microcyclops gracilis* (Lilljebborg) **, [c]					+
247	*Microcyclops varicans* (G. O. Sars, 1863) [c]					+
248	*Oithona atlantica* Farran, 1908		+		+	

No	Taxa	BP[1]	WBS[2]	NBS[3]	SBS[4]	EBS[5]
249	*Oithona similis* Claus, 1866	+	+		+	+
250	*Paracyclops* sp.	+				
251	*Paracyclops affinis* (G.O. Sars, 1863) [c]					+
252	*Paracyclops fimbriatus* (Fischer, 1853) [c]				+	+
253	*Thermocyclops crassus* (Fischer, 1853) [c]				+	+
254	*Thermocyclops oithonoides* Sars, 1863		+	+	+	+
255	*Tropocyclops prasinus* (Fischer, 1860) [c]				+	
	Copepoda, Monstrilloida					
256	*Cymbasoma rigidum* Thompson, 1888 **		+			
257	*Cymbasoma thompsoni* (Giesbrecht, 1892)**		+			
258	*Monstrilla helgolandica* (Claus, 1863)		+			
	Copepoda, Harpacticoida					
259	*Canthocamptus staphylinus* (Jurine, 1820)		+		+	+
260	*Dactilopodia vulgaris* (Sars) **, [c]					+
261	*Ectinosoma melaniceps* Boeck, 1865		+			+
262	*Halectinosoma curticorne* (Boeck, 1872)	+	+		+	
263	Harpacticoida indet.	+	+	+	+	+
264	*Microsetella norvegica* (Boeck, 1865)		+		+	+
265	*Microarthridion littorale* (Poppe, 1881) [c]	+				
266	*Nitokra hibernica* (Brady, 1880) [c]				+	
267	*Onychocamptus mohammed* (Blanchard and Richard, 1891) (Syn.: *Laophonte mohammed* Blanchard and Richard, 1891) [c]				+	
	Pteropoda					
268	*Limacina retroversa* (Fleming, 1823)	+	+			
	Polychaeta					
269	*Bylgides sarsi* (Kinberg in Malmgren, 1865)	+	+	+		+
270	*Harmothoe imbricata* (Linnaeus, 1769)		+			
271	*Harmothoe impar* (Johnston, 1839)		+			+
272	*Nephtys* sp.		+			+
273	*Nereis diversicolor* O.F. Müller, 1776		+	+		
274	*Pygospio elegans* Claparède, 1863	+	+	+		+
275	*Tomopteris helgolandica*	+	+			
	Polychaeta, larvae	+	+	+	+	+

No	Taxa	BP[1]	WBS[2]	NBS[3]	SBS[4]	EBS[5]
	Chaetognatha					
276	*Parasagitta elegans* (Verrill, 1873)	+	+		+	+
277	*Parasagitta setosa* (Mueller, 1847)	+	+			+
278	*Sagitta bipunctata* Quoy & Gaimard, 1828		+			
	Copelata					
279	*Fritillaria borealis* Lohmann, 1896	+	+	+	+	+
280	*Oikopleura dioica* Fol, 1872	+	+		+	+
	Larvae of Bivalvia (Mollusca) (Plate 5.3.31)	+	+	+	+	+
	Larvae of Gastropoda (Mollusca) (Plate 5.3.31)	+	+	+	+	+
	Larvae of Cirripedia (Crustacea) (Plate 5.3.32)	+	+	+	+	+
	Larvae of Bryozoa (Plate 5.3.35)	+	+	+	+	+
	Larvae of Echinodermata (Plate 5.3.35)	+	+	+	+	

[1] **BP:** **Baltic Proper:** after Ackefors (1965, 1969), Ostenfeld (1931), Mankowski (1948b, 1950b, 1951, 1959), Siudzinski (1965), Mielck & Künne (1932-1935); Holmborn et al., 2011;

[2] **WBS:** **Western Baltic Sea** (Kieler Bight, Mecklenburg Bight): after Remane (1940), Gerlach (2000), Kube et al. (2007a, b); Holmborn et al., 2011;

[3] **NBS:** **Northern Baltic Sea** (Archipelago Sea, Bothnian Sea): after Vuorinen (pers. com.), Lindquist (1959), Ostenfeld (1931); Holmborn et al., 2011;

[4] **SBS:** **Southern Baltic Sea** (Darss-Zingst Bodden Chain; Gdansk Basin; Vistula Lagoon; Curonian Lagoon): after Mankowski (1948a, 1950a, b), Telesh & Heerkloss (2002, 2004, and references therein); Alekseev et al., 2009; Holmborn et al., 2011 ; Sukhikh et al., 2013;

[5] **EBS:** **Eastern Baltic Sea** (Gulf of Riga; Gulf of Finland, *including* the freshwater Neva Bay): after Purasjoki (1958), Flinkman (pers. com.), Telesh (pers. com), Silina (1997), Telesh & Heerkloss (2002, 2004, and references therein), Rodionova et al. (2005), Rodionova & Panov (2006); Alekseev et al., 2009; Holmborn et al., 2011; Sukhikh et al., 2013.

*Syn. – synonyms; ** – not registered in ITIS; **c** – species found mainly in the coastal nearshore (oligohaline or fresh) waters

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CHAPTER 6

Description of major groups of meso- and macrozooplankton

This Chapter provides brief information on morphology, reproduction modes, development and ecology of the most common representatives from the major taxonomic groups of meso- and macrozooplankton in the Baltic Sea.

6.1 Cnidaria

Cnidarians are diploblastic metazoans; i.e. they consist of two epithelial layers only – an ectodermal epidermis and an endodermal gastrodermis, separated by a primarily acellular extracellular matrix called mesogloea. The most characteristic structures are the cnidae (nematocysts) produced by specific cells and generally used to catch prey that may be much larger than the individual itself may.

Cnidarians not only use larvae as means of dispersal in the open waters. Additionally, they have achieved an obligate generation completely committed to propagation; a clear and concise description of this process is given elsewhere (Larink and Westheide, 2006). In an alternation of generations, called metagenesis, this sexually reproducing generation usually is a free-swimming **medusa**, which arises from a polypoid generation through budding. In some cases, medusae may also arise asexually from other medusae, but characteristically medusae produce and broadcast either sperm or eggs. The fertilized eggs develop into ciliated free-swimming planulae that later become attached to the bottom and metamorphose into the **polyp**. Polyp and medusa of one species may be very different in phenotype and their relationship is rarely apparent; thus, in many cases they were described as different species.

The Cnidaria comprise **Anthozoa**, **Cubozoa** (exclusively tropical forms), **Scyphozoa**, and **Hydrozoa**, all different in structure, size and reproduction of their polypoid and medusoid forms. In the Hydrozoa, medusae are often secondarily suppressed, in which case the asexual buds of the polyp do not develop into free-swimming medusae but remain sessile. In the Anthozoa, no metagenesis occurs and the exclusively polypoid forms reproduce both sexually and asexually. Planktonic stages of all Anthozoa, Scyphozoa and Hydrozoa can be found in the sea (Figures 6.1–6.3).

The moon jelly, a scyphomedusae *Aurelia aurita* is the most dominant species of the Baltic Sea. Barz et al. (2006) and other authors characterise it as a species, which can reduce the stocks of mesozooplankton communities considerably in years of high abundance (e.g. Möller, 1980; Matsakis & Conover, 1991; Purcell, 1992; Olesen, 1995;

Omori et al., 1995; Lucas et al., 1997; Schneider & Behrends, 1998). These medusae compete for zooplankton with commercially important planktivorous fish species and ctenophores, but they may also prey on fish eggs and larvae and thus directly affect their recruitment (Barz et al., 2006). The Belt Sea, the western Baltic Sea, and the Archipelago Sea are known as strobilation areas for *A. aurita*. However, ephyra are not regularly found in the Baltic Proper. Some authors concluded that *A. aurita* does not strobilate in this area (Janas & Witek, 1993; Barz & Hirche, 2005). However, the occurrence of the other larger Scyphomedusae, *Cyanea capillata* in the western Baltic Sea and in the Baltic proper is always a sign for salt-water influx from the Kattegat area. An indication for strong salt-water influxes is the occurrence of the hydromedusae *Euphysa aurata* in the western Baltic Sea (Wasmund et al., 2004).

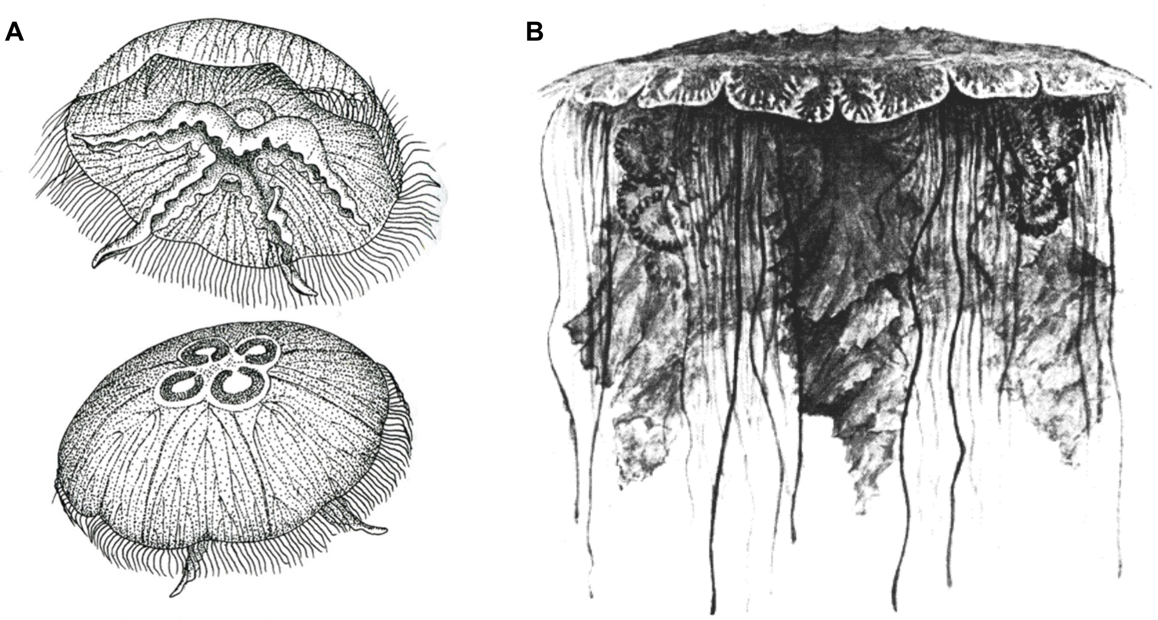

Figure 6.1: Cnidaria, Scyphomedusae: **A**, *Aurelia aurita* (modified from Hayward & Ryland, 2005); **B**, *Cyanea capillata* (after Russel, 1970).

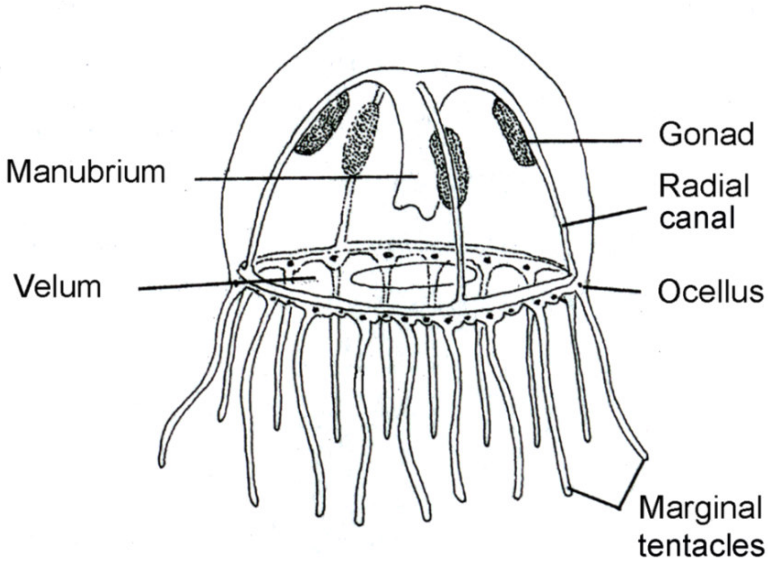

Figure 6.2: Typical hydroid medusae (modified from Hayward & Ryland, 2005).

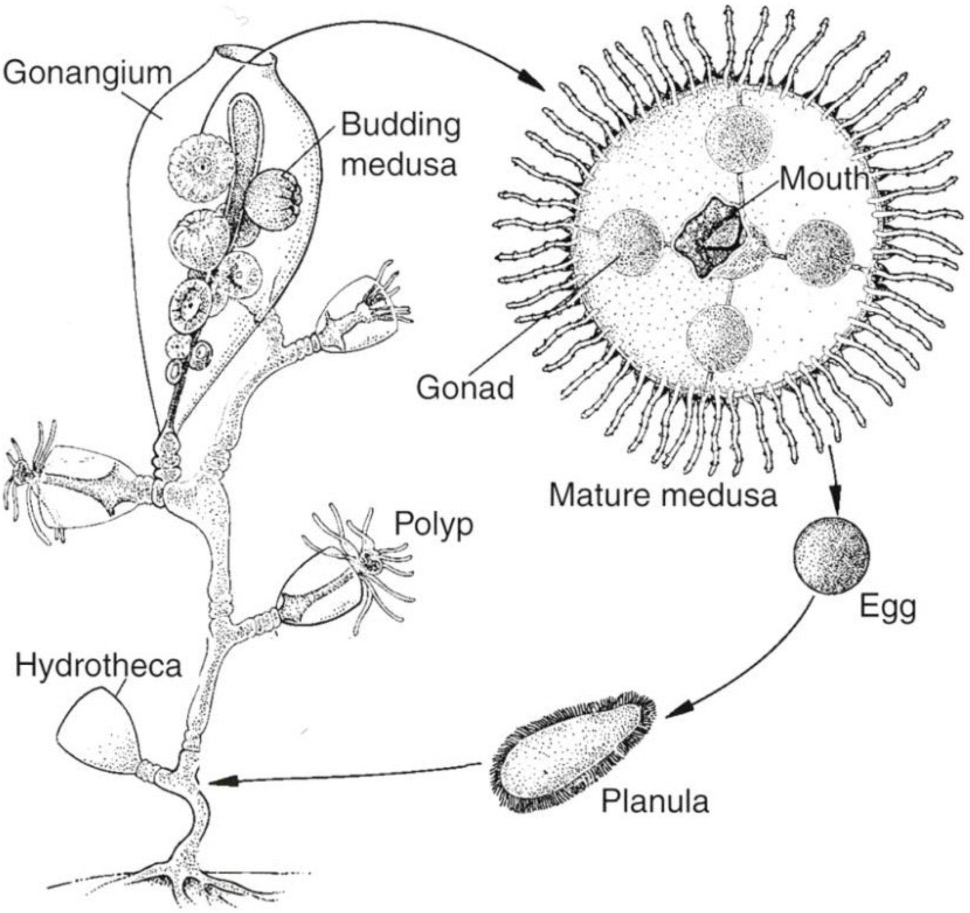

Figure 6.3: Life cycle of a Leptomedusae *Obelia geniculata* (modified from Larink & Westheide, 2006).

6.2 Ctenophora

Ctenophora, or comb jellies, are presumably holoplanktonic organisms. Usually they are several centimetres long; they occur in all seas, and most of the ctenophore species are considered to be cosmopolitan (Larink & Westheide, 2006).

The body of comb jellies has biradial symmetry: one central plane passes through both tentacle pouches and another plane is at a right angle to this, passing through the mouth slit (Fig. 6.4). Each plane divides the body into equal halves. Eight comb rows (ctenes) consisting of transverse plates of fused cilia are the locomotory organs by which the animals actively swim, the oral pole forward.

The **Tentaculifera** species have two long contractile tentacles, each emerging from the bottom of a deep epidermal pouch – the example is the ovoid species of the genus *Pleurobrachia*; their regular branches (tentilles) are covered with sticky colloblasts that on contact adhere to prey (e.g., to planktonic copepods and other smaller organisms). **Lobata** (e.g. *Bolinopsis infundibulum*) are tentaculiferan comb jellies with two additional oral lobes flanking the mouth and the reduced tentacles. The lobes form a large cavity into which water and potential prey organisms are drawn by large cilia during the mouth-forward locomotion. The **Atentaculata** lack tentacles completely, the example is the cylindrical species of the genus *Beroe*. They feed on other ctenophores by swallowing them through their large slit-like mouth.

The ctenophore species are usually closely paired in predator-prey relationships that control their abundance. In the Northern and Baltic seas, once per year (between March and July) these comb jellies reproduce massively, increasing in abundance by as much as four orders of magnitude within one to three months (Larink & Westheide, 2006). *Pleurobrachia pileus* feeds on herbivorous zooplankton, especially on the copepods that appear in spring: one individual *P. pileus* may eat as many as 300 copepods per day; then usually *Beroe gracilis* appears which feeds exclusively on *P. pileus* and practically eliminates it within three weeks. *Beroe cucumis* feeds mainly on *B. infundibulum*.

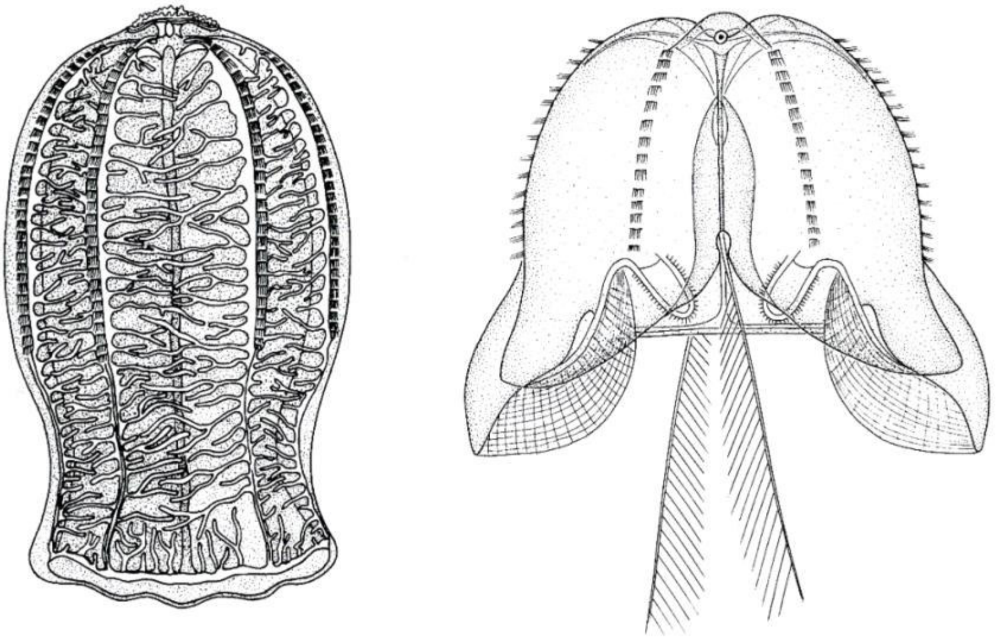

Figure 6.4: Ctenophores; general schematic view of *Beroe* sp. (left) and *Bolinopsis* sp. (right, modified from Westheide & Rieger, 1996).

The ctenophore species *Mnemiopsis leidyi* is one of the most recent invaders to the Baltic Sea. In summer 2006, the first observations of this West Atlantic comb jelly in Northern Europe were reported from the North Sea, the Skagerrak and the south-western Baltic Sea (Faasse & Bayha, 2006; Hansson, 2006; Javidpour et al., 2006). During autumn/winter 2006 and spring 2007, the further spread of this invasive ctenophore from the south-western towards the central Baltic Sea up to the south eastern Gotland Basin was reported (Kube et al., 2007a). The abundances were generally low (max. 4 ind. m^{-3}). While *M. leidyi* was found in the entire water column in Kiel Bight, it occurred exceptionally below the halocline in the deep stratified central Baltic basins. Data of a weekly sampling program at a nearshore location in Mecklenburg Bight between January and May 2007 showed that up to 80% of the individuals were juveniles, smaller than 1 mm total body length, and that *M. leidyi* survived the winter in the Southern Baltic Sea, even when abundances dropped down to <1 ind. m^{-3} in February. During the summer of 2007, a regional gradient in population density of *M. leidyi* remained. The abundances west off Darss Sill exceeded those in the Baltic proper by one to two orders of magnitude. The maximum abundances of 500 ind. m^{-3} in Kiel Bight corresponded to those in the area of origin of *M. leidyi* – off the North American coast, and to those in the Black Sea during the 1980s. Generally, the adults were smaller in the Baltic Sea (6 cm) than in the Black Sea (18 cm) (Kube et al., 2007b). In 2007, *M. leidyi* spread up to the entrance of the Gulf of Finland and the central Bothnian Sea, where it was recorded by the Finish Institute of Marine Research in August/September 2007 at abundances lower than 10 ind. m^{-3}. The highest densities including juveniles were found in the water layers around the halocline.

A first assessment of the physiological demands of this species versus the environmental conditions of the Baltic Sea showed that the successful establishment of this ctenophore is probable in the south-western and central Baltic Sea (Kube et al., 2007a). At present, it is likely that *M. leidyi* has been successfully established in the Baltic Sea as the fifth ctenophore species.

6.3 Rotifera

The phylum Rotifera, or rotifers in English usage, is a group of microscopic aquatic or semi-aquatic invertebrates, which comprises around 2000 species of unsegmented, bilaterally symmetrical pseudocoelomates. The majority of rotifers inhabit fresh waters; however, some genera also occur in brackish and marine habitats. For example, about 20 of 32 species comprising the genus *Synchaeta* are described as marine (Nogrady, 1982). Only one order (Seisonidea, containing a single genus) and about 50 species of rotifers are exclusively marine; only two species are encountered in the plankton of the open Atlantic Ocean (Nogrady et al., 1993). Rotifers are not as diverse or abundant in marine environments as microcrustaceans but they are common in many brackish, coastal, near shore and interstitial marine communities (Egloff, 1988), where they occasionally comprise the dominant portion of the zooplankton biomass (Schnese, 1973; Johansson, 1983). In the brackish waters of the open Baltic Sea, rotifers form a highly diverse and widely distributed group due to significant influence of the waters from the extended coastal areas with the rich fauna of freshwater and euryhaline rotifers (Telesh & Heerkloss, 2002; Telesh, 2004).

Morphologically, rotifers possess two main distinctive features: corona and mastax. The ciliated region at the apical end (head) of a rotifer is called the **corona** (“wheel organ”); it is used for locomotion and food gathering (Fig. 6.5). In adults of rotifers from some families, ciliation is reduced and the corona is replaced by a funnel or bowl-shaped structure (the infundibulum), at the bottom of which the mouth is located. Along the edge of the infundibulum of most species, there is a series of long setae (bristles).

The other universal characteristic of rotifers is a muscular pharynx, the **mastax**, possessing a complex set of hard jaws called **trophi** (Fig. 6.6).

Most rotifers are free living, they swim in the pelagial or crawl on substrata (bottom sediments, stems of macrophytes); however, many species live permanently attached to plants (the latter are called sessile rotifers). Very few rotifers are parasitic; the vast majority of rotifers are solitary but some (ca. 25 species) form colonies of various sizes (Wallace, 1987).

Nearly all free-living rotifers are suspension-feeders that utilise microalgae smaller than 12 µm in diameter (sometimes as large as 18 µm), bacteria and detritus (Pourriot, 1977); some are obligate or occasional predators.

Most rotifers are either obligatory parthenogenetic (e.g. the whole class of bdelloids) or produce males for a brief period, sometimes only a few days, each year or season (Nogrady et al., 1993). Male rotifers are usually strongly reduced in size and sometimes only slightly resembling the females of the same species (Fig. 6.5).

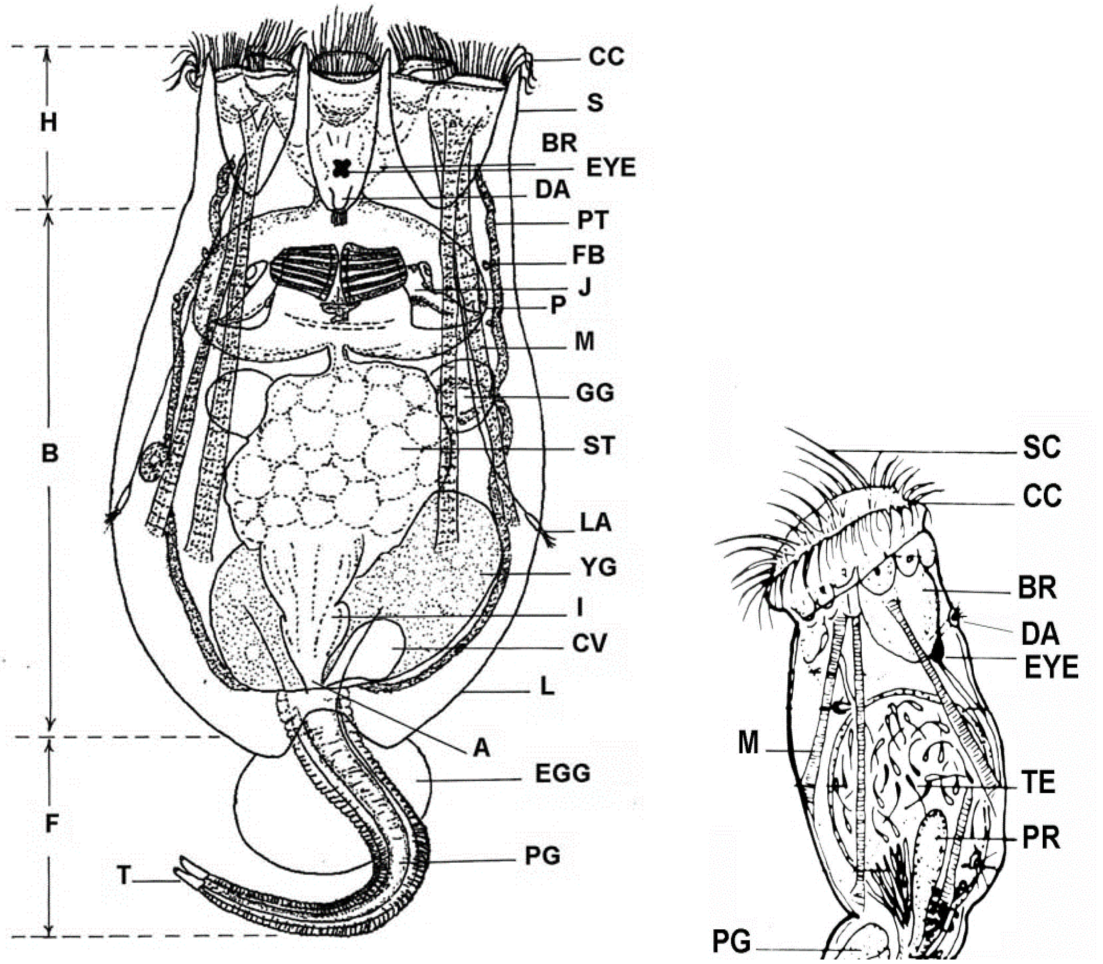

Figure 6.5: Morphology of a rotifer *Brachionus calyciflorus*: female on the left (dorsal view, modified from Pontin, 1978), male on the right (lateral view, modified from Koste, 1978). H – head, B – body, F – extended foot, A – anus position, BR – brain, CC – coronal cilia, CV – contractile vesicle, DA – dorsal antenna, EYE – eye, EGG – egg, FB – flame bulb, GG – gastric gland, I – intestine, J – jaws, L – lorica, LA – lateral antenna, M – muscle, P – pharynx, PE – penis, PG – pedal gland, PR – prostate, PT – protonephridium, S – spine, SC – sensory cirry, ST – stomach, T – toes, TE – testis, YG – yolk gland (after Telesh & Heerkloss, 2002).

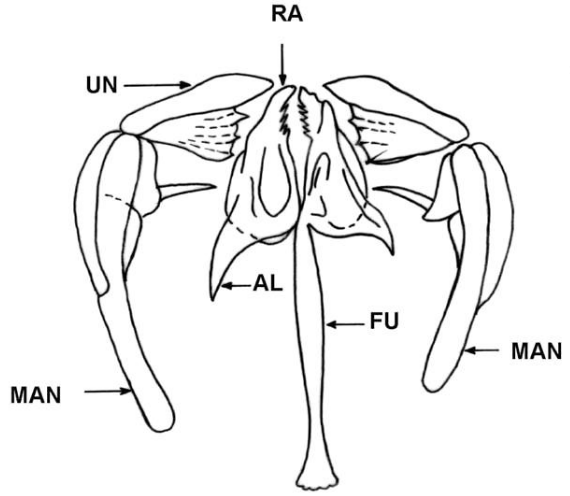

Figure 6.6: General structure of trophi, dorsal view: RA – ramus, UN – uncus, MAN – manubrium, FU – fulcrum, AL – alula (after Telesh & Heerkloss, 2002).

Polymorphism is a common phenomenon to many rotifer species. Individuals of the same species collected from one locality over a period of time often show changes in one or more characteristics from one generation to another (e.g., length of spines, or proportions of the body). In some localities these variations are season-specific: a phenomenon known as cyclomorphosis, which is most common in some loricate rotifers (e.g., *Keratella* and *Brachionus*), but also can be observed in the illoricates (e.g., *Asplanchna*).

Although rotifers can be considered as a relatively small phylum, they are extremely important in the environments that they inhabit because their reproductive rates are the fastest for any metazoan (Nogrady et al., 1993). They can populate vacant niches with exceptional rapidity, convert primary (algal) and bacterial production into a form usable for secondary consumers (e.g. insect larvae and fish fry), and perform this transformation with remarkable efficiency producing up to 95% of total zooplankton biomass (e.g., in rivers and estuaries) (Telesh, 1995; Telesh & Heerkloss, 2002).

6.4 Cladocera

The commonly accepted today name of the order Cladocera according to Fryer (1987) belongs to a group of crustaceans of polyphyletic origin (see Telesh & Heerkloss, 2004, and references therein). The order Cladocera includes crustaceans that nearly all, with the exception of just several species, range in size from 0.2 to 3.0 mm. Cladocera are primarily freshwater organisms, and aside from rapid streams and strongly polluted waters, they can be abundant in every water body. In the estuaries, the greatest abundance of species may be collected in the vegetation, and at margins of the macrophytes stands and open water. Many species inhabit weedy littoral areas, some live on/near bottom. Limnetic forms (*Daphnia*, *Diaphanosoma*, *Holopedium*, *Leptodora* and others) are usually light-coloured and translucent; littoral and bottom-dwelling species are ranging in colour of carapace and body tissues from yellowish-brown to reddish-brown, greyish, or nearly black.

The general schemes of body morphology of different cladocerans are presented in Figures 6.7–6.9.

In the Baltic Sea, the Onychopod cladocerans from the genera *Podon*, *Pleopsis* and *Evadne* can be very abundant, especially in spring (see also Chapter 2). *Evadne* individuals consume dinoflagellates and tintinnids, various other particles as well as small zooplankters. *Bosmina* spp. are among other common zooplankters in the open Baltic waters. The majority of species and almost all common ones are eurythermal. Many species can withstand oxygen concentrations of less than one part per million.

Patchiness in spatial distribution and diurnal vertical migrations are common features of cladoceran crustaceans. However, characteristics of aquatic environment expose greater changes along the vertical than along the horizontal dimensions in the water body. Thus, the two contrasting needs of many zooplankters: to feed within the most illuminated zone and not to be seen by visual predators – result in regular movements of the whole populations into and out of the upper illuminated layers (Brandl, 2002).

Different species of *Bosmina* (*Eubosmina*) are the common cladocerans in the Baltic Sea; meanwhile, **taxonomy of the genus *Bosmina* even now remains a field in need of revision** (see review in Telesh & Heerkloss, 2004, p. 36).

Among cladocerans, there are three non-indigenous species that have recently invaded different regions of the open Baltic Sea: *Cercopagis pengoi, Evadne anonyx* and *Cornigerius maeoticus* (for details see: Chapter 2; Ojaveer & Lumberg, 1995; Rodionova et al., 2005; Rodionova & Panov, 2006, and references therein).

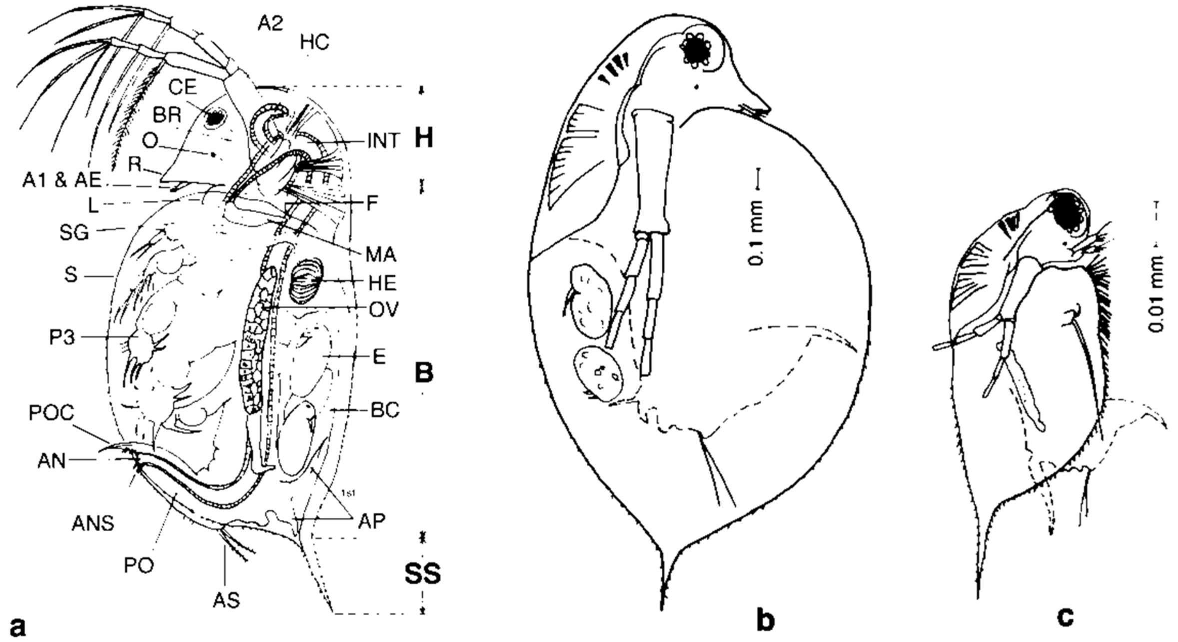

Figure 6.7: *Daphnia*, schematic, lateral. **a,** Female: A1 – first antenna (antennule), A2 – second antenna, AE – aesthetascs, AN – anus, ANS – anal spines, AP – abdominal processes, AS – abdominal setae, B – body, BR – brain, BC – brood chamber, CE – compound eye, E – embryo, F – fornix, H – head, HC – hepatic caecum, HE – heart, INT – intestine, L – labrum, MA – mandible, O – ocellus, OV – ovary, PO – postabdomen, POC – postabdominal claw, P1 – P5 – trunk limbs 1–5, R – rostrum, S – shell, SG – shell gland, SS – shell spine; **b,** *D. pulex*, female; **c,** *D. pulex*, male (after Telesh & Heerkloss, 2004).

The great importance of planktonic Cladocera in the aquatic trophic webs as food for fish was emphasised first in late XIX century, and since then by innumerable investigators (see Telesh & Heerkloss, 2004, and references therein). The dynamics of fish and zooplankton have been linked intimately ever since fish evolved from macrophagy to microphagy (Kerfoot & Lynch, 1987). Various studies of the stomach contents of young fish show from 1% to 95% of Cladocera by volume, and very few studies show less than 10% (Pennak, 1978). However, some cladoceran species (e.g., a large-bodied predatory cladoceran of the Ponto-Caspian origin, *Cercopagis pengoi*, one of the recent invaders in the Baltic Sea), being a suitable food item for planktivorous fish, may also demonstrate structural and functional impact on zooplankton community thus performing competitive interactions for food (smaller crustaceans) with fish populations as shown recently for the Baltic proper (Gorokhova, 1998), the Gulf of Riga (Ojaveer & Lumberg, 1995), and the Gulf of Finland (Antsulevich & Välipakka, 2000; Telesh et al., 2000; Telesh & Ojaveer, 2002; Naumenko & Telesh, 2019; Telesh & Naumenko, 2021).

In general, the role of zooplankton for the earlier juvenile fish is critical to high fish survival so that they can take advantage of an abundance of phytoplankton and detritus when available (Fernando, 2002).

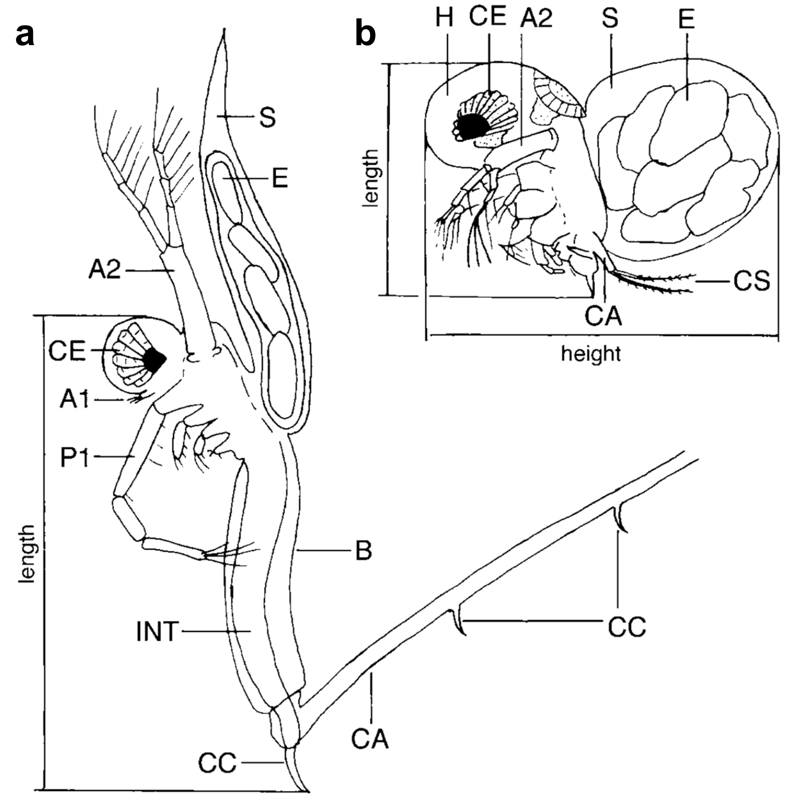

Figure 6.8: Morphology of Onychopoda: **a** – *Cercopagis*, **b** – *Polyphemus*: A1 – first antenna (antennule), A2 – second antenna, B – body, CA – caudal appendage, CC – caudal claw, CE – compound eye, E – parthenogenetic embryos, CS – caudal setae (setae notatoria), H – head, INT – intestine, P1 – trunk limb (thoracic leg) 1, S – shell (brood chamber) (after Telesh & Heerkloss, 2004).

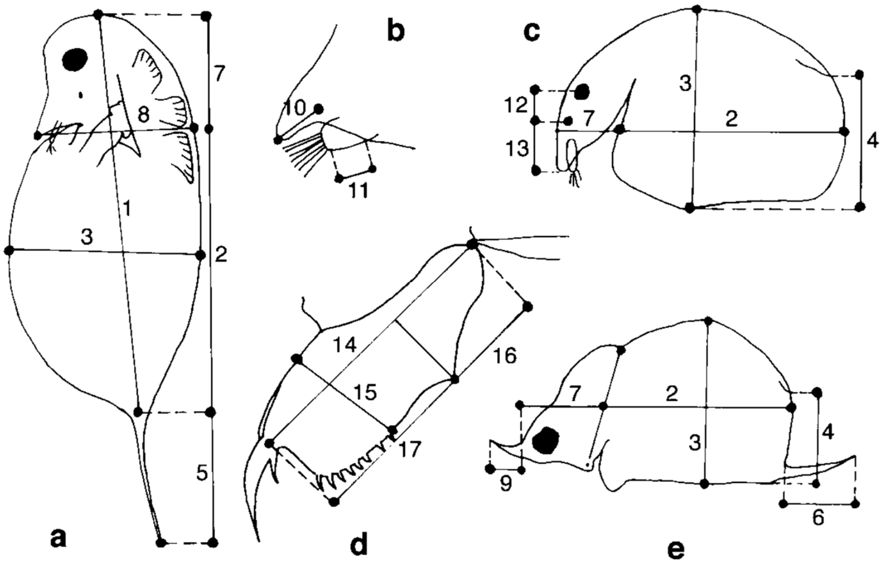

Figure 6.9: How to measure Cladocera: **a, b** – *Daphnia*; **c, d** – *Alona*; **e** – *Scapholeberis*. **1** body length, **2** length of carapace, **3** maximum height of valve, **4** height of posterior margin of valves, **5** length of shell spine, **6** length of mucro, **7** length of head, **8** height of the posterior margin of head shield, **9** length of the horn on the proximal edge (vertex) of head shield, **10** length of rostrum, **11** length of antenna 1, **12** distance between eye and ocellus, **13** distance between ocellus and the end of rostrum, **14** length of postabdomen, **15** maximum width of postabdomen, **16** length of proximal part of postabdomen, **17** length of distal part of postabdomen (from Telesh & Heerkloss, 2004, adapted from Flössner, 2000).

6.5 Copepoda

Copepoda is a very diverse and the most abundant group of metazoans in the pelagial of the World Ocean (Larink & Westheide, 2006). Free-living planktonic copepods range in body length from 0.5 to 5 mm. Copepod crustaceans from three suborders inhabit the open waters of the Baltic Sea: Calanoida, Cyclopoida and Harpacticoida (Fig. 6.10). These crustaceans form a ubiquitous component of the zooplankton community.

Copepods differ in size, external morphology, ecology and feeding habits. Most Calanoida are free-living, planktonic, herbivorous, fine particles filter feeders. Cyclopoida are also planktonic crustaceans, but very often they inhabit near-bottom biotopes; they are generally micro-predators that feed on small invertebrates and even fish larvae but also consume algae. Harpacticoida are mainly meiobenthic or epibenthic grazers, they occur in plankton only sporadically, being washed out from their bottom habitats by strong water movements. In general, Harpacticoida are only temporarily in plankton, although these crustaceans are often found in zooplankton samples collected in the shallow estuarine waters.

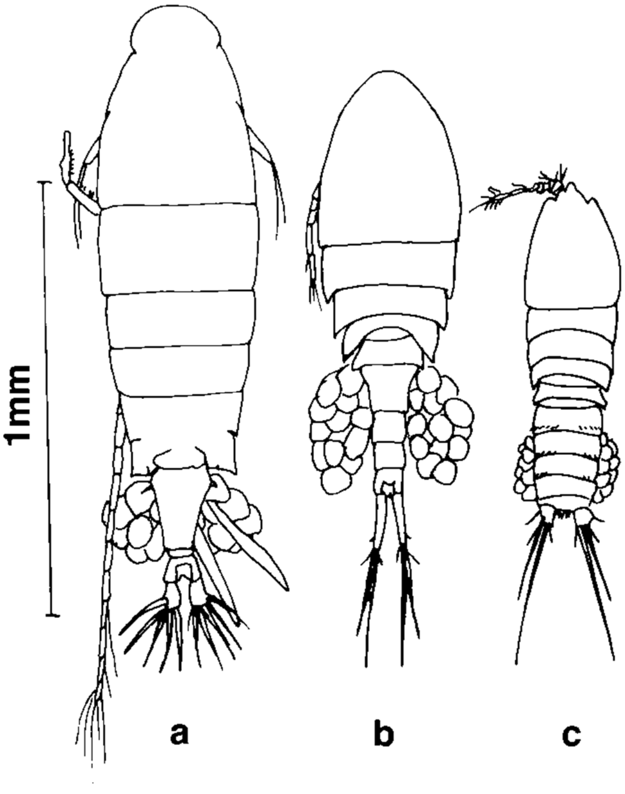

Figure 6.10: Scheme of calanoid (**a**), cyclopoid (**b**) and harpacticoid (**c**) copepods (after Telesh & Heerkloss, 2004).

Copepods are food to many predators, mainly planktivorous fish. The choice of a copepod as a prey is a function of its size, morphology, motion (angle, speed, escape ability) and pigmentation. The coloured species are more vulnerable to predation than pale or transparent ones. Presence of fish can influence physiological parameters and population dynamics of copepods. To limit predation, some copepods can retreat to habitats devoid of the predator, perform vertical migrations, form swarms, or enter into dormancy (Dussart & Defaye, 2001).

Copepods have different tolerance to salinity; the presence or absence of some species allows deductions on the physical-chemical characteristics or the degree of pollution of the environment (Dussart & Defaye, 2001).

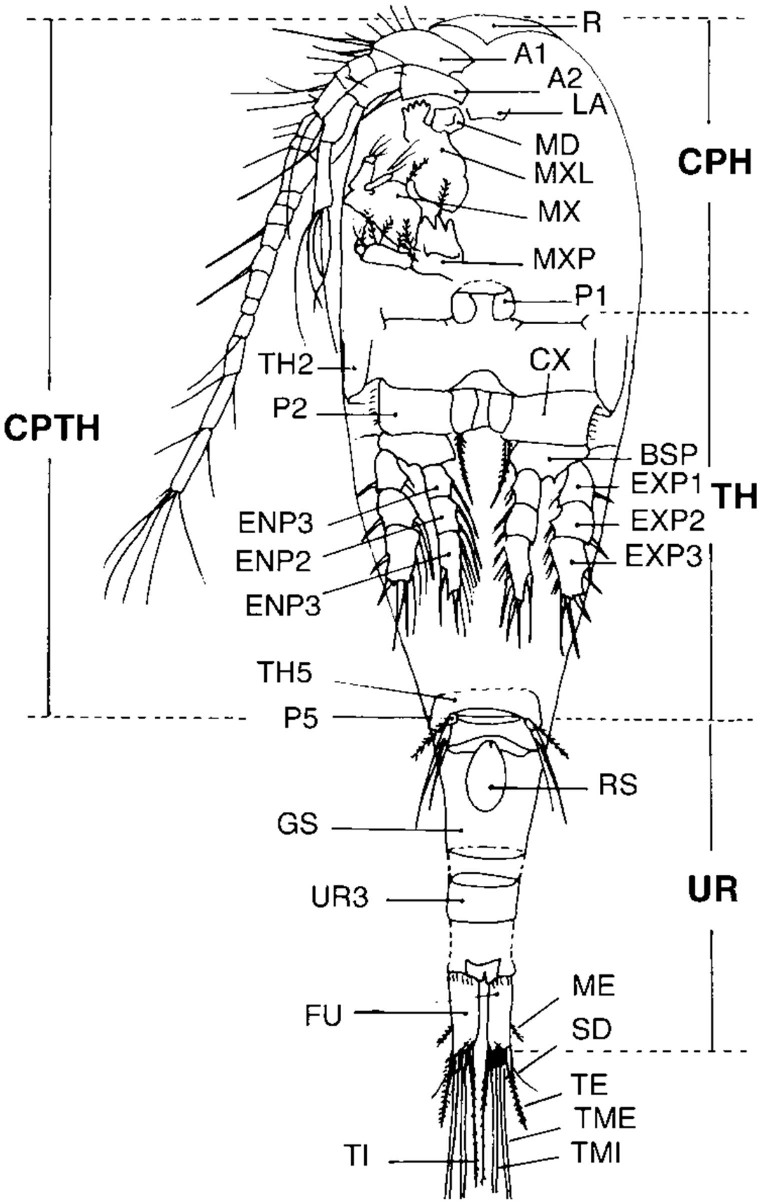

Figure 6.11: Morphology of a female cyclopoid (ventrally): CPH – cephalosome, TH – thoracosome, CPTH – cephalothorax, UR – urosome, R – rostrum, A1 – antennule (antenna 1), A2 – antenna 2, LA – labrum, MD – mandible, MXL – maxillule, MX – maxilla, MXP – maxilliped, P1, P2, P5 – swimming legs 1, 2, 5, TH2, TH5 – thoracic somites 2 and 5, CX – coxa, BSP – basipodite, EXP1, EXP2, EXP3 – exopodites 1-3, ENP1, ENP2, ENP3 – endopodites 1-3, GS – genital double somite, RS – seminal receptacle (= *receptaculum seminis*), UR3 – urosomite 3, FU – furca, ME – marginal (external) furcal seta, SD – dorsal furcal seta, TE – terminal external furcal seta, TME – terminal medial external seta, TMI – terminal medial internal seta, TI – terminal internal furcal seta (from Telesh & Heerkloss, 2004, after Dussart & Defaye, 1995, with modifications).

However, the important role of copepods as biological indicators cannot be assessed unless the copepod species identification is properly fulfilled. Taxonomic differentiation of copepods is based mainly on external morphology of mature females and males. Species identification of copepods is an important though tedious procedure. Shape, colour and size of the body, relative size of the appendages (particularly the length of antennules relative to the cephalosome or the urosome) and other measurements are noted. After general observations, drawings of the whole animal should be made.

For cleaning the crustacean and making its body more transparent, the animal must be kept in a drop of concentrated lactic acid ($CH_3CHOHCOOH$) for a time from 1 h up to overnight, depending on the size of the crustacean. Sometimes it is possible to recognize the copepod species without dissection (Alekseev, 2002; Telesh & Heerkloss, 2004). However, in most cases, species identification of copepods requires not only examination of the whole crustacean under the microscope but also a dissection and mounting of relevant structures. For more details of this procedure see Downing and Rigler (1984), Huys and Baxshall (1991), ICES (2000), Dussart and Defaye (2001), Alekseev (2002).

Copepods can be of different shape: elongated, fusiform, or cylindrical. General schemes of body morphology of cyclopoid and calanoid copepods are presented in Figures 6.11 and 6.12; schematic drawings of their nauplia and copepodites are given in Figures 6.13–6.15.

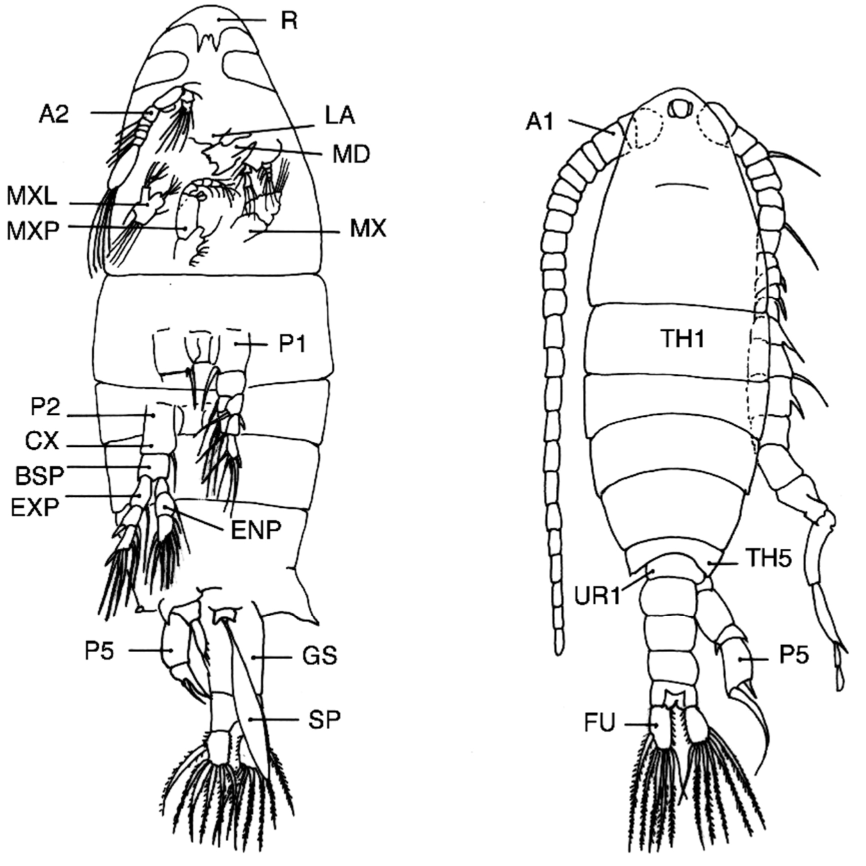

Figure 6.12: Morphology of a female (ventrally) and male (dorsally) calanoid: R – rostrum, A1 – antennule (antenna 1), A2 – antenna 2, LA – labrum, MD – mandible, MXL – maxillule, MX – maxilla, MXP – maxilliped, P1, P2, P5 – swimming legs 1, 2, 5, TH1, TH5 – thoracic somites 1 and 5, CX – coxa, BSP – basipodite, EXP – exopodite 1, ENP – endopodite, GS – genital double somite, RS – seminal receptacle (= *receptaculum seminis*), UR1 – urosomite 1, FU – furca, SP – spermatophore (from Telesh & Heerkloss, 2004, after Dussart & Defaye, 1995, with modifications).

Most copepods reproduce sexually; however, some cases of parthenogenesis have been reported and checked experimentally (Dussart & Defaye, 2001). The sex ratio (males/females) in a copepod population is usually below 1, often due to a different behaviour of the sexes.

Sexual reproduction implies that the male deposits a spermatophore near the genital aperture of the female. Fertilized eggs develop within a single egg sac attached to the ventral side of the genital somite centrally in Calanoida, or in two symmetrically located egg sacs in Cyclopoida. The duration of the embryonic development depends on many factors, among which temperature is one of the most important. When embryonic development is completed, in most copepods, the female loses the egg sac(s), and the eggs hatch together.

Among Crustacea, copepods have been cited as exhibiting the most complete example of metamorphosis (Dussart & Defaye, 2001). They consequently pass through 6 nauplial (Fig. 6.13) and 5 copepodite stages (Figs 6.14, 6.15) before maturation. The eggs hatch into a larva called nauplius – the typical planktivorous larva of crustacean arthropods. In calanoids, naupliar larvae are ovoid, slender and somewhat compressed laterally (Fig. 6.13a). In cyclopoids, nauplii are dorsoventrally compressed and have a compact, pear-shaped body (Fig. 6.13b).

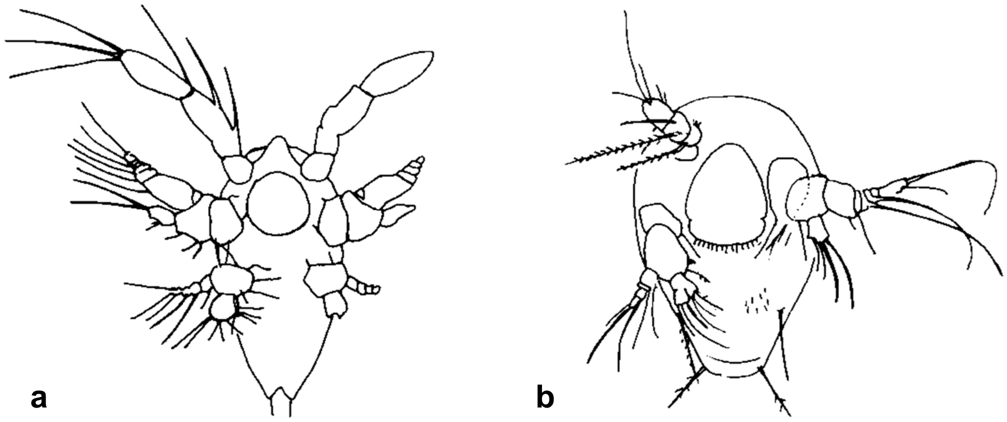

Figure 6.13: Nauplii N2 of calanoid (**a**) and cyclopoid (**b**) copepods, ventral view (modified from Einsle, 1993).

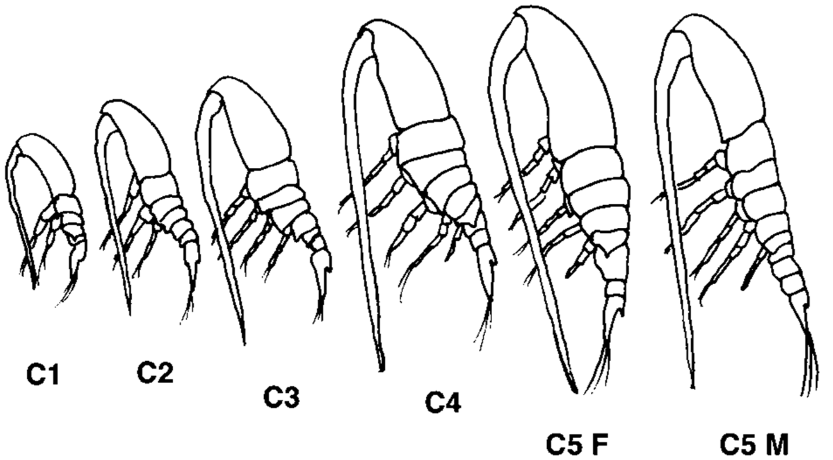

Figure 6.14: Development of copepodite stages (C1-C5, C5F – female, C5M – male) of a calanoid copepod, lateral view (modified from Einsle, 1993).

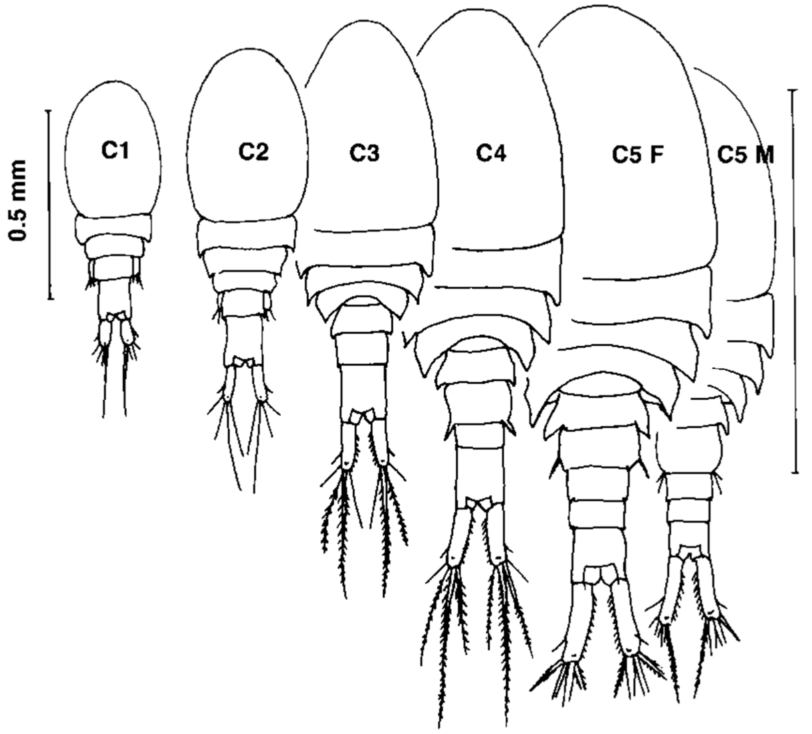

Figure 6.15: Development of copepodite stages of a cyclopoid copepod, dorsal view (modified from Einsle, 1993). Abbreviations as in Fig. 6.14.

6.6 Chaetognatha

The majority of Chaetognatha (arrow worms) are holoplanktonic marine invertebrates that can reach relatively high densities in the sea pelagial waters.

Arrow worms of the genera *Sagitta* and *Parasagitta* perfectly represent the type of optimally adapted voracious predators in the plankton community: they are relatively large (15-45 mm), fast, visual, transparent and streamlined animals that see and attack their prey by short forward darting motions when attacking various pelagic organisms, mostly copepods but also small fish, as large as themselves. A *Sagitta* may consume the equivalent of 64% of its body mass in food per day; otherwise, they are an important prey for fish (Larink & Westheide, 2006).

Chaetognaths are protandrous hermaphrodites: paired testes are located in the tail of the elongate body, paired ovaries – in the posterior part of the trunk (Fig. 6.16). Arrow worms have no larvae: development is direct and very rapid for the feeding juveniles.

The most common species in the Baltic Sea are *Parasagitta elegans* and *Parasagitta setosa*. These two species are difficult to distinguish, especially when the specimens are juveniles; but when adult, *P. elegans* becomes larger (up to 20 mm) than *P. setosa* (up to 14 mm). Besides, *P. setosa* is known to prefer more saline waters, and thus its distribution varies with the extent to which Atlantic oceanic water penetrates into the coastal water bodies (Larink & Westheide, 2006).

Chaetognaths are very mobile and are able to swim against substantial water current. They migrate horizontally some hundred meters per day and undergo daily vertical migration. Many of them escape when sampling is performed with inappropriately small plankton net.

6.7 Appendicularia

Appendicularia are the exclusively holoplanktonic tunicates (Chordata, Tunicata). They are also called Larvacea because of their apparent retention of ascidian larval organisation. Appendicularians are tiny solitary animals with peculiar anatomy and unique filter feeding system.

The two types of larvacean that are commonly found in plankton samples can be readily separated by reference to the shape and size of their body and tail. Members of the Oikopleuridae have a relatively compact body and linear tail (Fig. 6.17a), while Fritillaridae have a more delicate body and thin, broad tail (Fig. 6.17b).

Oikopleura dioika is one of the most common appendicularians, rather abundant in the Baltic Sea. It looks like one of the tadpole ascidian larvae, but the prominent tail with notochord and nerve cord is persistent. It is positioned below the trunk, perpendicular to the long axis of the animal and is five times longer than the trunk, reaching 3 mm.

In the plankton samples, commonly only these "naked" animals will be observed. Meanwhile, actually in the sea they live inside of a mucous construction, the so-called house (Fig. 6.18). This construction is almost spherical in shape; it consists of a number of intercommunicating chambers, funnels, filters, intake openings and outlets, and functions as a complicated filtration system. Even very small particles (below 0.5 µm) can be trapped from the water by this system, accumulated and transported to the mouth of the appendicularian. Interestingly enough, it was here in the appendicularian house that the presence of nanoplankton organisms in the sea was first demonstrated by the filtering activity of these animals (Larink & Westheide, 2006).

Water is moved through the appendicularian house by the pressure generated by the beats of the tail. When the tail beats slowly, the animal hardly moves through the water, and filtering is optimal. If particles are few, the tail beats more rapidly; then water is ejected in a greater quantity and thus a jet effect propels the house forward.

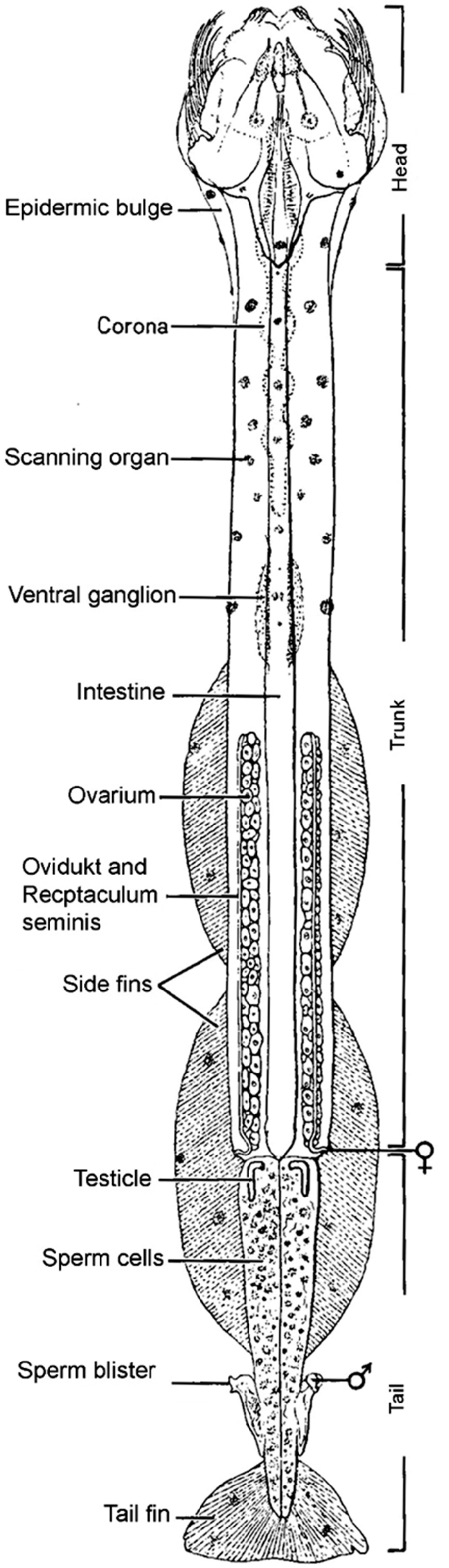

Figure 6.16: *Sagitta bipunctata*, scheme of body morphology (modified from Storch & Welsch, 1999).

The fragile construction of the house is secreted by gland cells (oikoblasts) in the epidermis. When filters are clogged with particulate matter, the animal deserts the house. This also happens when it is captured by plankton net or disturbed otherwise. Before leaving the house, the appendicularian builds (secretes) a new proto-house which can be inflated within few seconds; 4 to 16 new houses can be secreted by one appendicularian every day.

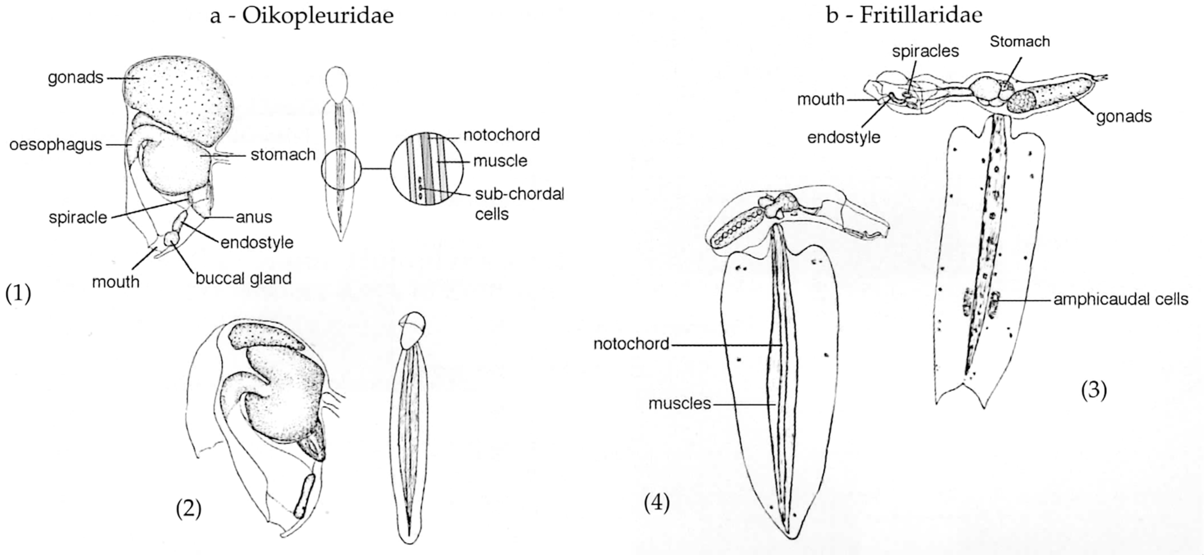

Figure 6.17: Appendicularia, schematic lateral view: a – Oikopleuridae, b – Fritillaridae; 1 – *Oikopleura dioika*, detail of body, whole animal and diagrammatic magnification of tail; 2 – *O. longicauda*, detail of body, whole animal; 3 – *Fritillaria megachile*; 4 – *F. haplostoma* (from Fenaux, 1967, cited after Gibbons, 1997, with modification).

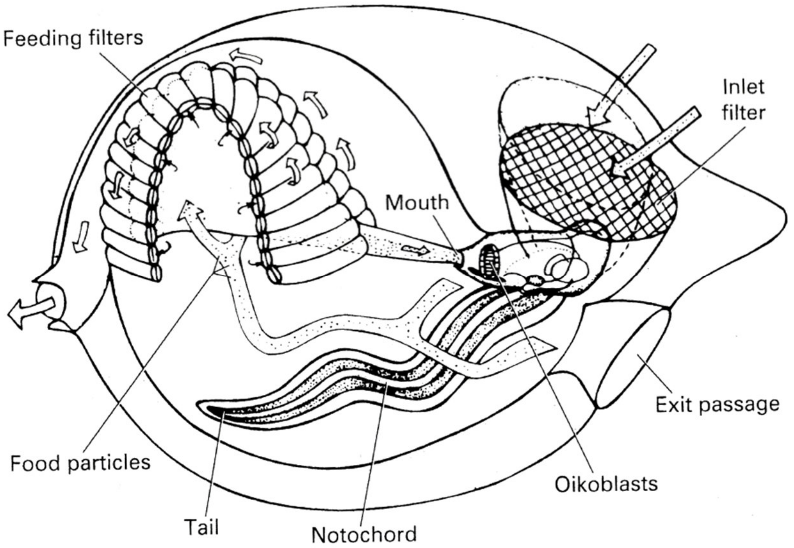

Figure 6.18: *Oikopleura dioika* in its “house” (modified from Larink & Westheide, 2006).

6.8 Polychaeta

Polychaetes are the basal group of the segmented worms (Annelida). The group comprises ca. 9,000 species distributed almost exclusively in the marine environment. They occur in the pelagial: (a) as larval stages lasting a few hours to several weeks, (b) as modified swimming stages of mature males or females (epitokes, hetero-nereids), or (c) as transparent pelagic holoplanktonic species, the latter belonging to seven families.

Among the enormous diversity of reproductive modes in polychaetes, **epitoky** is the most striking. Epitokous planktonic stages are mature individuals of mainly the benthic species, which have undergone morphological, physiological and behavioural modifications that enable them to leave the bottom and to swim and broadcast their gametes in the water column.

These metamorphosed sexually mature worms are produced by two processes.

(A) The whole animal is transformed into a swimming epitoke, and once the gametes are released after a short pelagic existence this animal dies, or sometimes reverts to the atokous state (epigamy).

(B) The (mostly) posterior part of the mature worm is modified, usually equipped with a new head, and then becomes detached as a free-swimming gamete-baring stolon. Whereas this stolon dies after the release of gametes, the unchanged anterior benthic stock of the worm continues to live for further reproductive activity by multiple stolonisation (=schizogamy).

The **trochophora** (Fig. 6.19, left) is a typical larva of polychaetes. Often it follows a spherical **prototrochophore** that is entirely covered with short cilia. The trochophore is characterised by a ciliary band, the **prototroch**, which encircles the body anterior to the mouth and is used for locomotion and feeding. Another parallel circumferential band of cilia is **metatroch**, which posteriorly borders the mouth region. A ciliated region between the two bands is called the food groove.

Early larvae with only a few segments often are called **metatrochophores**, or polytrochous larvae if they possess additional ciliary bands. In metatrochophore I, parapodia are not yet developed. Larvae with additional outer segmental structures are called metatrochophore II. Segmented larvae with functioning parapodia and prominent bundles of chaetae are called **nectochaetae** (Fig. 6.19, right, 6.20).

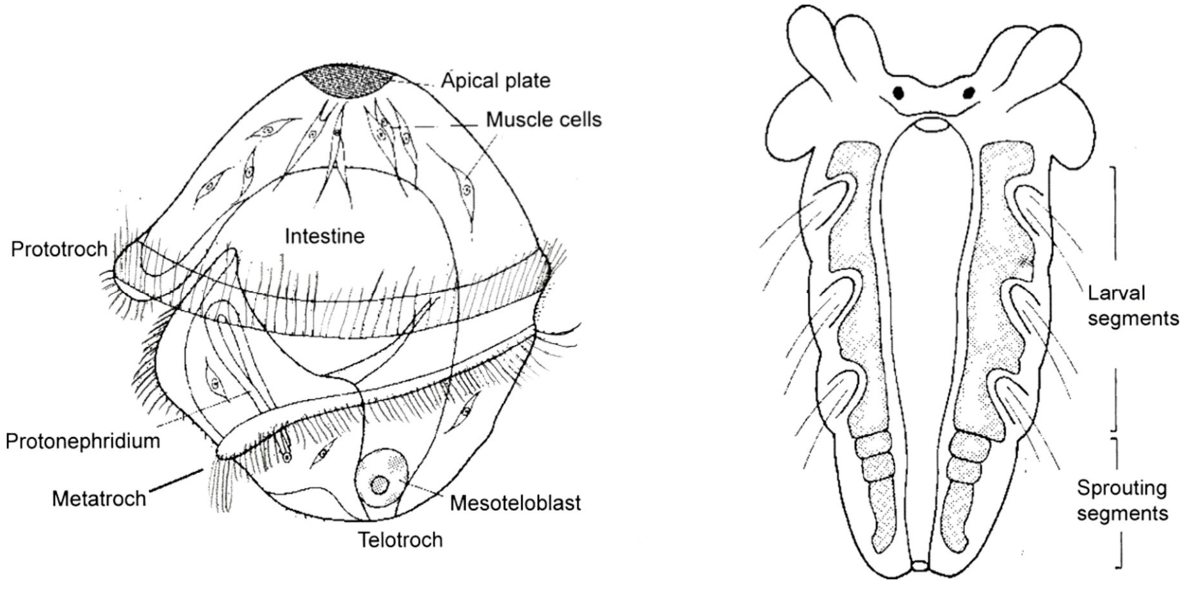

Figure 6.19: Larvae of Polychaeta: trochophora (left) and nectochaeta (right) (from Westheide & Rieger, 1996, with modification).

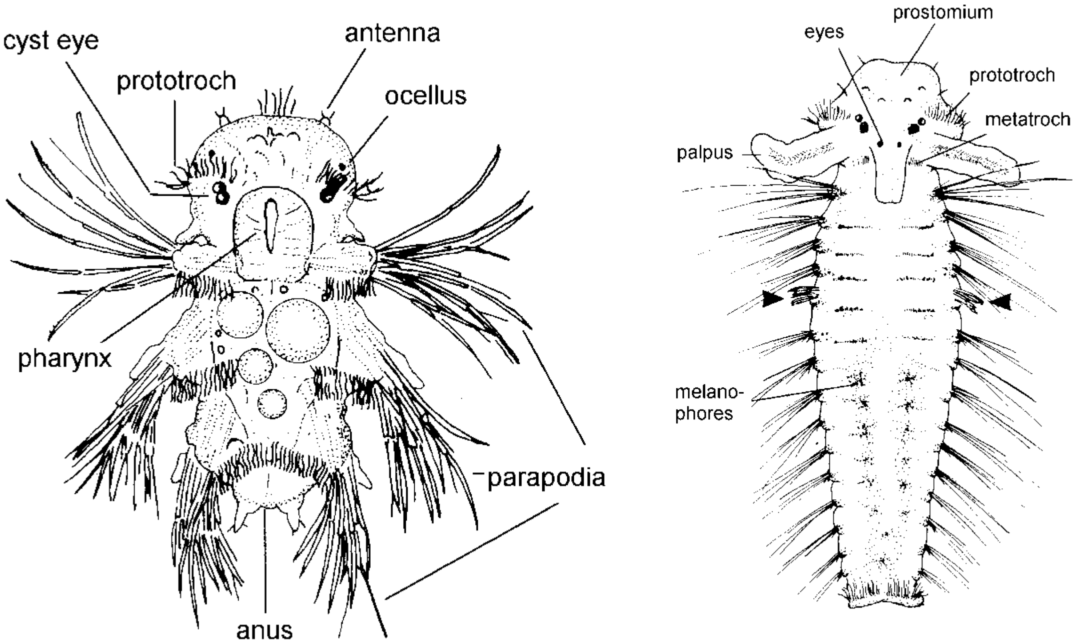

Figure 6.20: Larvae of Polychaeta: nectochaeta at different stages of development (from Storch & Welsch, 1999, with modification).

Trochophores and metatrochophores of polychaetes are easily confused with each other and are difficult to assign to a specific genus, or even to a family taxon.

Larvae of Spionidae (palp worms, the largest group of benthic, sessile of hemi-sessile polychaetes) are generally the most common developmental stages of polychaetes that can be found in plankton throughout the year. High abundance of polychaetes larvae in the pelagial of the sea is not only due to the large number of species in the coastal areas but also to the often long-lasting periods of their development.

Zooplankton composition, abundance, and distribution patterns depend on type and geographical location of the water body, season, time (considering daily vertical migrations), trophic status and a large number of other internal characteristics of the water body as well as numerous environmental (external) factors influencing the aquatic biota. Therefore, adequate sampling design should be developed prior to collecting zooplankton samples, relevant sampling methods should be selected, and appropriate sampling intervals chosen (for details see Telesh et al., 2009).

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CHAPTER 7

Hints for identification of selected mesozooplankton taxa

This chapter provides brief information on how to distinguish some most common and/or abundant mesozooplankton representatives in the zooplankton samples collected in the Baltic Sea. The following groups of organisms are described and illustrated:

1. **Cladocera – genera: *Eubosmina* (*Bosmina*), *Podon, Pleopsis, Evadne***
2. **Copepoda – genera: *Acartia, Centropages, Pseudocalanus, Temora, Eurytemora, Oithona***
3. **Rotifera – genera: *Keratella, Brachionus, Synchaeta***
4. **Meroplanktonic larvae – Cirripedia, Polychaeta, Mollusca**

Brief descriptions of the selected genera and species of zooplankton in this chapter are supported by schematic drawings and original photographs made using the zooplankton samples from the Baltic Sea. More information on morphology and biology of these organisms can be found in the previous chapters of this edition as well as in the books and research papers listed in the References.

7.1 Cladocera

Cladocera are lower crustaceans that form significant part of mesozooplankton. These organisms are very diverse in body shape, which varies from spherical, oval and triangular to somewhat abstract elongated forms. The body is covered with carapace and therefore its segmentation is not visible. The shape of carapace is an important feature for the species identification. The body size of cladocerans generally ranges from 0.2 to 3.0 mm, with the exception of certain species (e.g., *Cercopagis pengoi*). Many cladocerans have rather big, black eyes that are clearly seen. In comparison with the Copepoda, most Cladocera have relatively short antennules. Examples of body shapes of Cladocera species are given in Figures 6.7, 6.8, and 6.9 (see Chapter 6).

7.1.1 Genus *Eubosmina* (*Bosmina*), Family Bosminidae (Figures 2.10, 7.1, 7.2)

There are a few species of the genus *Eubosmina* (*Bosmina*) that belong to the family Bosminidae, and they are widely distributed around the Baltic Sea. Taxonomy of this genus is a field in need of revision, but most of its representatives can be easily identified to the species level due to the species-specific shape of carapace. To identify these organisms to the genus level, it is important to know and distinguish the following features:

- variable shape of carapace: from roundish to elongated, oval or irregular-shaped
- post-abdomen usually more or less rectangular
- often with two small (or sometimes relatively long) carapace spines at distal end
- two relatively long antennules (each looks like a “trunk”)
- medium-sized but well seen black eyes (compound eye)

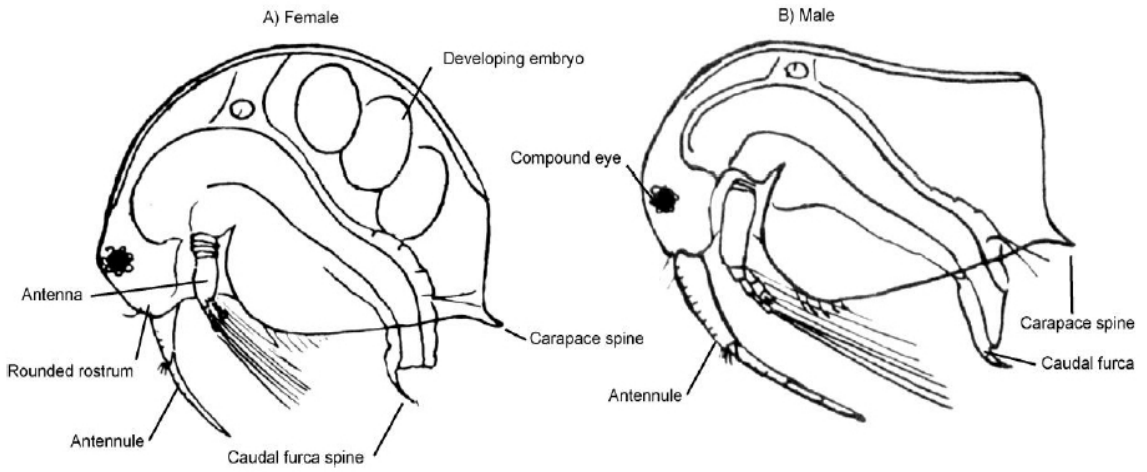


Figure 7.1: *Eubosmina* sp.: female (left), male (right) (after Telesh & Heerkloss, 2004).

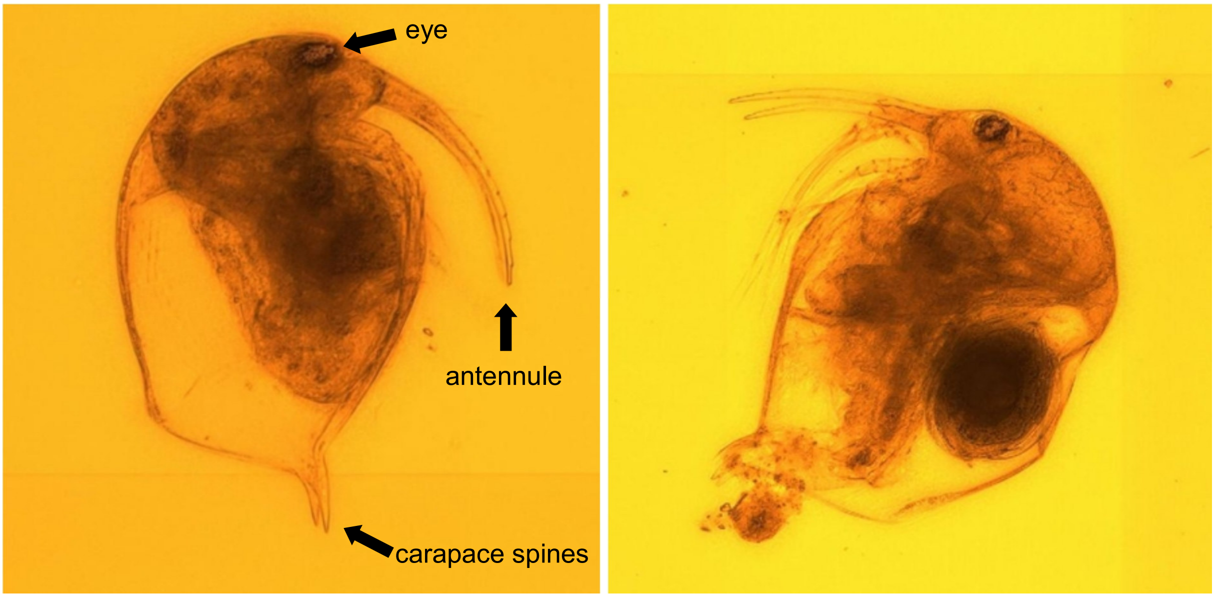


Figure 7.2: *Eubosmina* sp.: antennule, carapace spines and eye shown by arrows. Left – female with an empty brood pouch; right – female with a resting egg in the brood pouch (photos: C. Volkmann).

7.1.2 Genera: *Podon*, *Pleopsis* and *Evadne*, Family Podonidae (Figures 2.5, 7.3, 7.4)

Four species from the family Podonidae that occur in the Baltic Sea zooplankton are described here: *Podon leuckarti*, *Podon intermedius*, *Pleopsis polyphemoides* and *Evadne nordmanni*. It is important to know the morphological differences between these species. The brief species descriptions of *P. leuckarti*, *P. intermedius* and *P. polyphemoides* are given below.

Podon leuckarti

(Figures 2.5, 7.3, 7.4)

- large body (average size of males and females ca. 1.0 mm)
- round-shaped head with relatively big black eyes
- head and body are offset from each other
- hemispherical brood pouch (looks a bit like a backpack)
- with ONE long seta (kemp) located at the joint of the first thoracic limb:
  - actually, this is the only real though not easily seen identification characteristic.

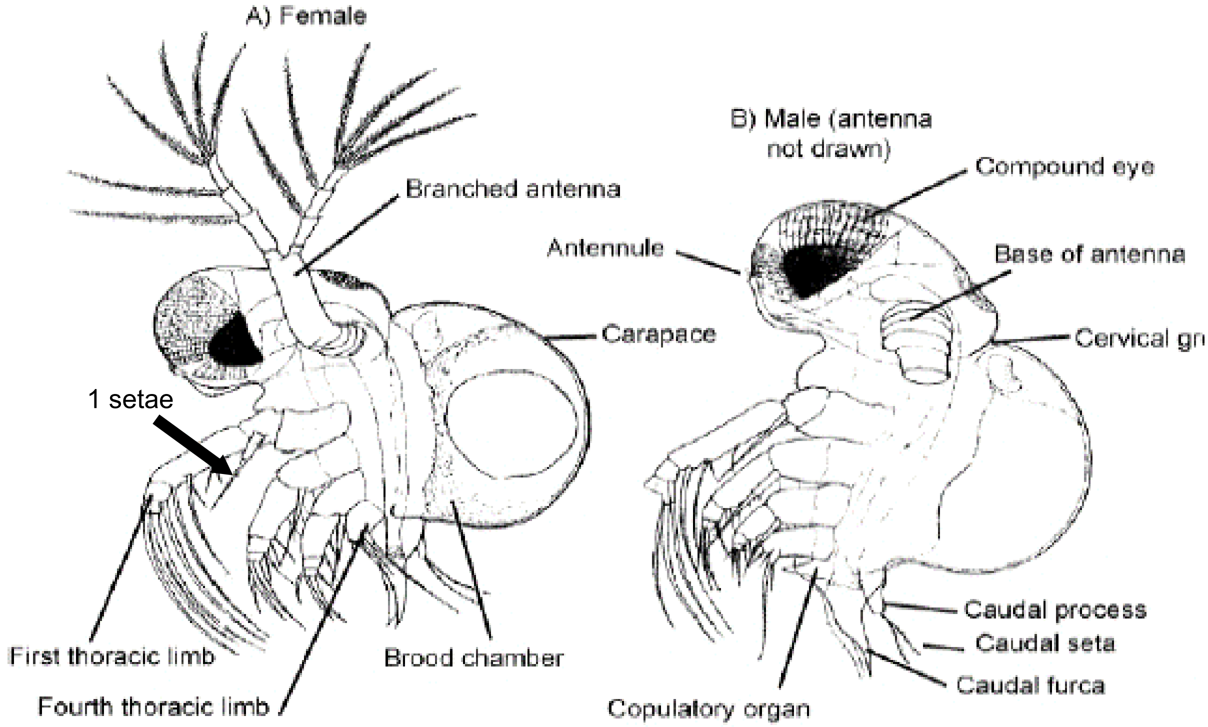


Figure 7.3: *Podon leuckarti*, female (left), male (right) (from Lilljeborg, 1901, as *P. leuckarti*).

Podon intermedius

- large body (average size of males ca. 0.9 mm, females 1.0–1.2 mm)
- round-shaped head with big black eyes
- head and body are offset from each other
- oval to hemispherical brood pouch (brood chamber), which looks a bit like a backpack
- TWO setae at the joint of the first thoracic limb:
    - ➢ actually, this is the only real identification characteristic but also not easy to see

Podon leuckarti and *P. intermedius* look quite similar and differ only by the number of setae (one or two, respectively) at the joint of the first thoracic limb.

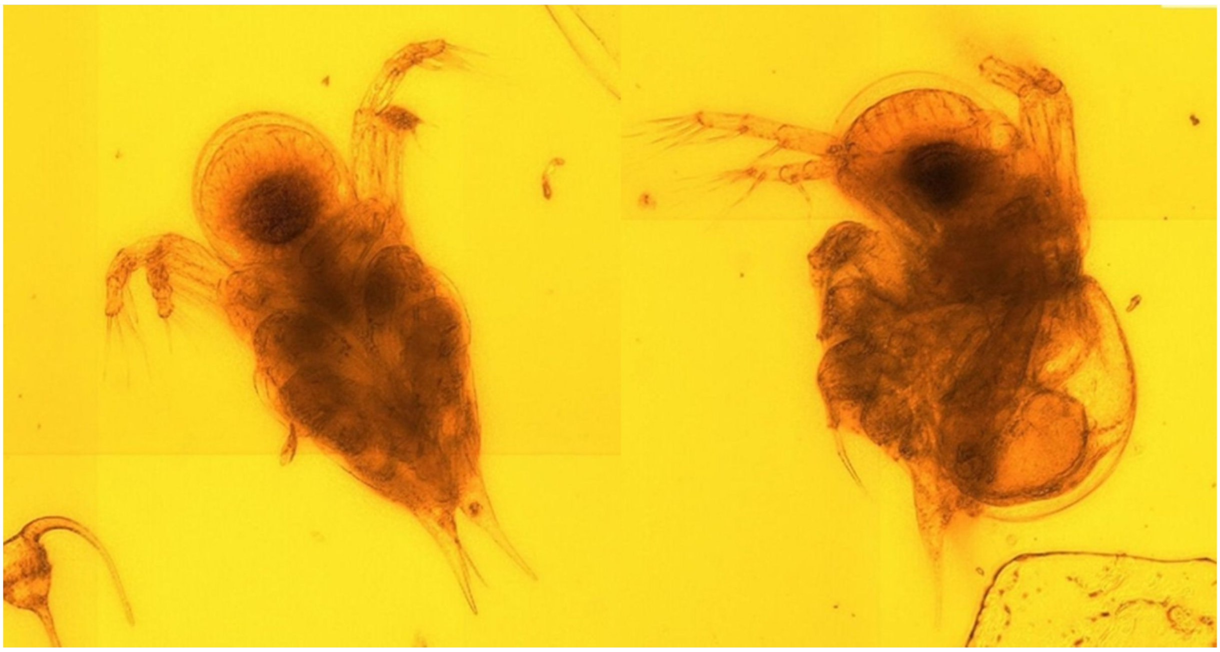


Figure 7.4: *Podon* sp.; left – ventral view, right – lateral view (photos: C. Volkmann).

Pleopsis polyphemoides
(Figure 7.5.)

- small body (in contrast to *P. leuckarti* and *P. intermedius*): average size from 0.4–0.55 mm (males) to 0.6–0.65 mm (females)
- round-shaped head with big black eyes
- head and body are offset from each other
- spherical brood pouch (looks like a **big**, **round** backpack)
- with THREE setae located at the joint of the first thoracic limb:
    - ➢ the only certain identification characteristic but really hard to see (it takes a bit of experience because thoracic limbs could be pretty close to each other).

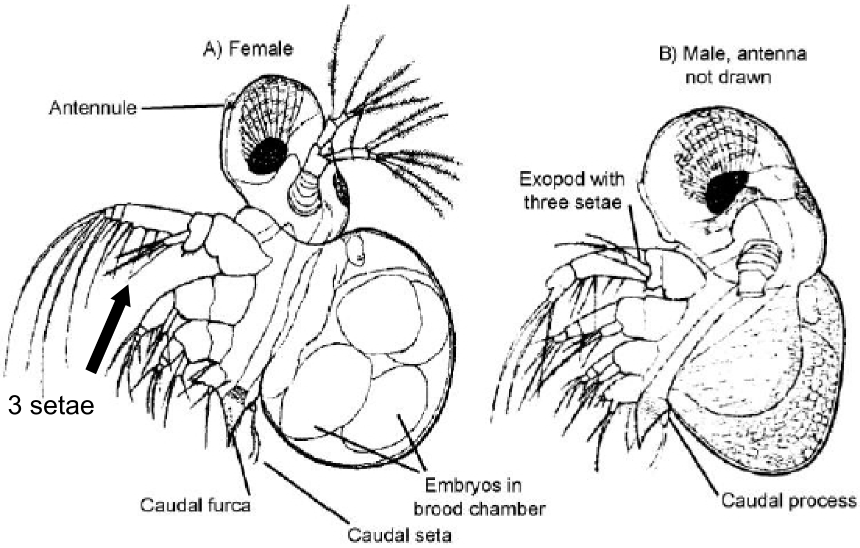


Figure 7.5: *Pleopsis polyphemoides*, female (left), male (right) (from Lilljeborg, 1901, as *P. leuckarti*).

7.1.3 Genus *Evadne* (Figures 2.5, 7.6, 7.7)

Two species from the genus *Evadne*, *E. nordmanni* and *E. anonyx*, are common in the Baltic Sea; however, it is often difficult to discriminate between these *Evadne* species according to their morphological characteristics only. The following features are attributed to *Evadne* spp.:

- round head;
- triangular-shaped carapace (very easy to recognize);
- head and body are NOT offset from each other;
- big black eyes.

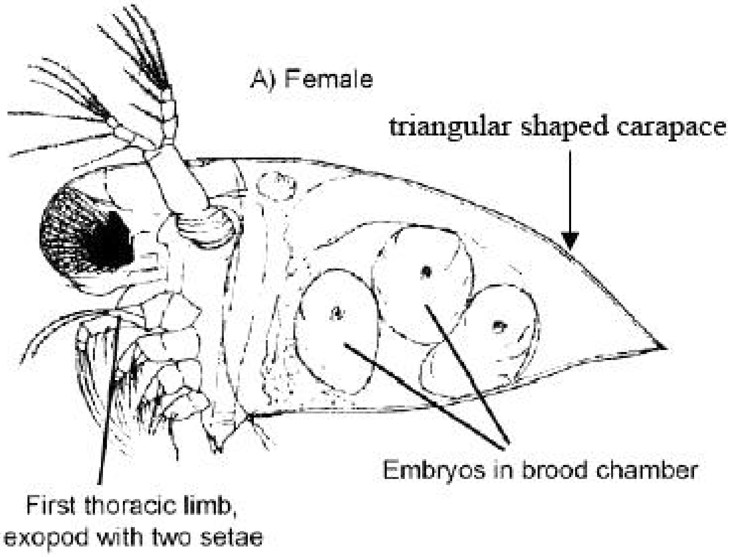


Figure 7.6: *Evadne* sp., female (from Lilljeborg, 1901).

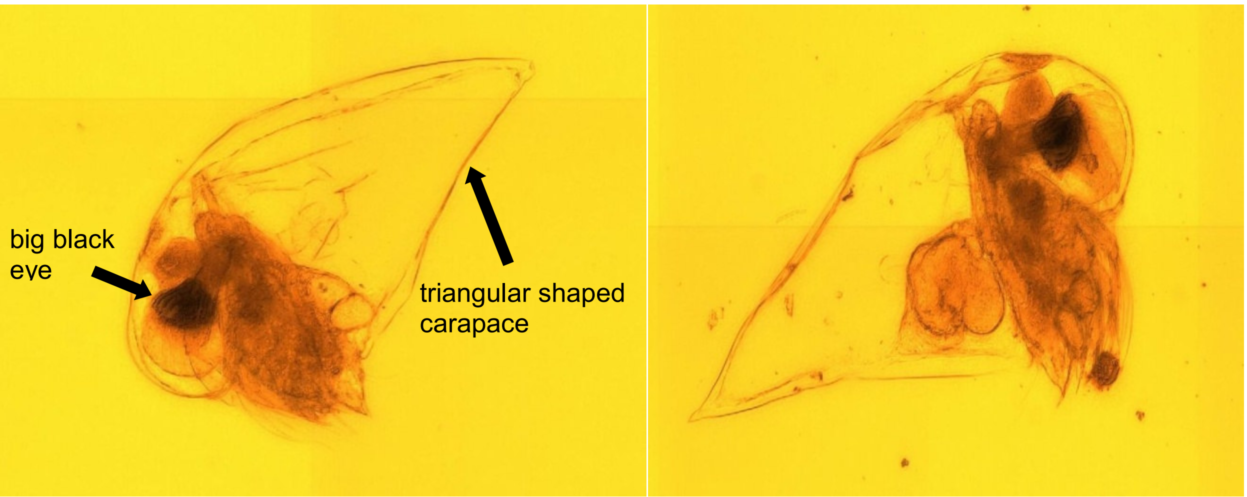


Figure 7.7: *Evadne nordmanni* (photos: C. Volkmann).

7.2 Copepoda

The Copepoda are lower crustaceans that are represented in plankton by three different Orders: Calanoida, Cyclopoida, and Harpacticoida. Morphologically, copepods from these three orders differ significantly in body shape and the length of their antennae (Figure 7.8).

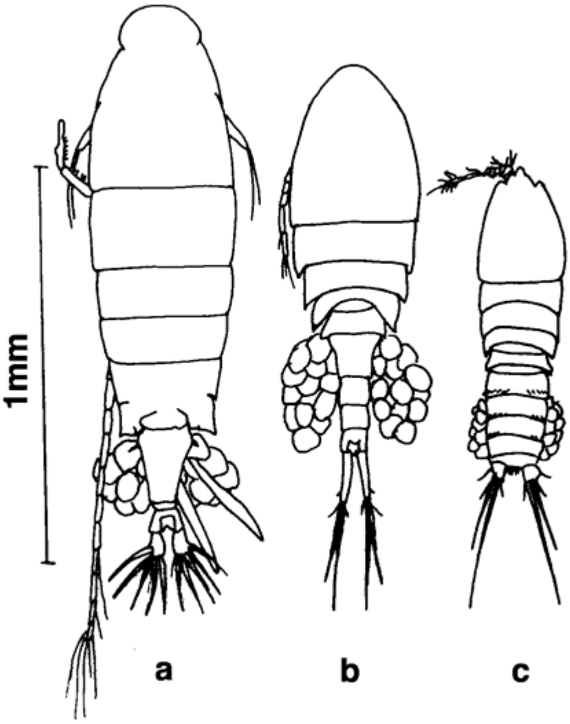


Figure 7.8: Scheme of calanoid (a), cyclopoid (b) and harpacticoid (c) copepods (after Telesh & Heerkloss, 2004).

The description of Copepoda and more details of their morphology (including adults, copepodites and nauplial stages) are given above (see Chapter 6). Calanoid copepods have more or less slim, elongated body shape and long paired first antennae, A1 (nearly as long as their body, or even longer). The body of cyclopoid copepods is slightly spindle-shaped and the antennae are clearly shorter than in calanoid copepods. The antennae are usually with setae. You can often see the eye, especially in cyclopoids. Copepods have a clear segmented cephalothorax and urosome (see Figures 6.11 and 6.12).

In contrast to cladocerans, copepods run through different developmental stages while their life cycle. Nauplius larvae, which develop from the egg, have altogether VI stages. Further on, nauplii develop into the six copepodite stages, the last one (stage VI) being the adult organism, although signs of males and females can already be distinguished at the copepodite stage V (see Figures 6.14 and 6.15).

Copepods at different developmental stages can be distinguished by certain morphological features. The best way to verify the stage is to count the number of pairs of swimming legs in relation to body size. At the first copepodite stage, the individuals have two pairs of swimming legs. After each moult one pair of legs is added. The maximum number of pairs of swimming legs (4 or 5 pairs), depending on the species, is present already at stage IV.

Another possibility to determine the stage of copepods is to count the prosome somites. However, it is necessary to mention that this method is not very reliable for a beginner at zooplankton counts because in some species the somites can be fused or there is hardly a difference between the numbers of somites at different stages.

For the only one cyclopoid copepod listed here, *Oithona similis*, it is very difficult to distinguish between the copepodite stages.

Acartia sp., nauplius
(Figures 7.9, 7.10)

- anterior end of body strait (significantly more strait than in the juvenile and adult individuals of *Acartia* spp.)
- first pair of limbs is frequently stretched forward
- the body is nearly oval
- at the distal end of the body there are two short spines that are more or less parallel to each other:
  - these spines are hardly visible at the first, the smallest Nauplii-larvae stage
  - the best determination characteristic for the smallest individuals is the flat body

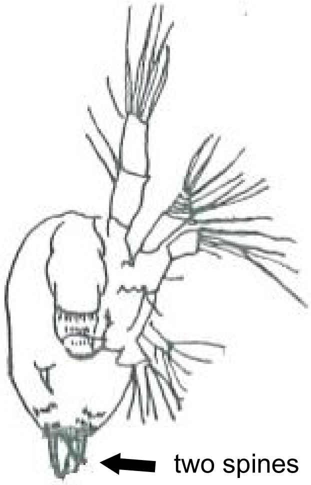


Figure 7.9: Nauplius of *Acartia* sp.

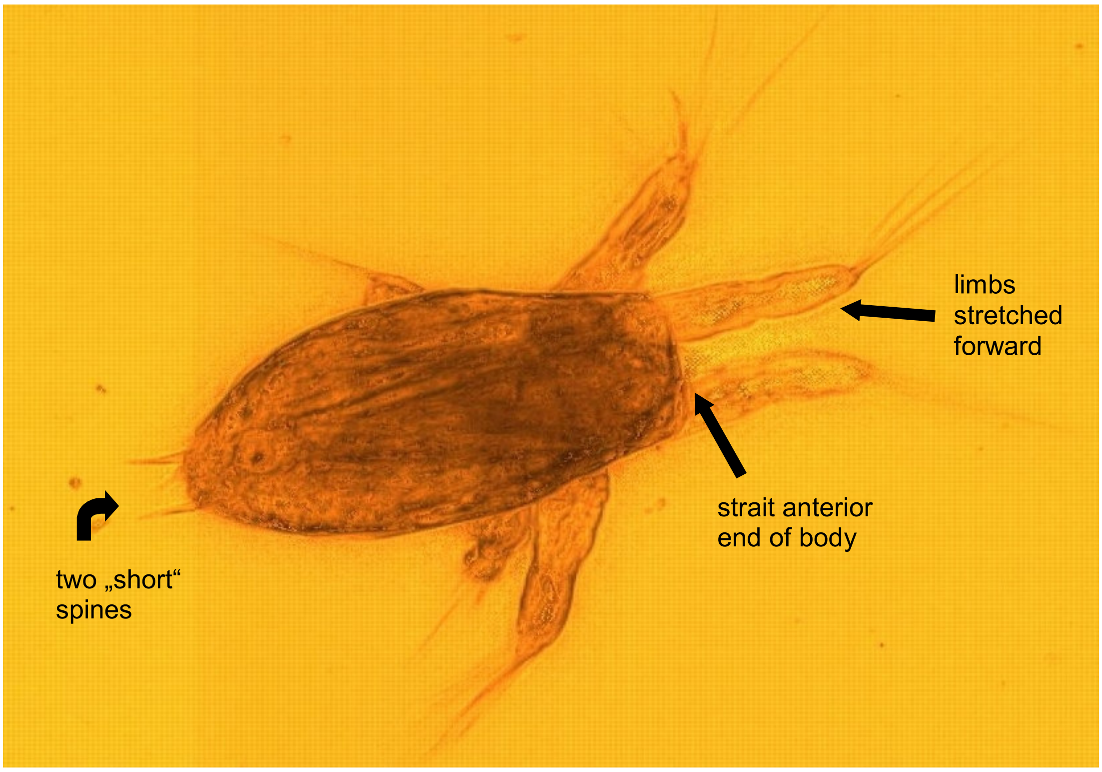


Figure 7.10: Nauplius of *Acartia* sp. (photo: C. Volkmann).

***Acartia* sp., adult**

(Figures 2.4, 7.11–7.13)

- strait, slightly edged head
- first pair of antennae is irregularly haired with long setae
- ‘hairs’ can be close-fitting to the antennae; therefore, ‘hairs’ sometimes are not easy to see in the juvenile individuals
- after two-thirds of the body length, the thorax is slightly thickened but backwards it is narrowing again
- visible eye (sometimes red colored)
- the fifth swimming leg (P5), located at the last thorax segment, in males looks like a “wrinkled pincers”
- the right first antennae of male individuals is always twisted and buckled
- the female sexual organ, the genital somite, is located at the first abdominal segment, which is thickened
- the female fifth swimming leg P5 has two spines that can be crossed:
  - ➢ you can determine the sex only for adult individuals
- 5 pairs of swimming legs at stage IV

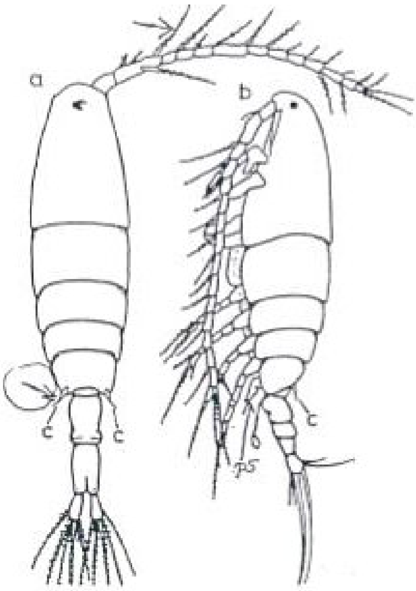


Figure 7.11: *Acartia* sp., female.

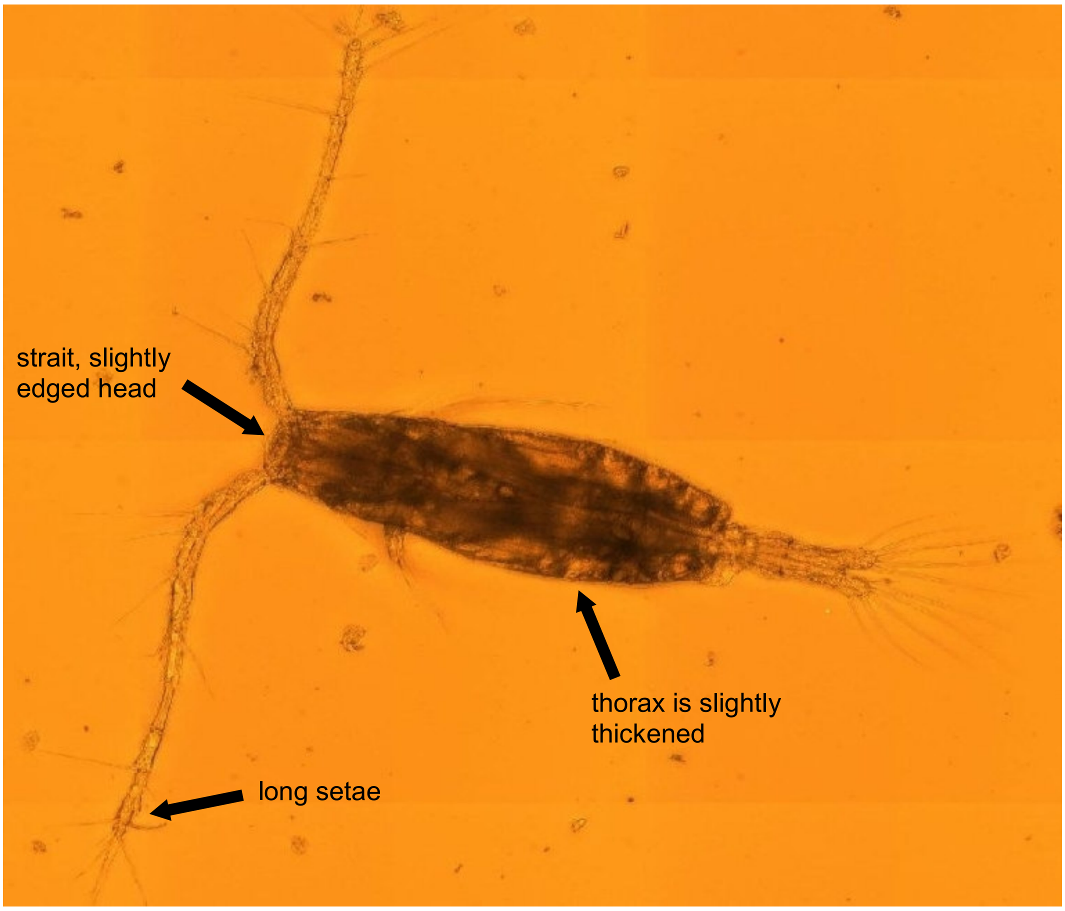


Figure 7.12: *Acartia* sp., female (photo: C. Volkmann).

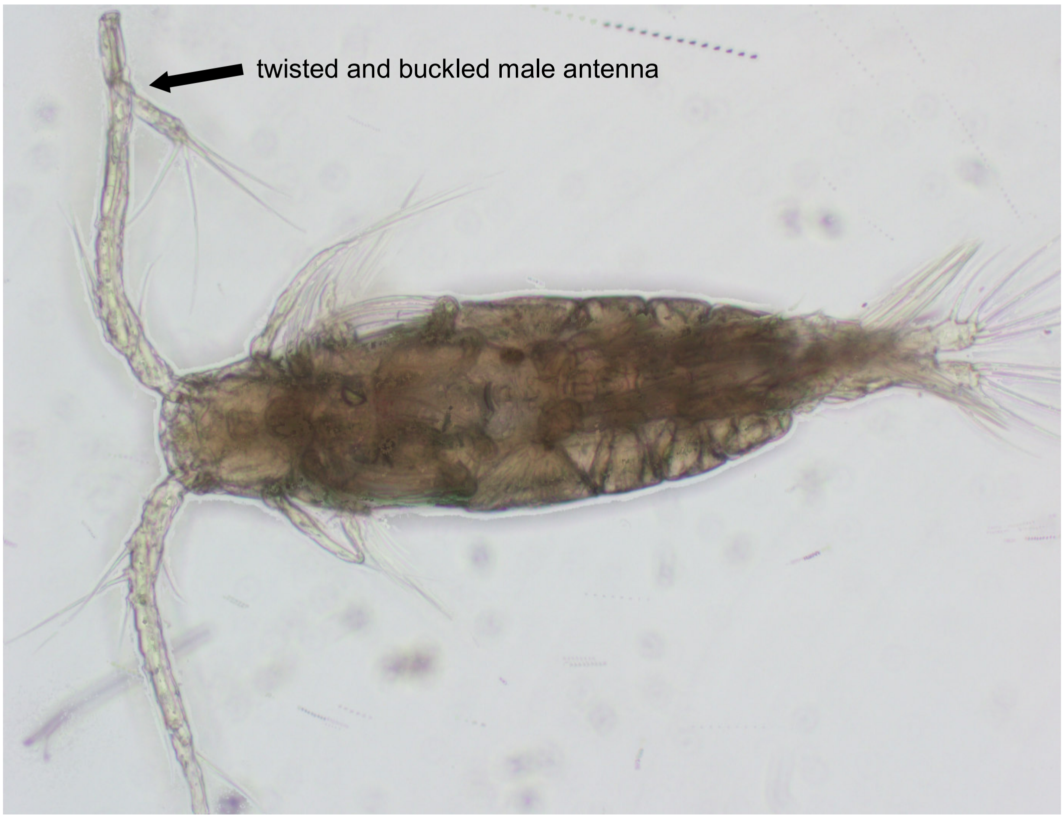


Figure 7.13: *Acartia* sp., male (photo: H. Rohde).

***Centropages* sp., nauplius**
(Figures 7.14, 7.15)

- round-shaped anterior end of body
- the body is getting continuously narrower backwards
- at the end of the body there is a long, thin median spine (relatively easy to recognize)

Figure 7.14: *Centropages* sp., nauplius

Figure 7.15: *Centropages* sp., nauplius (photo: C. Volkmann).

***Centropages hamatus*, adult**
(Figures 2.11, 7.16–7.18)

- head is getting narrower to the tip
- thorax is getting continuously narrower towards abdomen (especially in the juvenile individuals)
- the first antennae (A1) is relatively thick, with many short setae; in preserved samples often looks bent downward from the tip of the head
- the male P5 looks like a claw arm
- the last thoracic segment has one lateral spine at each distal corner:
    - sometimes these lateral spines are difficult to see in juvenile individuals
    - spines of female individuals are curved and significantly larger than in males
- the first abdominal segment in females is thickened
- 5 pairs of swimming legs at stage IV

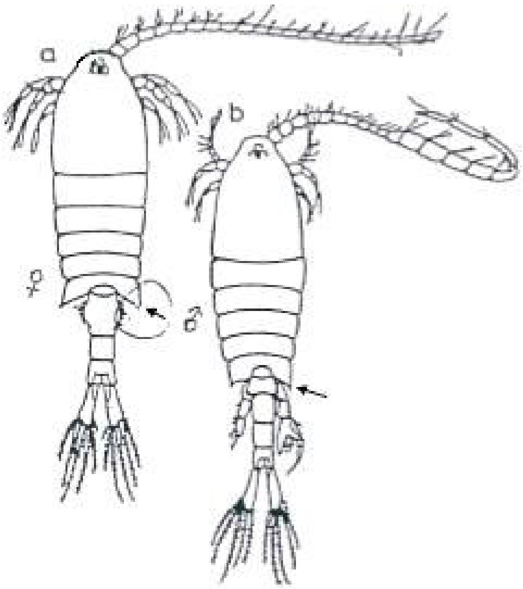


Figure 7.16: *Centropages hamatus*: female (left) and male (right); arrows show lateral spines at the last thoracic segment.

Figure 7.17: *Centropages hamatus*, male; arrows show the lateral spine at the last thoracic segment and the antenna bent downwards (photo: H. Rohde).

Figure 7.18: *Centropages hamatus*, male; arrows show the taxonomically important features (photo: H. Rohde).

***Pseudocalanus* sp., nauplius**

(Figures 7.19, 7.20)

- in general, the biggest of all Copepoda Nauplius larvae mentioned here
- the posterior end of the body looks telescopically drawn-out with a few short spines at the end (looks a bit like a paw)

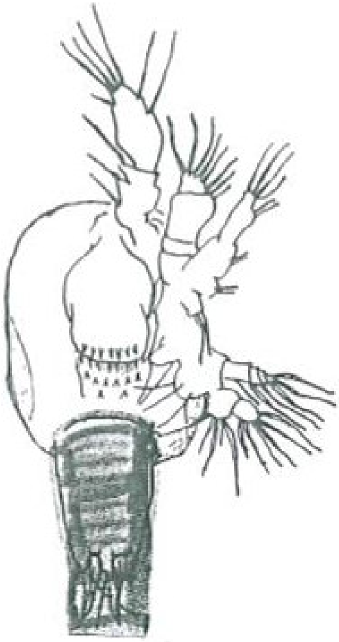


Figure 7.19: *Pseudocalanus* sp., nauplius.

Figure 7.20: *Pseudocalanus* sp., nauplius (photo: C. Volkmann).

***Pseudocalanus elongatus*, adult**

(Figures 2.3, 7.21, 7.22)

- round-shaped head
- straight and elongated body
- first antennae (A1) sometimes slightly short haired, especially at the tip
- antennae A1 often runs straight along the thorax
- relatively slim, straight and long abdomen:
    - with a short furca, in contrast to *Eurytemora affinis* and *Temora longicornis*
- male individuals with a quite long spine at P5:
    - not easy to recognize between other limbs (thorakopods)
- female individuals with a thickened first abdomenal segment (the genital segment):
    - at dorsal view, you can see inside the segment something that looks like two “air bubbles” - these are the ovaries
- maximum number of swimming legs at stage IV: female - 4, male - 5 pairs

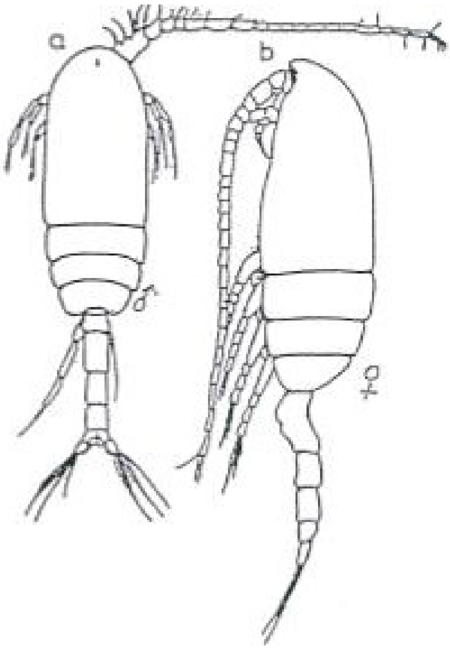
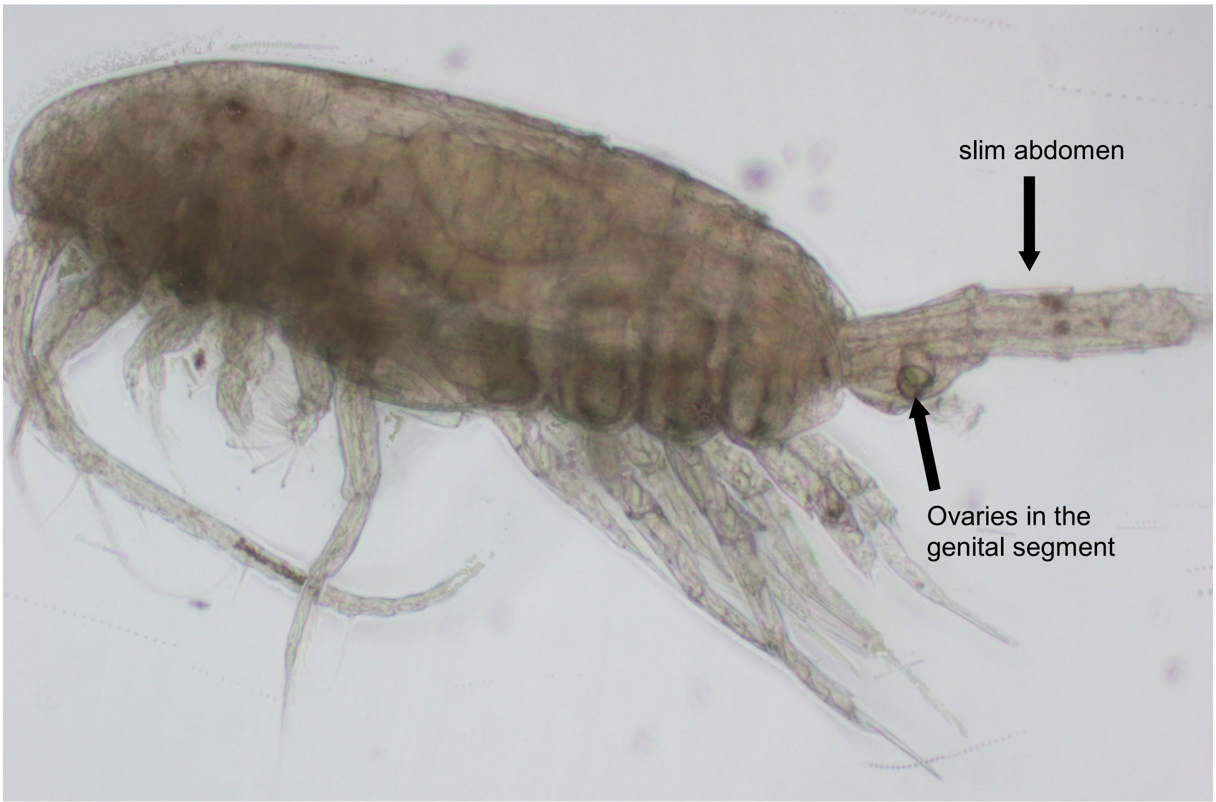


Figure 7.21: *Pseudocalanus elongatus*, male (left) and female (right).


slim abdomen

Ovaries in the genital segment

Figure 7.22: *Pseudocalanus elongatus*, female (photo: H. Rohde).

***Temora* sp., nauplius**
(Figures 7.23, 7.24)

- round-shaped anterior end of body
- body elongated but not oval
- two spines at the distal end of the body that are more or less parallel to each other but unequal in length (easy to see)
- sometimes the longer spine is aborted (but actually it is also well seen)

Figure 7.23: *Temora* sp., nauplius.

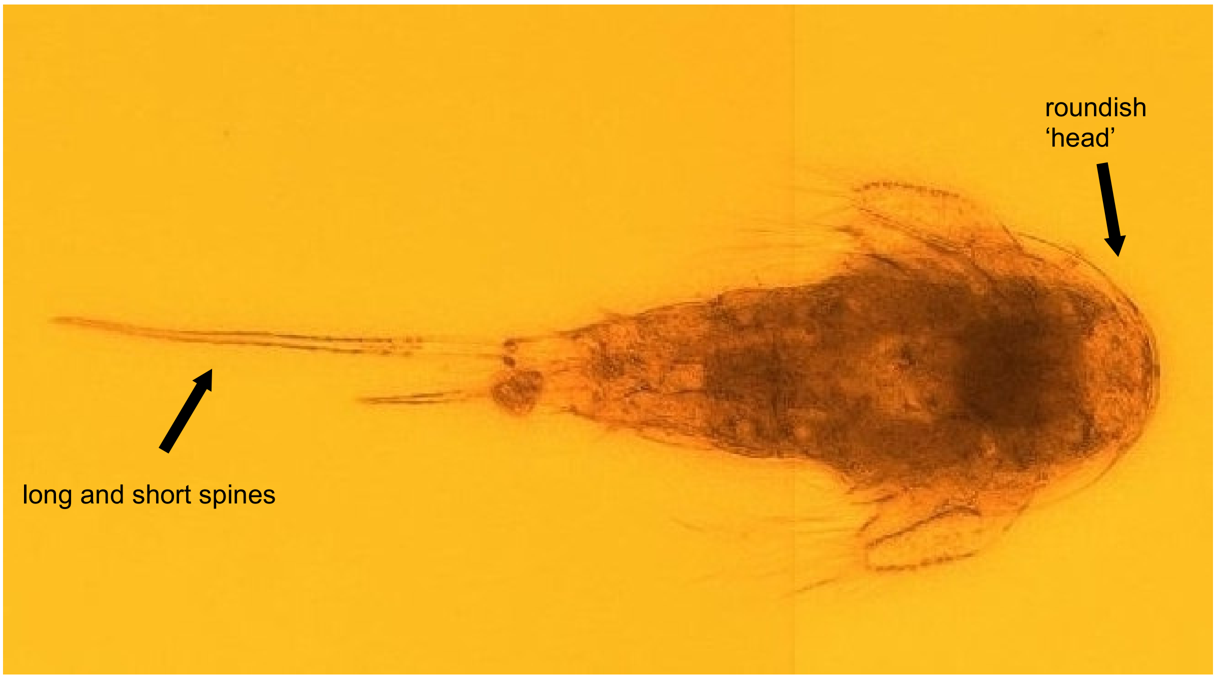


Figure 7.24: *Temora* sp., nauplius (photo: C. Volkmann).

***Temora longicornis*, adult**

(Figures 2.4, 7.25, 7.26)

- round-shaped head
- pear-shaped body at the dorsal view (very significant!)
- at the lateral view it has a kind of “hump”
- quite long furca
- the first antennae is bristly haired and often slightly curved
- male P5 looks like a big claw
- 5 pairs of swimming legs at stage IV

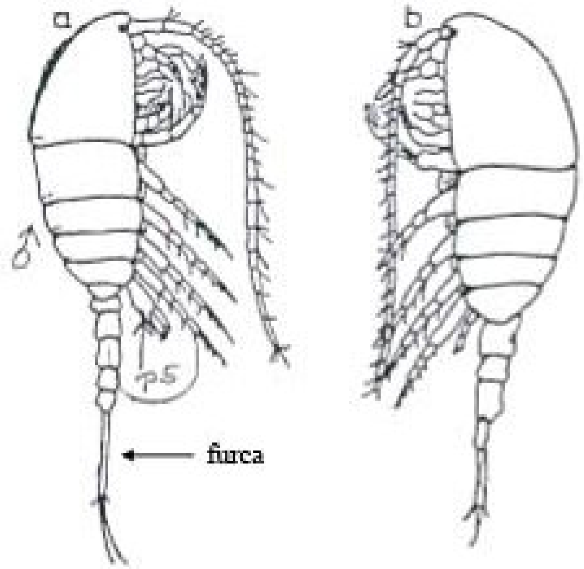


Figure 7.25: *Temora longicornis*, male (a, left) and female (b, right).

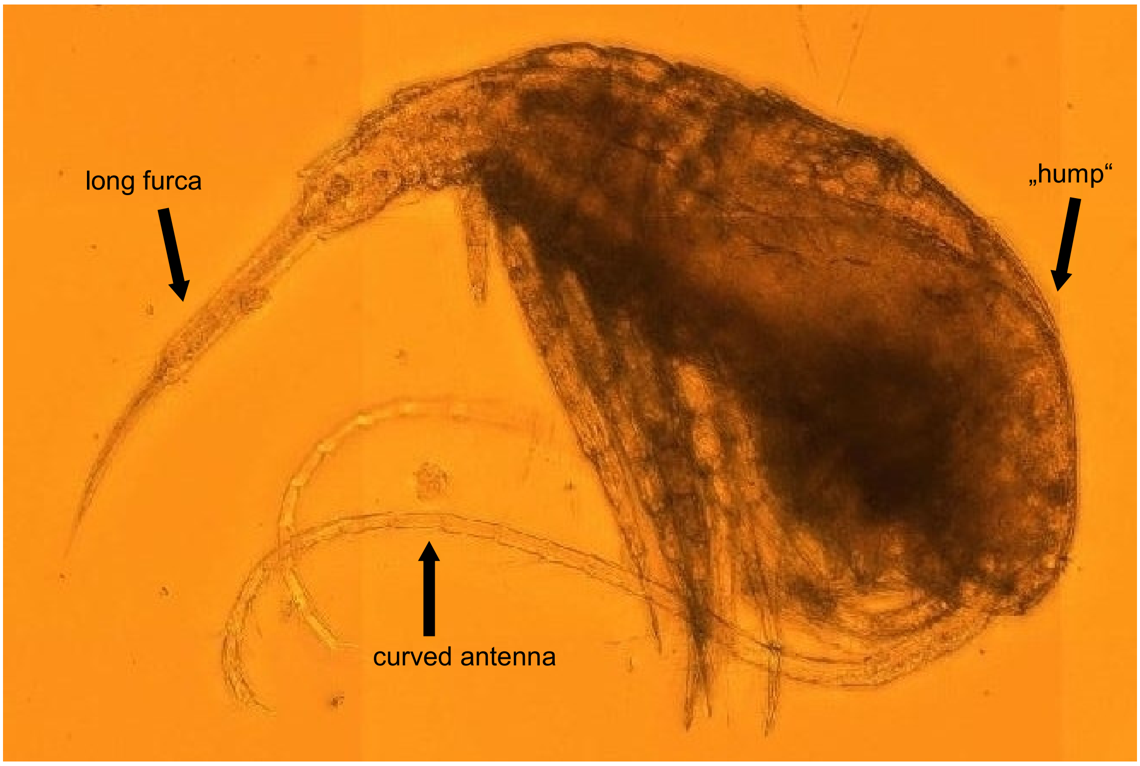


Figure 7.26: *Temora longicornis*, female (photo: C. Volkmann).

Eurytemora sp., nauplius

(Figures 7.27, 7.28)

- round-shaped anterior end of body
- tear-shaped body
- at the distal end of the body – two long, robust spines that are more or less parallel to each other:
    - ➢ spines are longer than in *Acartia* nauplii

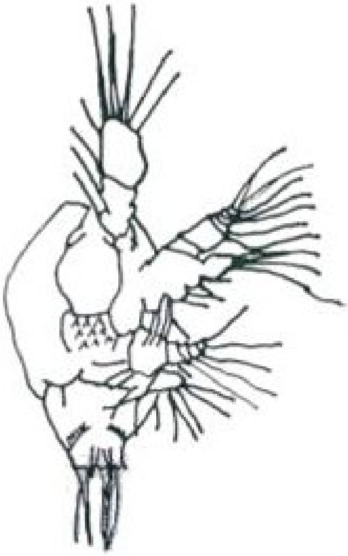


Figure 7.27: *Eurytemora* sp., nauplius.

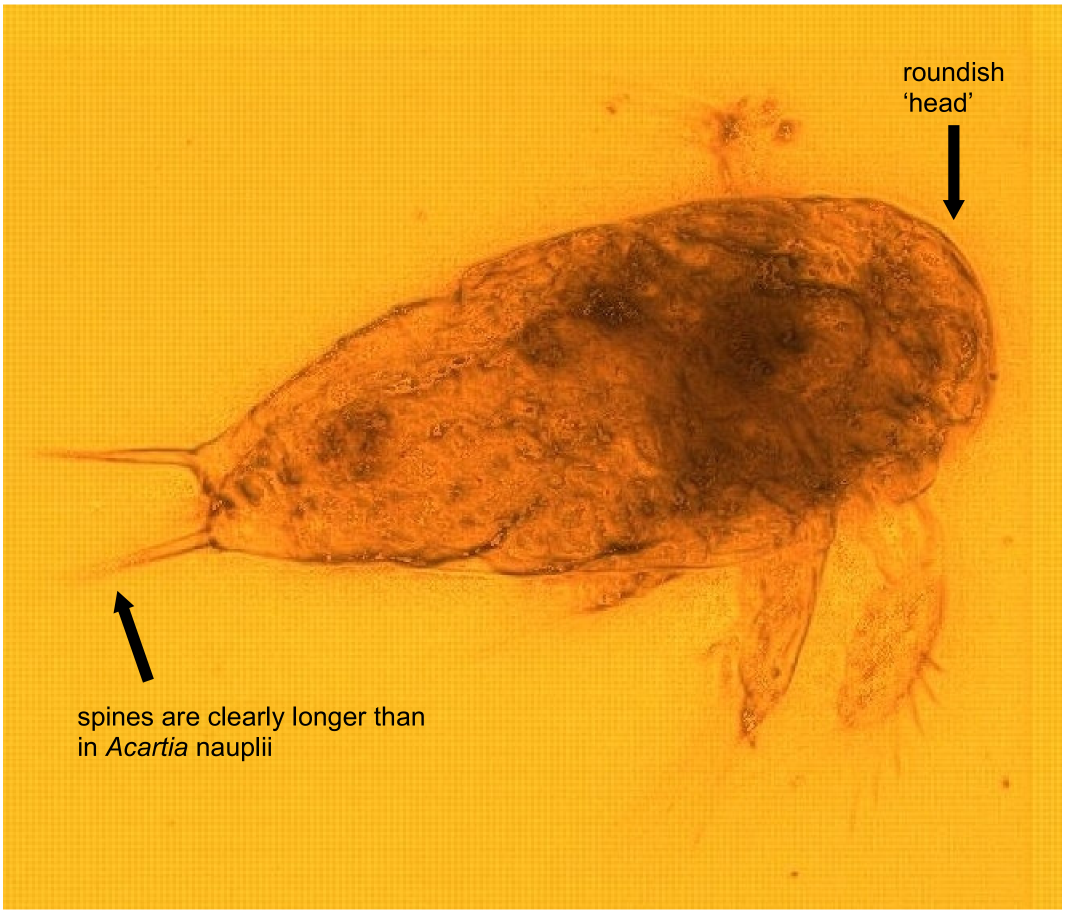


Figure 7.28: *Eurytemora* sp., nauplius (photo: C. Volkmann).

***Eurytemora affinis*, adult**

(Figures 7.29, 7.30)

- relatively round-shaped head
- slim body shape (no hump or pear-shaped body, unlike in *T. longicornis*)
- first antennae is often slightly curved in fixed condition
- the furca is nearly as long as the abdomen
- the last thoracic segment of female individuals is winged at the lateral corners
- the male P5 looks like a claw

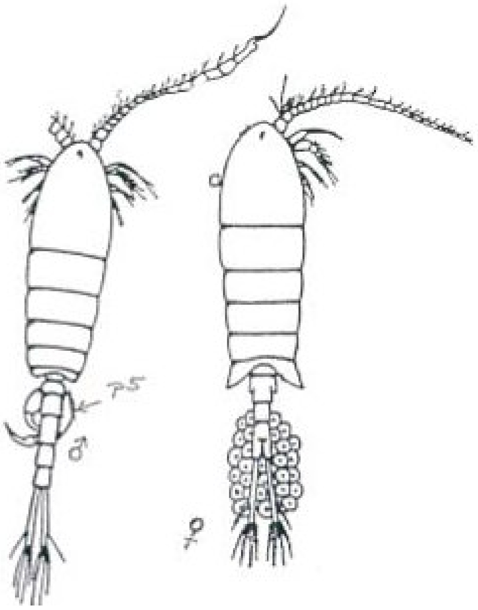


Figure 7.29: *Eurytemora affinis*, male (left) and female (right).

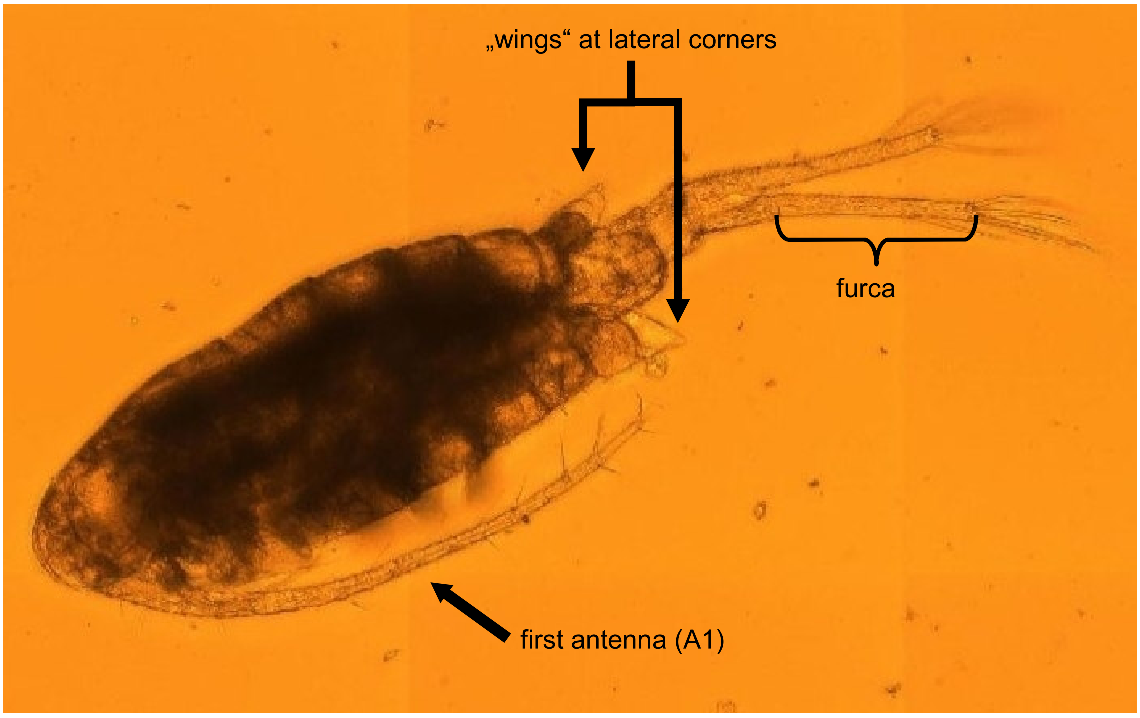


Figure 7.30: *Eurytemora affinis*, female (photo: C. Volkmann).

***Oithona* sp. (Cyclopoida), nauplius**

(Figures 7.31, 7.32):

- round-shaped anterior end of body
- relatively elongated, oval body
- two first pairs of limbs often stretched forward
- two short posterior spines at the end of the body are directed to the center (it looks like they form one big, short median spine)

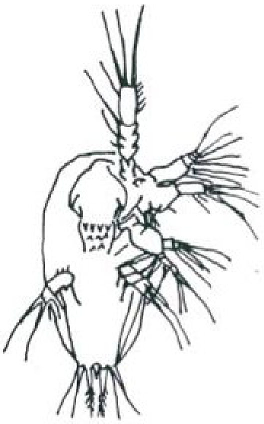


Figure 7.31: *Oithona* sp., nauplius.

Figure 7.32: *Oithona* sp., nauplius (photo: C. Volkmann).

Oithona similis **(Cyclopoida), adult**

(Figures 7.33, 7.34):

- first antennae (A1) are irregularly armored with relatively long setae (shown by arrow)
- the whole body (cephalothorax + thorax) is pronouncedly spindle-shaped
- the relation cephalothorax + thorax and abdomen + furca is close to 1:1
- the first antennae of female individuals are as long as the whole body
- the first antennae of male individuals is shorter and buckled like a "clothes hanger"

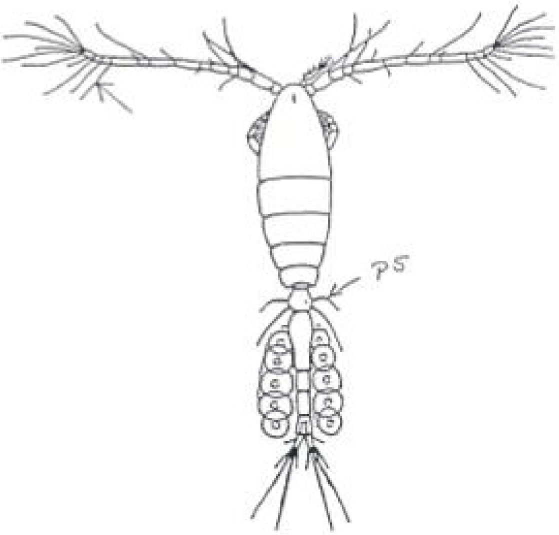


Figure 7.33: *Oithona similis*, female.

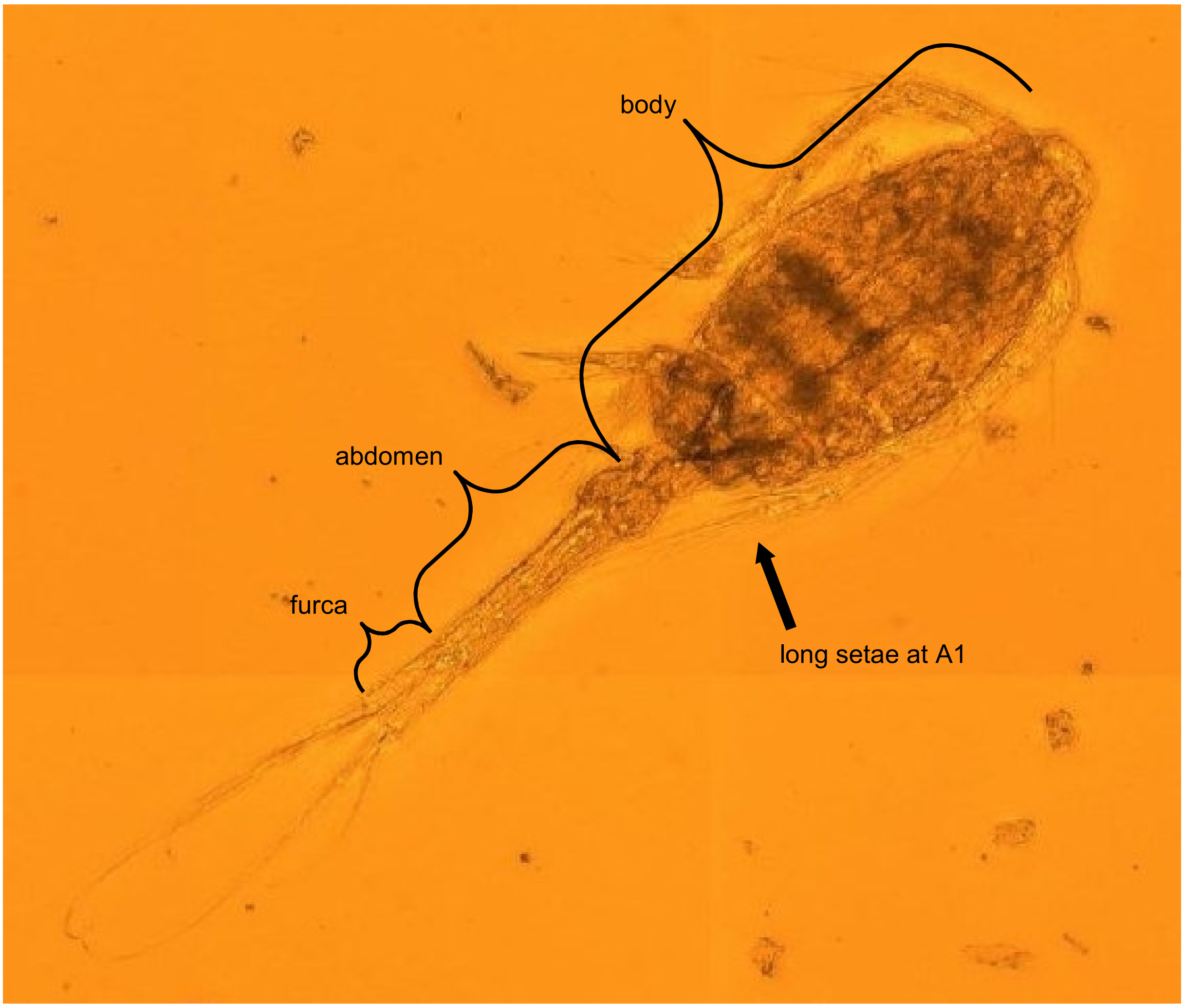


Figure 7.34: *Oithona similis*, female (photo: C. Volkmann).

7.3 Rotifera

Rotifera, or rotifers in English usage, is a group of microscopic aquatic or semi-aquatic unsegmented, bilaterally symmetrical pseudocoelomate invertebrates. In general, a rotifer consists of head, body and foot (for the details of morphology of rotifers see Chapter 6, Figure 6.5; more details, references and additional photographs of rotifers can be found in: Telesh & Heerkloss, 2002).

In comparison with the Cladocera and Copepoda, most Rotifera are rather small and more diverse in body shape. Body of most planktonic species of rotifers (except for the members of the genus *Asplanchna*) is smaller than 0.3 mm; however, some species have long spines (e.g. *Kellicottia*) or appendages (e.g. *Filinia*) that far exceed this length. The body of a rotifer may be cylindrical, sack- or bell-shaped, or laterally or dorso-ventrally flattened to various degrees; it may have thick cuticle or may be covered with lorica (carapace).

Morphologically, rotifers possess two main distinctive features: corona and mastax (for details see Chapter 6). Corona (a wheel organ) is the ciliated region at the apical end (head) of a rotifer. Corona is not always visible; sometimes it is withdrawn into body, especially in the preserved rotifers. Mastax is a muscular pharynx possessing a complex set of hard jaws called trophi (Figure 6.6). In some genera, the foot is lacking; but even if present, it may not be visible in the preserved animals because it is drawn into the body.

Identification of rotifers is based on the presence/absence of lorica, presence/absence of foot, body size and shape, body morphology, shape and morphology of lorica, and type of mastax. Species identification of the illoricate rotifers is possible only by examination of live organisms. Rotifers with lorica can be identified to species level also in the preserved samples, using the shape and structure of their lorica.

Here we describe and demonstrate only several rotifer species: Keratella cochlearis, Keratella cochlearis forma tecta, Keratella quadrata, Brachionus quadridentatus and Synchaeta sp.

Keratella cochlearis

(Figures 2.7, 7.35)

- no foot
- lorica dorsally curved, ventrally flattened or concave; with 6 anterior spines of almost equal length and one median posterior spine (thick, ventrally curved posterior spine in *K. cochlearis* f. *baltica*, and no posterior spine in *K. cochlearis* f. *tecta*):
    - dorsal surface of lorica with central line, on either side of which is a net-like pattern of lines and “fields” enclosed or partially enclosed by them
    - posterior spine may be long or short, varying seasonally and cyclically in length
    - lorica (with spines) <320 µm; male <90 µm. Lorica of *K. cochlearis* f. *tecta* <150 µm
- single red eye

Figure 7.35: *Keratella cochlearis* (photo: C. Volkmann).

Keratella quadrata

(Figures 2.5, 2.7, 7.36)

- no foot
- lorica almost rectangular, posterior end with 2 parallel or diverging spines usually long to medium, thin, sometimes short, usually of equal length, left spine may be shorter or absent, sometimes no posterior spines; very polymorphic
- lorica <350 µm, male <100 µm

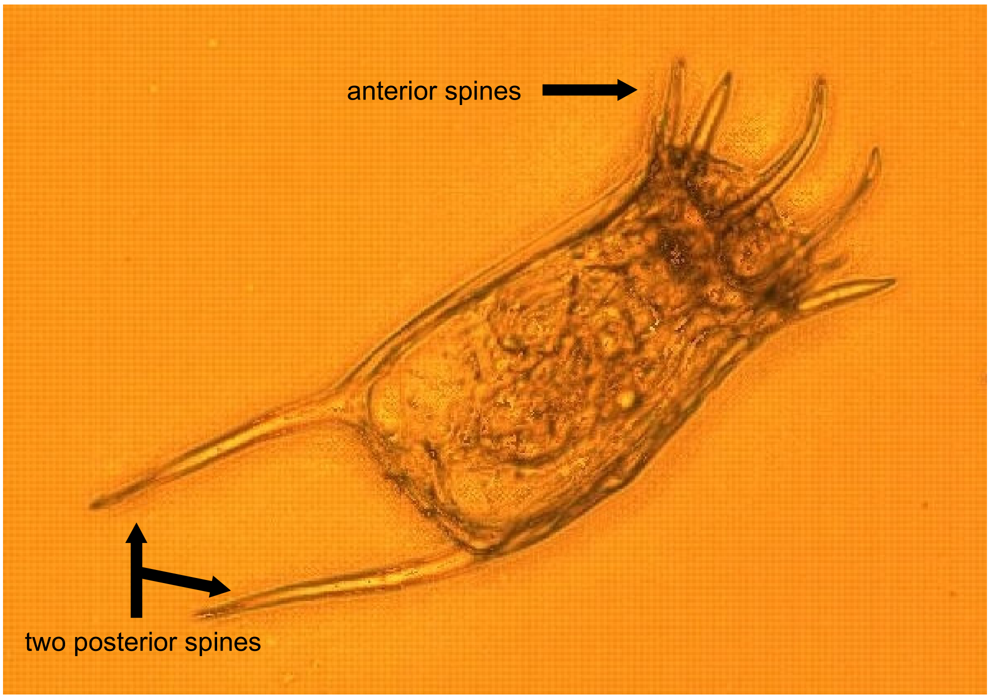


Figure 7.36: *Keratella quadrata* (photo: C. Volkmann).

Brachionus quadridentatus

(Figure 2.5, 7.37)

- lorica with 6 anterior spines, median pair usually long, curved to lateral or ventral
- posterior spines absent or present, short or long (seasonal variation in spine length occurs)
- foot opening tube-shaped, projecting ventrally with short lateral spines
- lorica often asymmetrical, length <415 µm; male <150 µm

Figure 7.37: *Brachionus quadridentatus* (photo: C. Volkmann).

Synchaeta sp.

(Figures 2.5, 7.38)

- foot short or fairly short, toes short, usually 2
- body bell- or cone-shaped, cuticle very thin and transparent
- head more or less convex, usually bearing 4 characteristic stiff sensory bristles or styli arising from triangular prominences
- corona of groups of cirri, also cirri on laterally-extending or dependent “ears” or auricles
- eye usually present, single or double, red or purple, and often pigment spots on head
- Notes: in preserved samples, rotifer species from the genus *Synchaeta* contract into completely unidentifiable mass; therefore, identification of these rotifer species requires examination of live organisms in addition to preserved samples that should be used for study of trophi

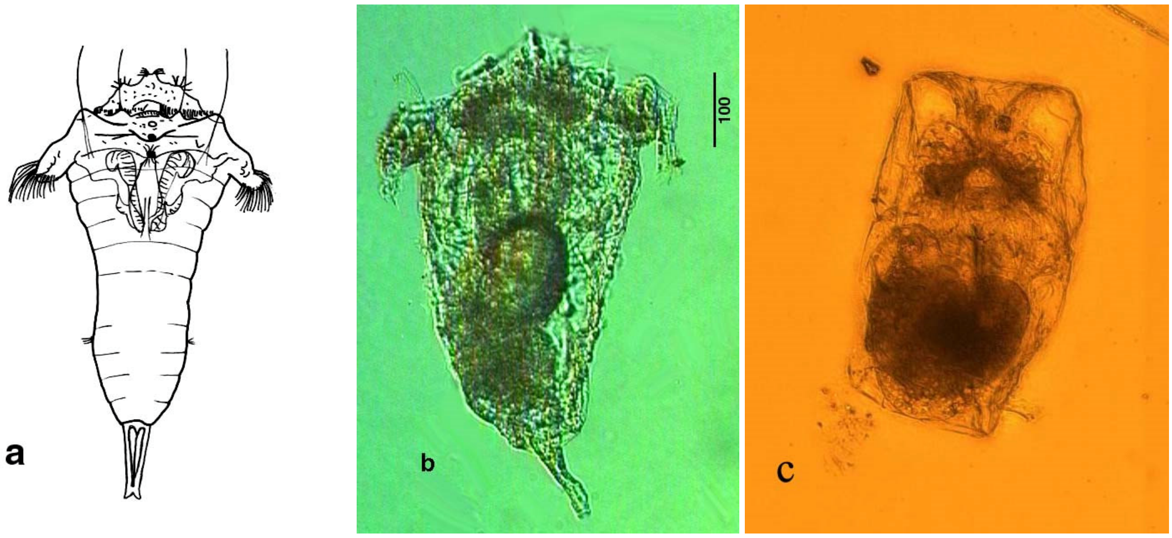


Figure 7.38: *Synchaeta* sp. **a**, *Synchaeta grandis*, female, dorsal view, modified and redrawn from Kutikova (1970); **b**, *Synchaeta grandis*, live individual (photo: I. Telesh); **c**, *Synchaeta* sp., preserved, leg and head withdrawn into body (photo: C. Volkmann).

7.4 **Meroplanktonic larvae**
(Figures 2.8, 2.9, 7.39–7.42)

Meroplanktonic larvae are larval stages of bottom-dwelling organisms that live in plankton for certain, usually relatively short time. Most often you can find in plankton samples the larval stages of Cirripedia (*Balanus* sp.), Polychaeta and Mollusca (Bivalvia or Gastropoda). Larval stage of *Balanus* is nauplius, which looks similar to nauplii of copepods; larvae of Polychaeta and Mollusca look similar to adult organisms. Some illustrations are given below.

Balanus* sp.*, nauplius
(Figure 7.39)

- carapace with two projections that look like “horns” laterally at the anterior part of body
- carapace elongated to a long spine at the posterior end
- this carapace shape is unique and, therefore, nauplius of *Balanus* sp. cannot be confused with any other nauplii

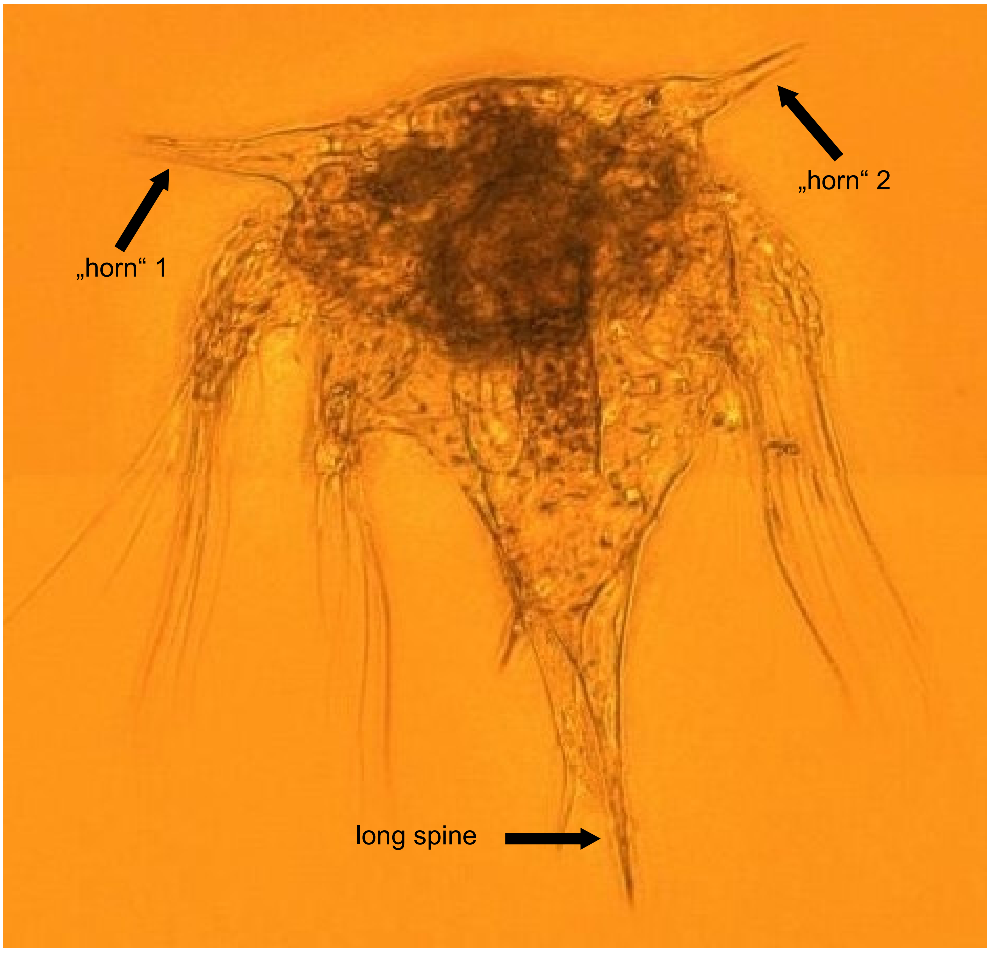


Figure 7.39: *Balanus* sp., nauplius (photo: C. Volkmann).

Figure 7.40: Polychaeta, larvae (photo: C. Volkmann).

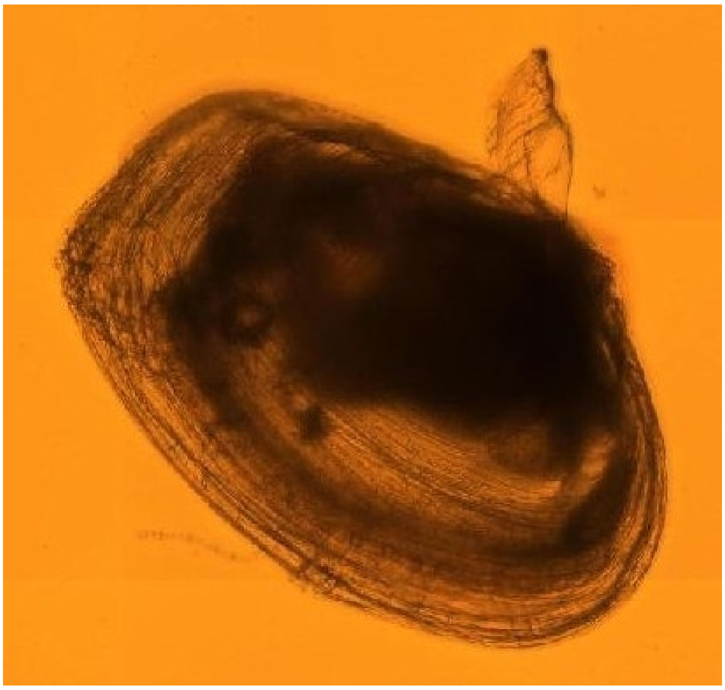


Figure 7.41: Bivalvia, larvae (photo: C. Volkmann).

Figure 7.42: Gastropoda, larvae (photo: C. Volkmann).

More information and photographs of the Baltic Sea zooplankton can be found in Telesh & Heerkloss, 2002, 2004; Telesh et al., 2009, and references therein (see the list of References).

Selected Internet Zooplankton Data Bases

- Integrated Taxonomic Information System (ITIS):
  http://www.itis.gov/

- The European Register of Marine Species (ERMS):
  http://www.marbef.org/data/erms.php

- The World Register of Marine Species (WoRMS):
  http://www.marinespecies.org

- ICES Identification Leaflets for Plankton:
  http://www.ices.dk/products/fiche/Plankton/START.PDf

- The Great Lakes water life photo gallery with a list of rotifer and crustacean sites:
  http://www.glerl.noaa.gov/seagrant/GLWL/GLWLife.html

- International Code of Zoological Nomenclature:
  http://www.iczn.org

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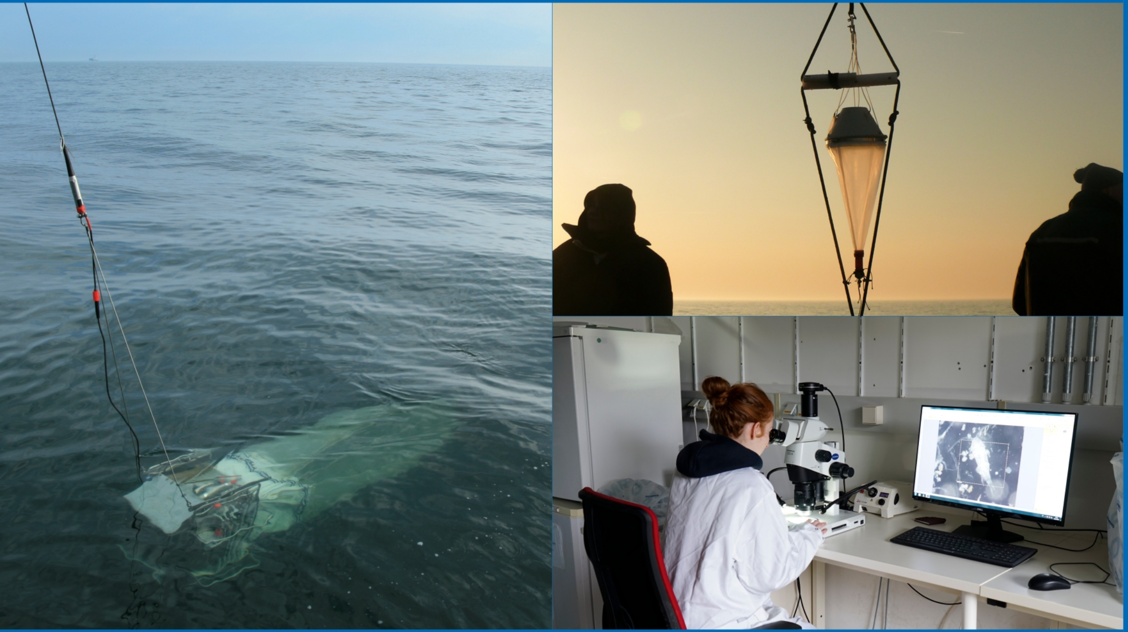

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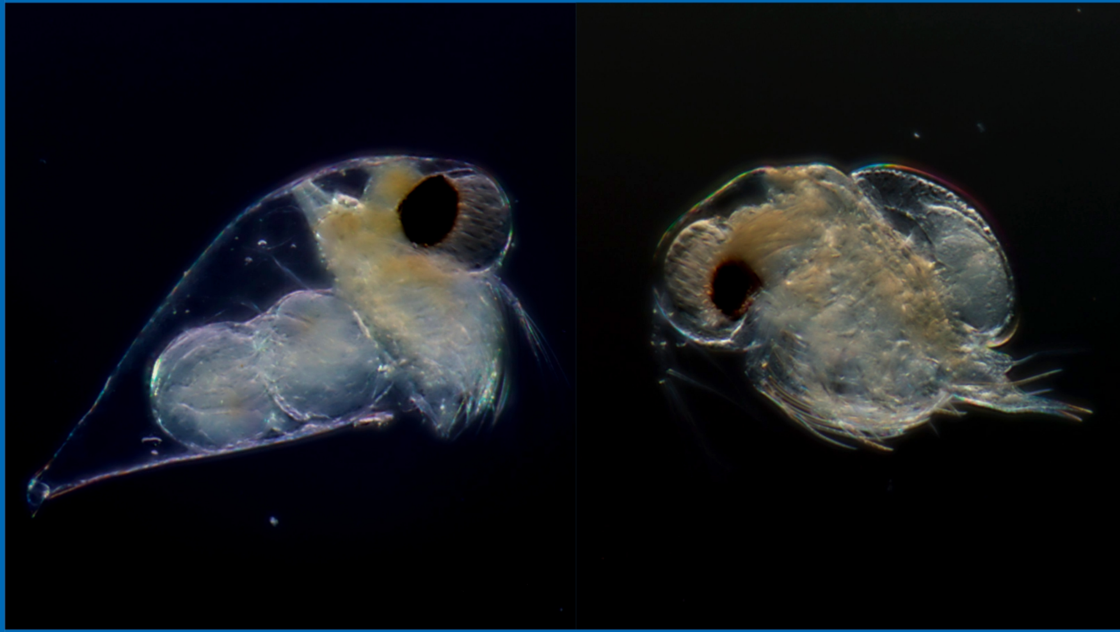

Heft 32

Zooplankton of the Baltic Sea: General Aspects and Identification Hints