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Long-term macrozoobenthos changes in a shallow boreal lagoon: Comparison of a recent biodiversity inventory with historical data

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Abstract

The European water framework directive (WFD) aims at achieving good ecological status of water bodies, which implies assessment of their current ecological quality status in respect to defined reference (pristine) conditions. In this paper, two historical biodiversity datasets (from 1920s and 1950s) and results from the recent inventory are used to trace the long-term changes of the macrozoobenthos in the eutrophic boreal lagoon of the Baltic Sea.

In comparison of datasets the highest congruence was obtained for molluscs and malacostracan crustaceans, which also had a similar level of taxonomic emphasis between studies. Considering inconsistencies in methodology and taxonomic determination, only few species extinctions in these groups did likely occur during the last 100 years. Two amphipod species (*Gammarus pulex* and *Gammarus lacustris*) were not found during the recent survey, whereas five new species of this taxonomic group occurred in the lagoon since 1950s. The causes of these extinctions remain unclear; however displacement by established new amphipods cannot be excluded. *Theodoxus fluviatilis* was recently recorded in the very restricted area of the lagoon, while in earlier studies the species was mentioned as common and widely distributed in the water body. On the other hand, 10 gastropod species and 9 bivalves were reported for the first time in the lagoon and most likely have been overlooked in earlier surveys. Approximately 10% of the species have their origin outside the Baltic Sea basin and the number of invasions considerably exceeds the number of likely extinctions. Assessment scheme of such changes is unclear following WFD guidelines, therefore elaboration of a framework for evaluation of the alien species diversity in a context of local biodiversity should attain more effort when implementing the WFD.

Keywords: Baltic Sea; Curonian Lagoon; WFD; Alien species; Reference conditions

Introduction

Enclosed water bodies (e.g. bays, coastal lagoons, etc.) have undergone drastic changes during the last decades. Being directly impacted by processes in the drainage basin, many of these systems in the Baltic Sea (e.g. Stettin Lagoon, Puck Lagoon, Vistula Lagoon, Curonian Lagoon and Gulf of Riga) have been enriched

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with nutrients (e.g. Cederwall, Jermakovs, & Lagzdins, 1999; Ezhova, Żmudzinski, & Maciejewska, 2005; Maslowski, 1993; Olenina & Olenin, 2002; Zmudzinski, 1997). Rate of species introductions was also increasing during the last century and resulted in structural and functional changes of local communities (Olenin & Leppäkoski, 1999).

The European water framework directive (WFD) establishes a framework for the protection of all waters and aims at achieving good ecological status. One of its main tasks is the classification of water bodies into different types assessing their ecological quality status in respect to defined reference (pristine) conditions. Reference conditions for biological parameters could be defined using modelling approaches, historical datasets and existing information on not impacted sites or expert judgement. However, historical information containing biodiversity list is usually the only source of data on the status of water bodies for periods long time ago.

Here we test the use of historical biodiversity datasets in tracing the long-term changes of macrozoobenthos diversity in the eutrophic boreal lagoon. We present results of an extensive faunistic inventory of major macrozoobenthic groups of the Curonian Lagoon. Then, these results are compared with two historical datasets originating from the beginning (Szidat, 1926) and the middle (Gasiunas, 1959) of the 20th century.

Materials and methods

The Curonian Lagoon, the largest coastal lagoon in the Baltic Sea, is a highly eutrophicated water body (Olenin & Klovaite, 1998). The mean water depth is 3.7 m. The enclosed shallow lagoon has a narrow connection to the Baltic Sea in the north and is exposed to the freshwater discharge of the river Nemunas (Memel) in its central part (Fig. 1). Therefore the southern and central parts of the lagoon are freshwater, while the northern part is oligohaline with irregular salinity fluctuations from 0 to 8 psu.

The historical information on macrozoobenthos in the Curonian Lagoon comes from two major studies. The investigations of Szidat (1926) were carried out in 1925 but the species list also includes information from earlier studies. Later on, the most extensive inventory of the macrozoobenthos in the lagoon was performed during several surveys in 1951 and in the period from 1954 to 1957 (Gasiunas, 1959).

In September 2004, 22 littoral stations were visited in the Lithuanian part of the Curonian Lagoon (Fig. 1). The bottom macrofauna was collected in depths down to 1 m using a hand net. Three different types of habitats (reeds, mixed sediment and soft bottoms) were sampled separately and present in a station. For each of these sample-units, we collected organisms by stirring and removing the surface sediments to a depth of about 5 cm. Invertebrates were also collected from stones and macrophytes. During the survey, 38 samples were taken spending approx. 10–15 min per sampling. Geographic coordinates, salinity, type of sediment, exposure (sheltered/exposed) and the distance from the shoreline were noted for each sampling site.

The collected fauna was preserved with 4% formaldehyde and a standard proceeding of samples was carried out in the laboratory. All identified taxonomic groups of organisms were classified as rare (abundance <10 ind. sample^{-1}), common (10–100 ind. sample^{-1}) or abundant (>100 ind. sample^{-1}). Different taxonomical groups were analysed with unequal quality of expertise. We completely covered the groups of molluscs (Gastropoda, Bivalvia) and malacostracan crustaceans, whereas oligochaetes and leeches were identified by assistance of taxonomical experts. Similarly taxonomic assistance was used to identify insects but most of them as well as other macrozoobenthos groups were identified to higher levels of taxonomic hierarchy only.

For comparison of recent data, both historical studies (Gasiunas, 1959; Szidat, 1926) were consulted. Taxonomic nomenclature used in these studies was revised before the comparison (e.g. Costello, Emblow, & White, 2001; Glöer & Zettler, 2005; Malicky, 2005; Nesemann & Neubert, 1999). Sampling design characteristics are compared in Table 1 (but see Discussion for more details).

Results

During our study, the benthic fauna was composed of 18 main zoological groups comprising a total of 174 taxa (see Appendix A.1 list), identified for the most part of animals at species (82%) or genus (13%) level. The groups of highest species diversity were the Gastropoda (32 species), Oligochaeta (26), Bivalvia (21), Hirudinea (21), Diptera (21) and Crustacea (17). The species diversity of other taxonomical groups was much less pronounced: Trichoptera (8), Coleoptera (7), Odonata (4), Heteroptera (4), Ephemeroptera (4), Cnidaria (2), Turbellaria (2), Porifera (1), Nemertini (1), Polychaeta (1), Megaloptera (1) and Arachnida (1).

Approximately a quarter (41) of species or higher rank taxa occurred in a single station only, whereas more than half (90) were found in less than 5 stations (occurrence $<20\%$) (Fig. 2). Consequently, less than 15% (25) of all identified taxa reached occurrence of 50% or more (Fig. 3).

The gastropod *Bithynia tentaculata*, the bivalve *Dreissena polymorpha*, the oligochaete *Stylaria lacustris*

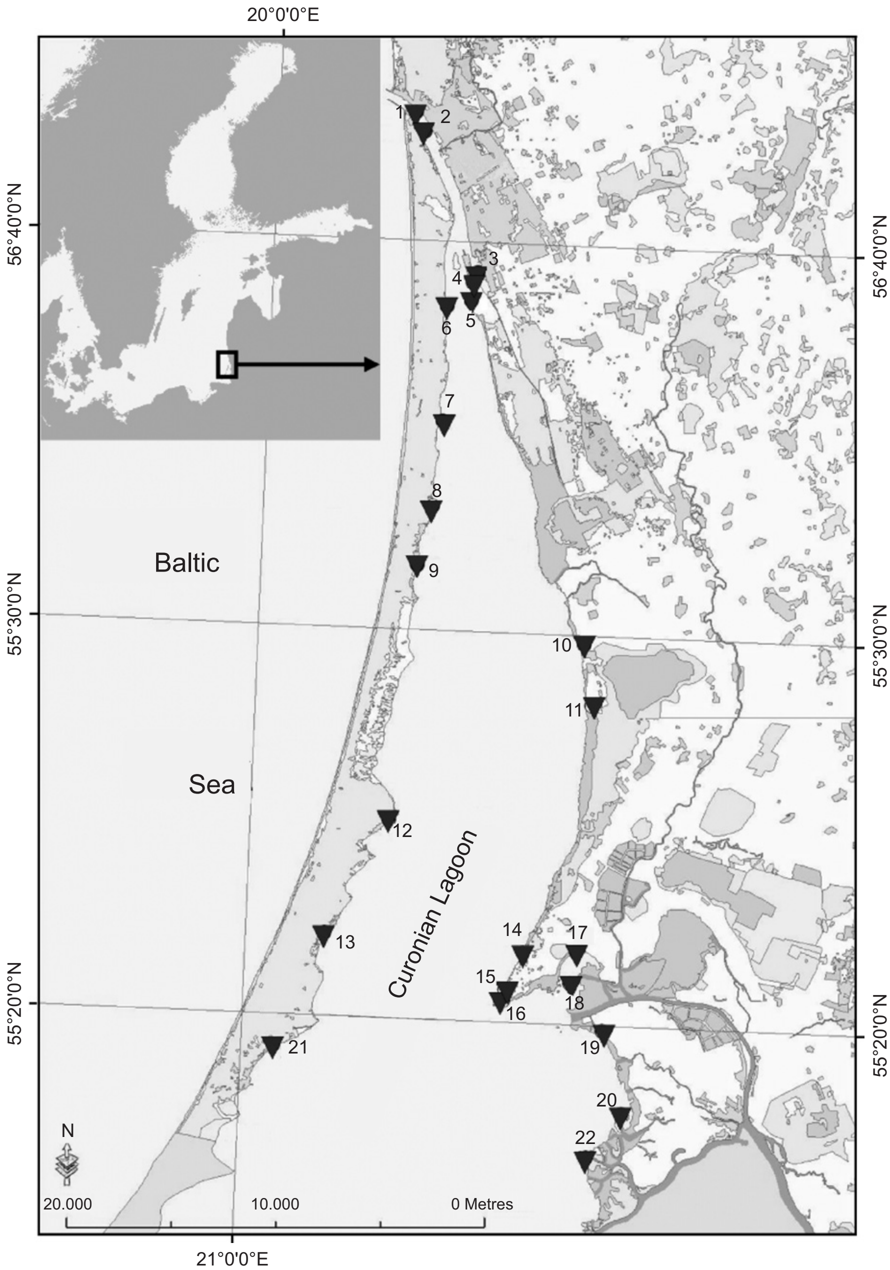

Fig. 1. The Lithuanian part of the Curonian Lagoon and sampling stations.

Table 1. Characteristics of recent and historical macrozoobenthos surveys of the Curonian Lagoon used for comparison

Survey	Sampling method	Number of stations/ samples	Depth range	Geographic range
1920s (Szidat, 1926)	Dredging[a]	Unknown/unknown	Littoral part	Along the western coastline
1950s (Gasiunas, 1959)	Ekman and Petersen grabs, core[a]	>200/unknown	Open part[b]	Entire lagoon
This study	hand net	22/38	Littoral part (< 1 m)	Lithuanian part

[a]Visual observations are very likely.
[b]Littoral sampling mentioned in the "Results" section.

and the amphipod *Obesogammarus crassus* occurred in samples most frequently. The highest abundances, however, were most often recorded for *Paramysis lacustris*, *O. crassus*, *S. lacustris*, *B. tentaculata*, *Limnomysis lacustris* and *Pontogammarus robustoides* (not shown in figure).

We found 12 euryhaline species with the polychaete *Marenzelleria neglecta*, the hydroid Cordylophora caspia and the crustaceans *Balanus improvisus*, *Corophium volutator*, *Corophium lacustre*, *Gammarus duebeni*, *Gammarus oceanicus*, *Gammarus zaddachi*, *Praunus flexuosus* and *Palaemon elegans* as the most characteristic for this group. Living specimens of freshwater neritid gastropod *Theodoxus fluviatilis* also occurred exceptionally with the above-mentioned species; however empty shells were recorded at 3 stations in the inner part of the lagoon.

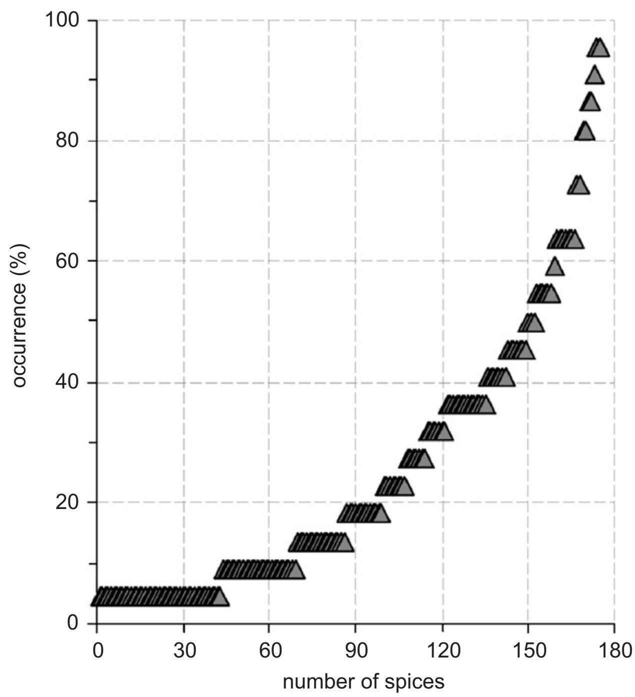

Fig. 2. Occurrence of macrofauna species found during the survey in 2004 versus their number.

The rest of species were mainly discriminated by two different habitat types – macrophytes-dominated bottoms and stony beds colonised by zebra mussels. In the presence of macrophytes, the bottom macrofauna was mainly consisting of gastropod molluscs (e.g. *Planorbis planorbis*, *Planorbis carinatus*, *Planorbarius corneus*, *Physa fontinalis*, *Radix balthica*, *Bithynia leachii*, *Gyraulus crista*, *Gyraulus albus*, *Lymnaea stagnalis* and *Anisus vortex*), whereas stony bottoms and zebra mussel beds were predominantly inhabited by crustaceans (*O. crassus*, *P. robustoides*, *Chaetogammarus warpachowskyi*, *Limnomysis benedeni* and *Paramysis lacustris)*, bivalves (*Pisidium supinum*, *Pisidium nitidum* and *Sphaerium corneum*) and some other gastropod species (*Stagnicola palustris*, *Radix auricularia* and *B. tentaculata*).

The first compilation of macrozoobenthos of the Curonian Lagoon (Szidat, 1926) contained 78 species of 18 higher taxonomical groups. Out of them 45 species were the same as found in our inventory and 34 species which did not occur in our samples (Fig. 4). On the other hand, 129 species detected during our survey were not included in Szidat's list. Two groups (Ephemeroptera and Odonata) were not covered by him, while bryozoan *Plymatella repens* was reported only in this older study. Particularly the species of Turbellaria,

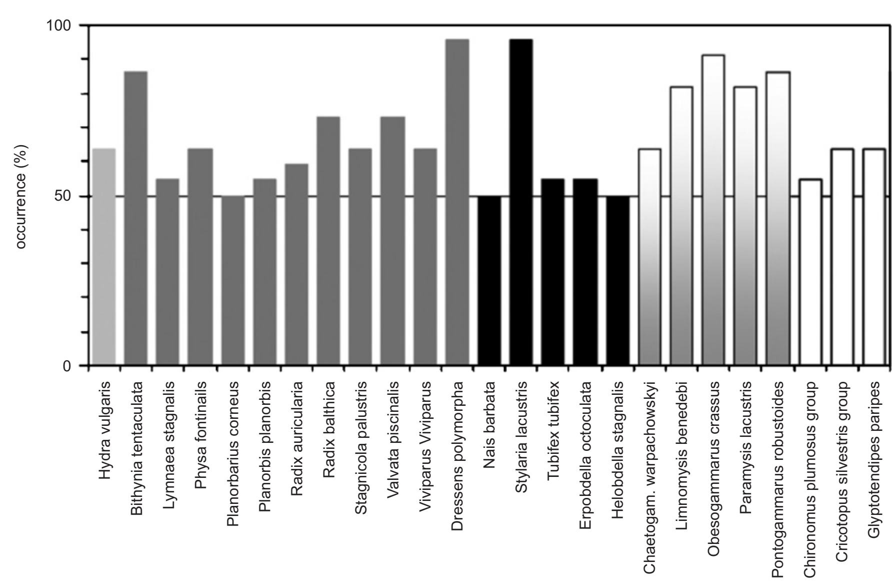

Fig. 3. Most frequent species (occurrence ⩾50%) of the Curonian Lagoon during the survey in 2004 (grey = Hydrozoa, dark grey = Mollusca, black = Annelida, grey shaded = Crustacea and white = Diptera).

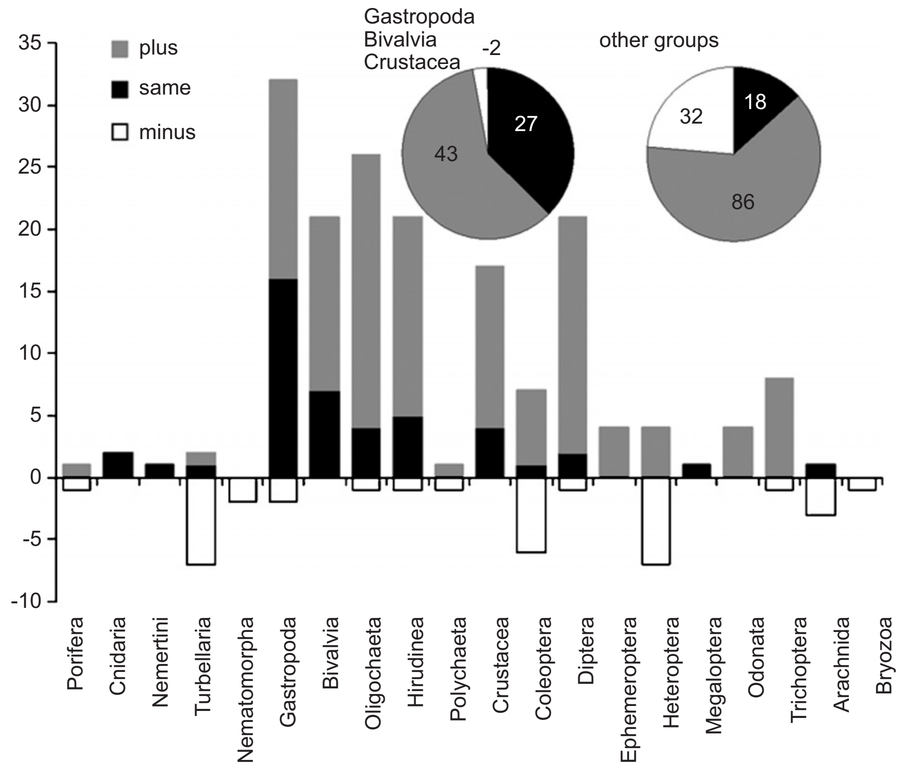

Fig. 4. Comparison of our data with Szidat (1926) in respect to specific taxa (174 vs. 78) found (same = within both time periods, plus = only in our study and minus = only in the older study). Pie charts show the difference between the two time periods for selected taxonomical groups (left) and for miscellaneous groups (right).

Coleoptera and Heteroptera were more extensively represented in Szidat's study.

The greatest congruence between our results and Szidat's list exists for gastropods and bivalves. We did not find two gastropods *Borysthenia naticina* and *Radix labiata* recorded during the historical inventory, whereas 16 gastropod species were confirmed and 18 species were additionally found. Among species in the later group relatively conspicuous *Lithoglyphus naticoides*, *R. auricularia*, *Acroloxus lacustris*, *Gyraulus albus* and *Gyraulus crista* are found with the occurrence higher than 40%. Among bivalves we found all the species mentioned in the Szidat's list, whereas all 10 species of the genus *Pisidium* (except largest in size *Pisidium amnicum*) were not mentioned in the historical list. Similarly, relatively common *Sphaerium solidum* (occurrence 36%), large *Unio tumidus* (36%) and *Anodonta cygnea* (18%) were not found in the beginning of 20th century. Within the group of Crustacea, only 4 species (*Asellus aquaticus*, *B. improvisus*, *Chelicorophium curvispinum* and *Gammarus zaddachi*) were recorded in both studies.

In the early 1950s (Gasiunas, 1959), 157 species of 16 higher taxonomical levels were counted excluding Nemertini, Coleoptera and Arachnida, but reporting the presence of Nematomorpha species, which were not found in our survey. Our recent survey confirmed presence of 61 species reported in early 1950s, while 113 species from our results were "new" and 96 species were not observed (Fig. 5). In particular, the species of Diptera and Odonata were more represented in the Gasiunas' list. Similarly to comparison of our results with Szidat's data, the greatest congruence between two time periods occurred for molluscs, but also was high for crustaceans.

Considering datasets for all three time periods macrozoobenthic diversity for the Curonian Lagoon covers 286 macrozoobenthic taxa (Fig. 6). The present study covered almost all taxonomic groups and only the species-poor groups of Nematomorpha and Bryozoa were not found. Some taxonomical groups and particularly those belonging to the insects were underrepresented in our inventory: from 59 potentially occurring species of Diptera only 21 and from 20 Odonata species only 4 were identified. The highest similarity in results was found for Gastropoda, Bivalvia, Oligochaeta, Hirudinea and Crustacea.

Summarising the results, our recent survey confirmed presence of 22 gastropod species reported earlier, 6 of them being missing in 1920s and 3 in 1950s. We did not find 4 gastropod species mentioned in earlier studies with 2 of them (*B. naticina* and *R. labiata*) found in both previous studies and another 2 (*Anisus spirorbis* and *Hydrobia ventrosa*) during 1950s only. On the other

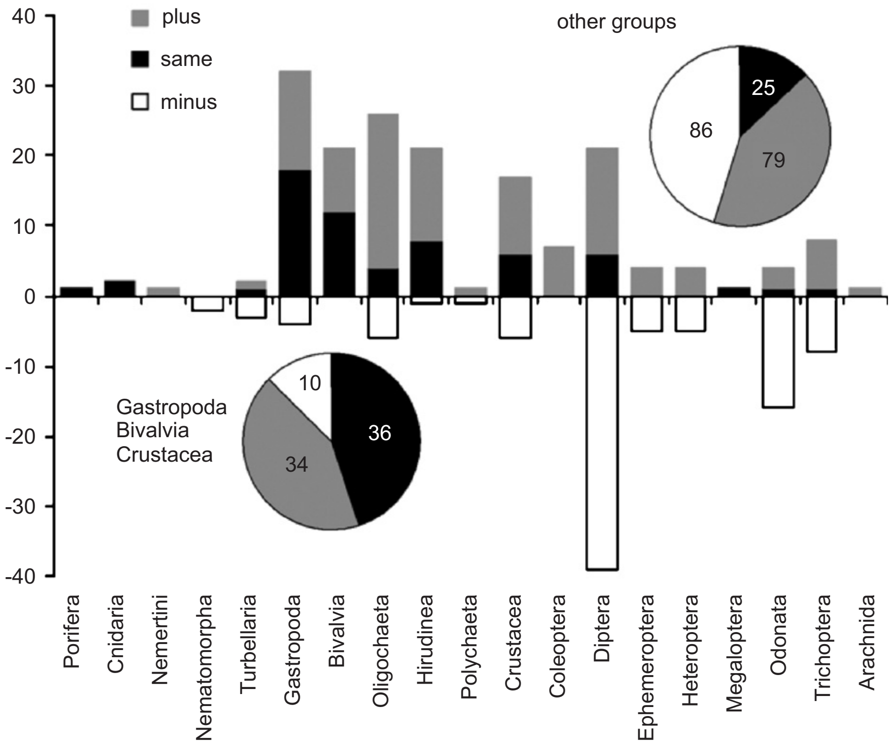

Fig. 5. Comparison of our data with Gasiunas (1959) in respect to specific taxa (174 vs. 153) found (same = within both time periods, plus = only in our study, minus = only in the older study). Pie charts show the difference between the two time periods for selected taxonomical groups (left) and for miscellaneous groups (right).

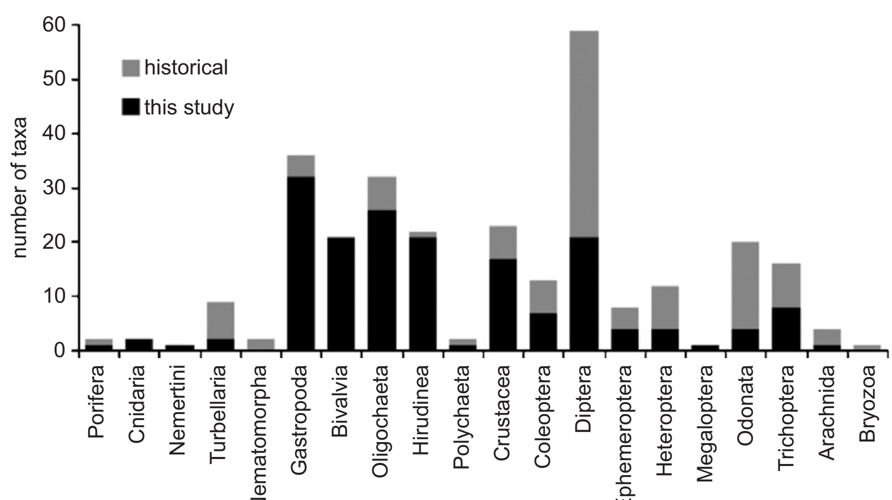

Fig. 6. Inventory of all 286 macrozoobenthic taxa of the Curonian Lagoon found during the last 100 years (Gasiunas, 1959; Szidat, 1926 and this study). The numbers found during this study are indicated by black bars. Species only found during historical surveys are indicated by grey bars.

hand, we found 10 gastropod species (*Ancylus fluviatilis*, *Bithynia troschelii*, *Gyraulus albus*, *Gyraulus crista* and *Gyraulus riparius*, *Hipeutis complanatus*, *Marstoniopsis scholtzi*, *Segmentina nitida*, *Stagnicola corvus* and *Valvata cristata*), which have not been mentioned neither in the list from 1920s nor among species found 1951–57.

Among bivalves, presence of all 12 species mentioned in earlier studies was confirmed, whereas 9 species found in the recent survey were not included in earlier lists: 7 of the later species belong to the genus of *Pisidium*, whereas another two are *A. cygnea* and *S. solidum*.

The complete list of Crustacea recorded in the Curonian Lagoon so far consists of 23 species, 6 of them being reported earlier and confirmed by our study, 6 were mentioned earlier and not observed in our study, whereas 11 were not mentioned in the Szidat's and Gasiunas studies. More than 50% of the crustacean species are allochthonous and 7 (out of 17 species in total) invaded the lagoon after the investigations of Szidat and Gasiunas.

Discussion

The present study was focused on the macrozoobenthos diversity in the largest lagoon of the Baltic Sea. Due to the high substrate variability and the high freshwater input from the Nemunas River, the Curonian Lagoon belongs to one of the most macrozoobenthos diverse estuaries of the Baltic Sea (e.g. in comparison with Vistula Lagoon, Stettin Lagoon, Boddens of Darß-Zingst) (Ezhova, Żmudziński, & Maciejewska (2005), Günther, 1998, own results). Investigated littoral habitats showed considerably higher species diversity than soft bottoms in the open lagoon. Long-term monitoring and other surveys performed during the period from 1980 to 2000 reported 85 species altogether (oligochaetes, chironomids and insects excluded) in the open parts of central and northern lagoon (Daunys, 2001). All organisms identified to the species level were also found in our survey and most of them have been determined as common in the lagoon. Similarly, in 5 littoral stations in the Strait area and adjacent waters we found 31 macrofauna species (excluding oligochaetes and chironomids), whereas 7 of those only have been mentioned after visiting 30 sites 3 times in the same year (Bubinas & Vaitonis, 2005). On the other hand, during seasonal sampling, these authors found some accidental brackish water species (*Mytilus edulis*, *Macoma balthica*, *Praunus inermis*, *Crangon crangon*, *Euridice pulchra*, *Idotea chelipes*), which we did not observe. Generally, this indicates that our littoral survey covers well the species, which permanently inhabit the lagoon; however, it may overlook taxa (originally from the marine waters off the estuary) occurring in the lagoon sporadically.

Three potential sources of differences in the results from three time periods can be identified: (1) different sampling efforts and methods, (2) differences in level of emphasis on distinct zoological groups and (3) species extinctions and introductions.

Sampling efforts and methods certainly differed between our and historical studies. It is unclear, how samples have been collected and sorted in the beginning of the 20th century (only dredging and observations were noted) as well as number and locations of stations remain unknown (Table 1). However, according to the description, sampling sites were restricted to the western coast of the lagoon and the number of littoral sites visited along the sea–river gradient was most likely lower than in both later studies. In contrast to Szidat's data, results published by Gasiunas (1959) originated from the very extensive survey carried out in the entire lagoon using Ekman-Birge and Petersen grabs as well as benthic corer. Out of 213 stations approximately 60 were located in the lagoon's area, which has been also covered by our stations. Although many species were described from a littoral part and the author most likely visited numerous places, number of these shallow stations remains unclear. It can be concluded that, according to the efforts spent in sampling, Szidat's study can be considered as a very first compilation of sporadic results by the time. Sampling effort was considerably lower than in two later studies; therefore, most likely widespread and characteristic species (particularly for groups of molluscs and crustaceans) did occur in samples only. In contrast, comprehensive species list from 1950s (Gasiunas, 1959) exhaustively reflects lagoon's biodiversity status 50 years ago. Many sampling sites were located in the open part of the lagoon, whereas grid of shallow sampling sites is comparable with that of our study. Since littoral stations are more efficient in covering biodiversity, we do no anticipate major differences between these two datasets due to sampling design.

Differences in level of emphasis on distinct zoological groups are also obvious when analysing data from various surveys. In Szidat's list nematodes (meiozoobenthos was not considered in the present study) and gastropods were probably the best-covered groups of benthic invertebrates, with bivalves and crustaceans only being sporadically noted. Similarly, Gasiunas' study provided extensive list of gastropods, but sampling and identification of bivalves and particularly insects were much more precise. Although leeches were relatively well described in all studies, analysis of changes in this group was obscured by taxonomic revisions, which took place during the last decades (Nesemann & Neubert, 1999). Therefore, considering taxonomic mismatches between the studies, analysis of long-term changes based on molluscs and malacostracan crustaceans is most reliable to reflect major trends in biodiversity changes.

In a context of taxonomical and methodolocical inconsistencies mentioned above, the most of possible species extinctions (from the major taxonomical groups of Mollusca, Crustacea and Hirudinea) are highly unlikely. Main explanations for missing species in the list of the recent inventory are rather trivial. One of such species, *H. ventrosa* is restricted to the brackish waters in the mouth of the Curonian Lagoon and can be permanently present during certain years (Bubinas & Vaitonis, 2005). It is likely that hydrological conditions during the year of our inventory were less suitable for this species; however, its sporadic appearance in the future is likely due to established population in the coastal waters of the south-eastern Baltic Sea.

The Ponto-Caspian gastropod *B. naticina* is typical for large running waters and common in the River Nemunas (Zettler, Zettler, & Daunys, 2005); therefore occasionally the species may expand its range into the lagoon by river outflow. *R. labiata* and *A. spirorbis* may live in the innermost freshwater area of the lagoon within ditches and swamps. These species are typical for swampy areas and not characteristic for the habitats we sampled. On the other hand, it is not completely clear if the taxonomical nomenclature was used correctly in the historical studies (see Zettler, Zettler, & Daunys, 2005; Glöer & Zettler, 2005). From the Hirudinea only *Haemopis sanguinea* was not observed in 2004, most likely due to the amphibian pattern of life.

Few exceptions should be emphasised in respect to species extinctions or remarkable decline in the occurrence. *T. fluviatilis* is one of the species, which both Szidat (1926) and Gasiunas (1959) accentuated as the common and of wide distribution over the brackish and fresh water parts of the Curonian Lagoon. Recently this gastropod was observed alive (and abundant) only in the relatively small brackish water area close to the sea. In the inner part of the lagoon, however, only empty (and old) shells were found. Cover of hard substrates due to increased organic material load in course of eutrophication might be one of possible explanations. Furthermore, high numbers of introduced amphipod species (see below) of the genera *Pontogammarus* and *Obesogammarus* are observed in the same habitat (under hard substrates) and may affect the dynamics of *Theodoxus* by predation on eggs and juveniles (q.v. Müller, Hendrich, Klima, & Koop, 2006).

Other potentially extinct species are the amphipods *Gammarus pulex* and *Gammarus lacustris* found by Gasiunas (1959) in the central part of the lagoon. Szidat (1926) mentioned *Gammarus pulex* as possibly overlooked species, which may colonise the eastern part of the lagoon. This shows that *Gammarus pulex* (or relations) could not have been common during the 1920s. In 1950s, both species were found more than once in gravel bottoms and among bottom vegetation on sheltered sites (Gasiunas, 1959). Later on these amphipods were not recorded in benthic communities, and the causes of their extinction remain unclear. In the Vistula River, the native European freshwater gammarid species *Gammarus pulex* was replaced already in the 1920s by the Ponto-Caspian *Echinogammarus ischnus* (Jazdzewski, Konopacka, & Grabowski, 2004), which was not recorded in Lithuanian waters since its introduction in the 1960s (Arbačiauskas, 2005). Native *Gammarus duebeni* and *Gammarus zaddachi* have been also replaced or at least outnumbered by the alien amphipods in the Vistula Lagoon (Grabowski, Konopacka, Jazdzewski, & Janowska, 2006). Therefore, it is likely that numerous introduced amphipod species (see Appendix A.1) could occupy the niches previously colonised by *Gammarus pulex* or *Gammarus lacustris*. However, misidentification and a confusion with the one by Jazdzewski (1975) afterwards described *Gammarus varsoviensis* cannot be excluded. This species we found in a mouth tributary of the River Nemunas.

During the present study, numerous species were recorded for the first time for the Curonian Lagoon. Even if results from additional literature sources are taken into account (e.g. Daunys, 2001; Gasiunas, 1959; Grahle, 1935; Loosjes, 1937; Lundbeck, 1935; Szidat, 1926), e.g. for the group of Mollusca, already more than 20 species were found for the first time (see Appendix A.1), but their occurrence is obviously not caused by recent introductions. Possible reasons could be (i) misidentification or ignore of the specific groups in earlier studies, (ii) different sampling methods or (iii) range expansion into the Curonian Lagoon from inland waters. In our opinion, the first two causes seem to be most likely. There are numerous examples of it, e.g. the taxonomical expertise for determining sphaeriid species (*Pisidium* and *Sphaerium*) is one reason for the enlarged species list in our study.

Approximately 10% of the species (16 species) have their origin outside the Baltic area. Particularly the introduced crustaceans were qualitatively and quantitatively dominant. Prominent representatives were the amphipods *Chaetogammarus warpachowskyi*, *Corophium curvispinum*, *P. robustoides*, *O. crassus*, *Gammarus tigrinus* and the mysids *L. benedeni* and *Paramysis lacustris.* Most of these species have a Ponto-Caspian origin and were introduced at the beginning of the 1960s in the tributary of the River Nemunas (Arbačiauskas, 2002). *Gammarus tigrinus*, a native amphipod of North American estuaries, however, was observed in the Curonian Lagoon during this study for the first time (Daunys & Zettler, 2006). Another North American species was the extremely tolerant euryhaline polychaete *M. neglecta*. This species was found permanently since its invasion in 1990 into the lagoon and is the only polychaete in the freshwater areas (Daunys, 2001). Most of the introduced molluscan species are established for several decades (e.g. *Potamopyrgus antipodarum*) and/or play an important role as an ecosystem engineer (*D. polymorpha*) (Daunys, Zemlys, Olenin, Zaiko, & Ferrarin, 2006).

In respect to the WFD, the characterisation of macrozoobenthos biodiversity in coastal waters of the Baltic Sea will be necessary in order to define their ecological quality status. The present investigation provides the most complete picture available so far on littoral fauna of the Curonian Lagoon and can be used in the future assessment of the lagoon ecosystem. The importance of eutrophication could be stressed more, but the main problem is that most of the abundant species (in all time periods) are tolerant to natural stressors such as in estuaries. The difficulties in determination of anthropogenic stress via indices or indicators within a naturally organic-rich system is the "paradox of estuarine quality" (see Dauvin, 2007, p. 272).

One of the main needs of the WFD is the inventory of the existing conditions of estuaries and monitor a few indicators over time at a limited number of sites. Therefore, benthic indicators in transitional waters have to be defined (Dauvin, 2007). Datasets analysed in this study cover pristine (Szidat, 1926), before major eutrophication (Gasiunas, 1959) and post-eutrophication periods. Theoretically both earlier studies may provide data for identification of reference status of the water body following guidelines to use historical information where available. Considering all benthos groups, generally minor changes relative to taxonomic and other inconsistencies between datasets are revealed by our expert-based comparison. Few potential species "extinctions" are lacking strong arguments and evidences for well-based explanations. Focusing on groups of higher accuracy of determination, major changes occurred due to introductions of alien species, which significantly increased local biodiversity. It remains unclear, how changes in a water body due to species invasions should be interpreted in a context of WFD. Even in the very eutrophic lagoon, the number of species invasions obviously exceeds the number of recorded extinctions resulting in overall increase in species diversity. Therefore, preparation of a framework for assessment of the role of alien species diversity (xenodiversity, *sensu* Leppäkoski & Olenin, 2000) in a local biodiversity should attain more efforts in the near future when implementing WFD.

Acknowledgements

Most invertebrate taxa could be identified to the present taxonomic level, only some groups needed help by specialists. For this excellent help, we would like to acknowledge to Clemens Grosser and Uwe Jueg (Hirudinea), Oleg Potjutko (Oligochaeta, Diptera) and Tomas Ruginis (Insecta). This work was partly funded by EU projects COLAR (EVK3-CT-2002-80007) and ELME (GOCE-CT-2003-505576).

Appendix A.1

Comparative list of zoobenthos species recorded in the Curonian Lagoon by different authors is provided in Table A.1.

Table A.1

Taxa/species	Until 1921[a]	1951–1957[b]	Abundance[c]	No of stns.[c]
Porifera				
Ephydatia fluviatilis L.	+	–	—	—
Spongilla lacustris (L.)	–	+	Rare	3
Cnidaria				
Cordylophora caspia (Pallas)	+	+	Common	5
Hydra vulgaris Pallas	+	+	Common	14
Nemertini				
Prostoma obscura (Schultze)	+	–	Rare	1
Turbellaria				
Bothromesostoma personatum (Schmidt)	+	–	—	—
Dendrocoelium lacteum (O.F. Müller)	+	+	Rare	7
Planaria polychroa (Schmidt)	+	–	—	–
Planaria torva (Schultze)	+	+	—	—
Polycelis nigra (Ehrenberg)	+	+	—	—
Microstomum lineare (O.F. Müller)	+	+	—	—
Plagiostomum lemani (Plessis)	+	–	—	—
Stenostomum leucops (Schmidt)	+	–	—	—
Turbellaria indet.	–	–	Common	8
Nematomorpha				
Gordius aquaticus L.	–	+	—	—
Mermis crassa (von Linstow)	+	+	—	—
Gastropoda				
Acroloxus lacustris (L.)	–	+	Rare	9
Ancylus fluviatilis (O.F. Müller)	–	–	Rare	3

Table A.1. (*continued*)

Taxa/species	Until 1921[a]	1951–1957[b]	Abundance[c]	No of stns.[c]
Anisus vortex (L.)	+	+	Common	7
Anisus spirorbis	–	+	—	—
Bathyomphalus contortus (L.)	+	–	Rare	6
Bithynia leachii (Sheppard)	+	+	Abundant	9
Bithynia tentaculata (L.)	+	+	Common	19
Bithynia troschelii (Paasch)	–	–	Common	5
Borysthenia naticina (Menke)	+	+	—	—
Gyraulus albus (O.F. Müller)	–	–	Rare	10
Gyraulus crista (L.)	–	–	Rare	10
Gyraulus riparius (Westerlund)	–	–	Rare	1
Hippeutis complanatus (L.)	–	–	Rare	4
Hydrobia ventrosa (Montagu)	–	+	—[d]	—
Lithoglyphus naticoides (C. Pfeiffer)	–	+	Rare	4
Lymnaea stagnalis (L.)	+	+	Common	12
Marstoniopsis scholtzi (A. Schmidt)	–	–	Rare	2
Myxas glutinosa (O.F. Müller)	–	+	Rare	1
Physa fontinalis (L.)	+	+	Common	14
Planorbarius corneus (L.)	+	+	Common	11
Planorbis carinatus (O.F. Müller)	–	+	Rare	6
Planorbis planorbis (L.)	+	+	Common	12
Potamopyrgus antipodarum (J.E. Gray)	–	+	Common	10
Radix ampla (W. Hartmann)	+	+	Rare	4
Radix auricularia (L.)	–	+	Common	13
Radix balthica (L.)	+	+	Common	16
Radix labiata (Rossmässler)	+	+	—	—
Segmentina nitida (O.F. Müller)	–	–	Rare	2
Stagnicola corvus (Gmelin)	–	–	Rare	3
Stagnicola palustris (O.F. Müller)	+	+	Common	14
Theodoxus fluviatilis (L.)	+	+	Common	6
Valvata cristata O.F. Müller	–	–	Common	8
Valvata macrostoma Mörch	+	–	Rare	2
Valvata piscinalis (O.F. Müller)	+	+	Common	16
Viviparus contectus (Millet)	+	+	Rare	5
Viviparus viviparus (L.)	+	+	Rare	14
Bivalvia				
Anodonta anatina (L.)	+	+	Rare	10
Anodonta cygnea (L.)	–	–	Rare	4
Dreissena polymorpha (Pallas)	+	+	Common	21
Musculium lacustre (O.F. Müller)	+	+	Rare	4
Pisidium amnicum (O.F. Müller)	+	+	Rare	7
Pisidium casertanum (Poli)	–	–	Rare	2
Pisidium crassum Stelfox	–	–	Common	3
Pisidium henslowanum (Sheppard)	–	+	Rare	8
Pisidium milium (Held)	–	–	Rare	2
Pisidium moitessierianum Paladilhe	–	–	Rare (shells)	3
Pisidium nitidum Jenyns	–	–	Common	10
Pisidium ponderosum Stelfox	–	–	Rare	9
Pisidium subtruncatum Malm	–	+	Common	7
Pisidium supinum A. Schmidt	–	+	Rare	8
Pisiduim obtusale (Lamarck)	–	–	Rare	1
Pseudanodonta complanata (Rossmässler)	+	+	Rare	2
Sphaerium corneum (L.)	+	+	Common	9
Sphaerium rivicola (Lamarck)	–	+	Rare	2
Sphaerium solidum (Normand)	–	–	Rare	8
Unio pictorum (L.)	+	+	Rare	4
Unio tumidus Philipsson	–	+	Rare	8

Table A.1. (*continued*)

Taxa/species	Until 1921[a]	1951–1957[b]	Abundance[c]	No of stns.[c]
Oligochaeta				
Aelosoma hemprichi Ehrenberg	+	+	—	—
Bothrioneurum vejdovskyanum Stolc	–	–	Rare	4
Chaetogaster diaphanus (Gruithuisen)	–	+	—	—
Chaetogaster limnaei von Baer	+	–	Rare	10
Criodrilus lacuum Hoffmeister	–	+	—	—
Dero sp.	–	–	Common	1
Eiseniella sp.	–	–	Rare	3
Enchytraeus albidus (Henle)	–	–	Common	1
Isochaetides newaensis (Michaelsen)	–	–	Rare	6
Limnodrilus claparedeanus Ratzel	–	–	Rare	3
Limnodrilus hoffmeisteri Claparede	–	+	Rare	8
Limnodrilus sp.	+	–	Rare	1
Limnodrilus udekemianus Claparede	–	+	—	—
Lumbriculus variegatus (Müller)	–	+	—	—
Nais barbata O.F. Müller	–	–	Rare	11
Nais bretscheri Michaelsen	+	–	Rare	3
Nais communis Piguet	–	–	Rare	3
Nais pardalis Piguet	––	–	Rare	2
Nais pseudobtusa Piguet	–	–	Rare	1
Nais simplex Piguet	–	–	Rare	3
Paranais uncinata (Oersted)	–	+	—	—
Pothamotrix hammoniensis (Michaelsen)	–	–	Common	8
Pothamotrix sp.	–	–	Rare	1
Pristina sp.	–	–	Rare	1
Psammoryctes albicola (Michaelsen)	–	–	Rare	1
Psammoryctes barbatus (Grube)	–	+	Rare	5
Stylaria fossularis Leidy	–	–	Common	5
Stylaria lacustris (L.)	+	+	Common	21
Tubifex costatus (Claparede)	–	–	Rare	6
Tubifex templetoni Southern	–	–	Rare	2
Tubifex tubifex (O.F. Müller)	–	+	Common	12
Hirudinea				
Alboglossiphonia heteroclita (L.)	+	+	Rare	8
Alboglossiphonia hyalina (O.F. Müller)	–	–	Rare	1
Alboglossiphonia striata (Apathy)	–	–	Rare	4
Batracobdelloides moogi Nesemann & Csanyi	–	–	Rare	1
Caspiobdella fadejewi (Epshtein)	–	–	Rare	2
Dina lineata (O.F. Müller)	–	–	Rare	2
Erpobdella monostriata Lindenfeld & Pietrusz.	–	–	Rare	8
Erpobdella nigricollis (Brandes)	+	+	Rare	8
Erpobdella octoculata (L.)	+	+	Common	12
Erpobdella testacea Savigny	–	+	Rare	1
Glossiphonia complanata (L.)	+	+	Rare	5
Glossiphonia concolor (Apathy)	–	–	Rare	5
Haemopis sanguisuga (L.)	+	+	—	—
Helobdella stagnalis (L.)	+	+	Common	11
Hemiclepsis marginata (O.F. Müller)	–	+	Rare	3
Pawlowskiella cf. *stenosa* Bielecki	–	–	Rare	2
Piscicola geometra (L.)	+	–	Rare	9
Piscicola pawlowskii (Sket)	–	–	Rare	1
Piscicola pojmanskae Bielecki	–	–	Rare	2
Piscicola sp.	–	–	Rare	9
Placobdella costata (Fr. Müller)	–	–	Common	2
Theromyzon tessulatum (O.F. Müller)	–	–	Rare	4

Table A.1. (*continued*)

Taxa/species	Until 1921[a]	1951–1957[b]	Abundance[c]	No of stns.[c]
Polychaeta				
Hediste diversicolor (O.F. Müller)	+	+	—[d]	—
Marenzelleria neglecta Sikorski & Bick	–	–	Rare	1
Crustacea				
Argulus foliaceus (L.)	–	+	Rare	3
Asellus aquaticus (L.)	+	+	Common	8
Balanus improvisus Darwin	+	+	Rare	8
Chaetogammarus warpachowskyi (G.O. Sars)	–	–	Common	14
Chelicorophium curvispinum G.O. Sars	+	+	Common	9
Corophium lacustre Vanhöffen	–	–	Rare	1
Corophium volutator (Pallas)	–	+	Rare	2
Crangon crangon (L.)	–	+	—[d]	—
Eurydice pulchra Leach	–	+	—[d]	—
Gammarus duebeni Lilljeborg	–	–	Abundant	1
Gammarus lacustris G.O. Sars	–	+	—	—
Gammarus oceanicus Segerstrale	–	–	Rare	1
Gammarus pulex (L.)	–	+	—	—
Gammarus tigrinus Sexton	–	–	Common	7
Gammarus zaddachi Sexton	+	+	Rare	1
Hemimysis anomala G.O. Sars	–	–	—[e]	—
Limnomysis benedeni Czerniavsky	–	–	Common	18
Neomysis integer Leach	–	+	—[d]	—
Obesogammarus crassus (G.O. Sars)	–	–	Abundant	20
Palaemon elegans (L.)	–	–	Common	3
Paramysis lacustris (Czerniavsky)	–	–	Abundant	18
Pontogammarus robustoides (G.O. Sars)	–	–	Common	19
Praunus flexuosus (O.F. Müller)	–	–	Rare	1
Talitrus saltator (Montagu)	–	+	—	—
Coleoptera				
Acilius canaliculatus (Nicolai)	–	–	Rare	1
Coleoptera indet.	–	–	Rare	3
Dytiscidae indet.	–	–	Rare	3
Gyrinus sp.	–	–	Rare	1
Haliplus confinis Stephens	+	–	—	—
Hydrophilus caraboides (L.)	–	–	Rare	1
Hydroporus sp.	+	–	Rare	1
Hygrobia tarda (Herbst)	–	–	Rare	1
Laccobius alutaceus Thomson	+	–	—	—
Laccophilus hyalinus (Degeer)	+	–	—	—
Noterus clavicornis (De Geer)	+	–	—	—
Noterus crassicornis (O.F. Müller)	+	–	—	—
Ochthebius pusillus Stephens	+	–	—	—
Diptera				
Ablabesmyia monilis group	–	+	—	—
Bezzia hydrophila Kieffer	–	+	—	—
Ceratopagonidae indet.	+	–	Rare	1
Cheilotrichia cinerascens (Meigen)	–	–	Rare	1
Chironomus plumosus group	–	+	Rare	12
Chironomus reductus group	–	+	—	—
Chironomus semireductus group	–	+	—	—
Chironomus thummi group	–	+	—	—
Cricotopus algarum group	–	+	—	—
Cricotopus silvestris group	–	+	Abundant	14
Cryptochironomus camptolabis group	–	+	—	—
Cryptochironomus conjugens group	–	+	—	—

Table A.1. (*continued*)

Taxa/species	Until 1921[a]	1951–1957[b]	Abundance[c]	No of stns.[c]
Cryptochironomus defectus group	–	+	—	—
Cryptochironomus fuscimanus group	–	+	—	—
Cryptochironomus monstrosus group	–	+	—	—
Cryptochironomus rolli group	–	+	—	—
Cryptochironomus sp.	+	+	—	—
Cryptochironomus viridulus group	–	+	—	—
Cryptochironomus vulneratus group	–	+	—	—
Diamesa campestris Edwards	–	+	—	—
Diamesa sp.	–	+	—	—
Endochironomus dispar group	–	+	—	—
Endochironomus tendens group	–	+	Abundant	7
Eukiefferiella sp.	–	+	—	—
Glyptotendipes gripekoveni group	–	+	Abundant	3
Glyptotendipes paripes group	–	–	Abundant	14
Heptatoma pellucens (Fabricius)	–	–	Rare	1
Limnochironomus nervosus group	–	+	—	—
Limnochironomus tritomus group	–	+	—	—
Limnophyes hydrophilus group	–	+	—	—
Limnophyes minimus (Meigen)	–	–	Rare	1
Metacnephia crassifistula (Rubzov)	–	–	Rare	1
Micropsectra praecox group	–	+	—	—
Microtendipes chloris group	–	+	Abundant	4
Orthocladius saxicola group	–	+	Rare	1
Parachironomus arcuatus group	–	–	Rare	5
Paratanytarsus sp.	–	–	Rare	10
Paratendipes albimannus group	–	+	—	—
Pelopia punctipennis Meigen	–	+	—	—
Pentapedilum exectum Kieffer	–	+	—	—
Polypedilum breviantennatum Cernovskij.	–	+	—	—
Polypedilum convictum group	–	+	—	—
Polypedilum cultellatum Goetghebuer	–	–	Rare	2
Polypedilum scalaenum group	–	+	—	—
Procladius choreus (Meigen)	–	–	Rare	4
Procladius sp.	–	+	—	—
Psectrocladius psilopterus group	–	+	—	—
Pseudochironomus prasinatus group	–	+	—	—
Simulim sp.	–	–	Rare	1
Stempelina sp.	–	+	—	—
Stictochironomus crassiforceps (Kieffer)	–	–	Rare	1
Stictochironomus psammophilus Cernovskij	–	+	—	—
Stictochironomus rosenschoeldi (Zetterst.)	–	–	Rare	8
Tabanidae indet.	–	–	Rare	2
Tanytarsus lauterborni group	–	+	—	—
Tanytarsus mancus group	–	+	Rare	3
Tendipedinae indet.	–	+	—	—
Thienemaniella sp.	–	+	—	—
Trissocladius brevipalpes group	–	+	—	—
Ephemeroptera				
Baetis sp.	–	–	Rare	1
Caenis horaria (L.)	–	+	Rare	1
Caenis macrura Stephens	–	+	—	—
Caenis sp.	–	–	Rare	2
Cloeon sp.	–	–	Rare	1
Ephemera vulgata L.	–	+	—	—
Potamanthus luteus L.	–	+	—	—
Serratella ignita (Poda)	–	+	—	—

Table A.1. (*continued*)

Taxa/species	Until 1921[a]	1951–1957[b]	Abundance[c]	No of stns.[c]
Heteroptera				
Aphelocheirus aestivalis Fabricius	–	+	—	—
Arenocoris fallenii (Schilling)	+	+	—	—
Heteroptera indet.	–	–	Abundant	2
*Ilyocaris cimicoide*s (L.)	–	–	Rare	1
Gerris odontogaster (Zetterstedt)	+	–	—	—
Gerris argentatus Schummel	+	–	—	—
Gerris lacustris (L.)	+	+	—	—
Limnoporus rufoscutellatus (Latreille)	+	–	—	—
Nepa cinerea L.	+	+	—	—
Notonecta glauca L.	+	+	—	—
Notonecta sp.	–	–	Rare	1
Sigara sp.	–	–	Common	7
Megaloptera				
Sialis lutaria (L.)	+	+	Rare	2
Odonata				
Aeshna grandis (L.)	–	+	—	—
Aeshna sp.	–	–	Rare	1
Aeshna viridis Eversmann	–	+	—	—
Coenagrion hastulatum (Charpentier)	–	+	—	—
Coenagrion lunulatum (Charpentier)	–	+	—	—
Coenagrion puella (L.)	–	+	—	—
Coenagrion sp.	–	–	Rare	4
Cordulia aenea (L.)	–	+	—	—
Enallagma cyathigerum (Charpentier)	–	+	—	—
Erythromma najas (Hansemann)	–	+	—	—
Gomphus vulgatissimus (L.)	–	+	—	—
Gomphus flavipes (Charpentier)	–	+	—	—
Ischnura elegans (van der Linden)	–	+	Rare	2
Lestes nympha Selys	–	+	—	—
Lestes sponsa (Hansemann)	–	+	—	—
Libellula depressa L.	–	+	—	—
Libellula quadrimaculata L.	–	+	—	—
Platycnemis pennipes (Pallas)	–	+	—	—
Stylurus flavipes (Charpentier)	–	–	Rare	1
Sympetrum flaveolum (L.)	–	+	—	—
Trichoptera				
Agraylea sexmaculata (Curtis)	+	+	—	—
Agraylea sp.	–	–	Rare	2
Anabolia laevis Zetterstedt	–	+	—	—
Cyrnus sp.	–	–	Rare	2
Cyrnus trimaculatus (Curtis)	–	+	—	—
Hydropsyche angustipennis (Curtis)	–	+	—	—
Hydroptila angulata Mosely	–	–	Rare	2
Hydroptila sp.	–	–	Rare	1
Limnephilus stigma Curtis	–	+	—	—
Molanna angustata Curtis	–	+	—	—
Mystacides sp.	–	–	Rare	1
Nemotaulius punctatolineatus (Retzius)	–	+	—	—
Oecetis sp.	–	–	Rare	4
Phryganea grandis L.	–	–	Rare	1
Phryganea sp.	–	–	Rare	1
Wormaldia subnigra McLachlan	–	+	—	—
Arachnida				
Hydracarina indet.	+	–	Rare	2

Table A.1. (*continued*)

Taxa/species	Until 1921[a]	1951–1957[b]	Abundance[c]	No of stns.[c]
Bryozoa				
Plumatella repens L.	+	–	—	—

[a]After Szidat (1926).
[b]After Gasiunas (1959).
[c]This study.
[d]Species recorded by Bubinas and Vaitonis (2005).
[e]Razinkovas (pers.comm.).

References

Arbačiauskas, K. (2002). Ponto-Caspian amphipods and mysids in the inland waters of Lithuania: History of introduction, current distribution and relations with native malacostracans. In E. Leppäkoski, S. Gollasch, & S. Olenin (Eds.), *Invasive Aquatic Species of Europe. Distribution, Impact and Management* (pp. 104–115). Dordrecht: Kluwer.

Arbačiauskas, K. (2005). The distribution and local dispersal of Ponto-Caspian Peracarida in Lithuanian fresh waters with notes on *Pontogammarus robustoides* population establishment, abundance and impact. *Oceanological and Hydrobiological Studies*, *34*(Suppl. 1), 93–111.

Bubinas, A., & Vaitonis, G. (2005). Benthic communities of the Klaipeda port aquatory. *Acta Zoologica Lithuanica*, *15*, 305–311.

Cederwall, H., Jermakovs, V., & Lagzdins, G. (1999). Long-term changes in the soft-bottom macrofauna of the Gulf of Riga. *ICES Journal of Marine Science*, *56*, 41–48.

Costello, M. K., Emblow, C. S., & White, R. (2001). European Register of Marine Species. A check-list of the marine species in Europe and a bibliography of guides to their identification. *Patrimoines Naturels*, *50*, 1–463.

Daunys, D. (2001). *Patterns of the bottom macrofauna variability and its role in the shallow coastal lagoon*. Ph.D. thesis, University of Klaipeda, 85pp.

Daunys, D., Zemlys, P., Olenin, S., Zaiko, A., & Ferrarin, C. (2006). Impact of the zebra mussel *Dreissena polymorpha* invasion on the budget of suspended material in a shallow lagoon ecosystem. *Helgoland Marine Research*, *60*, 113–120.

Daunys, D., & Zettler, M. L. (2006). Invasion of the North American amphipod (*Gammarus tigrinus* Sexton, 1939) into the Curonian Lagoon, south-eastern Baltic Sea. *Acta Zoologica Lituanica*, *16*, 20–26.

Dauvin, J.-C. (2007). Paradox of estuarine quality: Benthic indicators and indices, consensus or debate for the future. *Marine Pollution Bulletin*, *55*, 271–281.

Ezhova, E., Żmudziński, L., & Maciejewska, K. (2005). Long-term trends in the macrozoobenthos of the Vistula Lagoon, southeastern Baltic Sea. Species composition and biomass distribution. *Bulletin of the Sea Fisheries Institute*, *164*, 55–73.

Gasiunas, I. I. (1959). Kormovoy zoomakrobentos zaliva Kurschju mares. Trudy Akademii Nauk Litovskoy SSR, 191–291.

Glöer, P., & Zettler, M. L. (2005). Kommentierte Artenliste der Süßwassermollusken Deutschlands. *Malakologische Abhandlungen*, *23*, 3–26.

Grabowski, M., Konopacka, A., Jazdzewski, K., & Janowska, E. (2006). Invasions of alien gammarid species and retreat of natives in the Vistula Lagoon (Baltic Sea, Poland). *Helgoland Marine Research*, *60*, 90–97.

Grahle, H.-O. (1935). Zwei für das Kurische Haff neue Sphaerien und ihre mutmaßliche Verbreitung. *Archiv für Molluskenkunde*, *67*, 63–69.

Günther, B. (1998). Die Bedeutung des Makrozoobenthos für den Kohlenstoffumsatz im Sediment. *Greifswalder Geographische Arbeiten*, *16*, 286–315.

Jazdzewski, K. (1975). Remarks on *Gammarus lacustris* G. O. Sars, 1863, with description of *Gammarus varsoviensis* n. sp. (Crustacea, Amphipoda). *Bijdragen tot de Dierkunde*, *45*, 71–86.

Jazdzewski, K., Konopacka, A., & Grabowski, M. (2004). Recent drastic changes in the gammarid fauna (Crustacea, Amphipoda) of the Vistula River deltaic system in Poland caused by alien invaders. *Diversity and Distributions*, *10*, 81–87.

Leppäkoski, E., & Olenin, S. (2000). Non-native species and rates of spread: Lessons from the brackish Baltic Sea. *Biological Invasions*, *2*, 151–163.

Loosjes, F. C. (1937). Beitrag zur Molluskenfauna der Kurischen Nehrung. *Basteria*, *2*, 17–20.

Lundbeck, J. (1935). Über die Bodenbevölkerung besonders der Chironomiden des Frischen und Kurischen Haffes. *Internationale Revue der gesamten Hydrobiologie und Hydrographie*, *32*, 265–284.

Malicky, H. (2005). Ein kommentiertes Verzeichnis der Köcherfliegen (Trichoptera) Europas und des Mediterrangebietes. *Linzer Biologische Beiträge*, *37*, 533–596.

Maslowski, J. (1993). Long-term changes in bottom macrofauna of the Szczecin Lagoon (north-western Poland). *Acta Hydrobiologia*, *35*, 344–355.

Müller, R., Hendrich, L., Klima, M., & Koop, J. H. E. (2006). Das Makrozoobenthos des Oder-Spree-Kanals und der Fürstenwalder Spree in Brandenburg. *Lauterbornia*, *56*, 141–154.

Nesemann, H., & Neubert, E. (1999). Annelida, Clitellata: Branchiobdellida, Acanthobdellea, Hirudinea. In J. Schwörbel, & P. Zwick (Eds.), *Süßwasserfauna von Mitteleuropa*. Heidelberg und Berlin: Spektrum Akademischer Verlag.

Olenin, S., & Klovaite, K. (1998). Introduction to the marine and coastal environment of Lithuania. In H. von Nordheim & D. Boedecker (Eds.), *Red list of marine and coastal biotopes and biotope complexes of the Baltic Sea, Belt Sea and Kattegat*. HELCOM Baltic Sea Environment Proceedings, 75, 39–43.

Olenin, S., & Leppäkoski, E. (1999). Non-native animals in the Baltic Sea: Alteration of benthic habitats in coastal inlets and lagoons. *Hydrobiologia*, *393*, 233–243.

Olenina, I., & Olenin, S. (2002). Environmental problems of the South-Eastern Coast and the Curonian Lagoon. In E. Schernewski & U. Schiewer (Eds.), *Baltic coastal ecosystems. Structure, Function and Coastal Management* (pp. 149–156). Berlin: Springer.

Szidat, L. (1926). Beiträge zur Faunistik und Biologie des Kurischen Haffs. *Schriften der Physikalisch-ökonomischen Gesellschaft zu Königsberg*, *65*, 5–31.

Zettler, M. L., Zettler, A., & Daunys, D. (2005). Bemerkenswerte Süßwassermollusken aus Litauen. Aufsammlungen vom September 2004. *Malakologische Abhandlungen*, *23*, 27–40.

Zmudzinski, L. (1997). Resources and bottom macrofauna structure in Puck Bay in the 1960 and 1980. *Oceanological Studies*, *1*, 59–73.