Management of Biological Invasions (2013) Volume 4, Issue 1: 43–50
doi: http://dx.doi.org/10.3391/mbi.2013.4.1.06

Open Access

Research Article

The application of a Biopollution Index in German Baltic estuarine and lagoon waters

Anne K. J. Wittfoth and Michael L. Zettler*
Leibniz-Institute for Baltic Sea Research, Seestraße 15, D-18119 Rostock, Germany
E-mail: michael.zettler@io-warnemuende.de (MZ), wittfoth.anne@gmail.com (AW)
**Corresponding author*

Received: 2 May 2012 / Accepted: 17 December 2012 / Published online: 19 January 2013

Handling editor: Vadim Panov

Abstract

This paper assesses the status of three German Baltic estuarine and lagoon waters with respect to invasive species (macrozoobenthos) and their impact. A Biological Pollution Index was applied and evaluated. Overall 130 macrozoobenthic species were identified, 17 of which were aquatic alien species. The Szczecin Lagoon had the highest number of invasive species (13). Most species were of Pontocaspian origin; inland waterways are likely to play a significant role in their migration. According to the Biological Pollution Index Level (BPL) this lagoon was 'moderately influenced' by invasive species. Warnow Estuary had 11 invasive species; their origin noted generally from North-America, suggesting shipping traffic as the major distribution vector; invasive species had the same BPL as in the Szczecin Lagoon. In the Darß-Zingst-Bodden-Chain only 6 invasive species were observed, having the highest relative abundance (9–71%). Furthermore, this area had the highest BPL of all three areas, i.e. a strong negative impact. The BPL required a lot of data (including historical) and some ratings were subjective and comparisons with other areas assessed were difficult and often impossible. Due to these limitations, it is suggested that the BPL should only be used with restrictions as a universal assessment tool for invasive species in the estuarine and lagoon waters of the Baltic Sea.

Key words: Baltic Sea, invasive species, biopollution index level

Introduction

Economic globalization has resulted in the introduction of invasive alien species in different regions of the world, including Europe, with disturbing consequences to biological diversity (Genovesi and Shine 2004; DAISIE 2009). Some alien species have become invasive, i.e., an alien whose population undergoes exponential growth and rapidly extends its range (Occhipinti-Ambrogi and Galil 2004). The transfer of alien aquatic organisms by vessels has already resulted in serious impacts on natural environments and human health, and has also caused substantial economic losses (David et al. 2012). Concepts which define invasive species vary not only amongst countries, but also between scientists. In 1999, the IUCN defined an alien (synonyms non-native, non-indigenous, exotic, and introduced) species as a species intentionally or unintentionally introduced by humans, outside its past or present natural range and dispersal potential (IUCN 1999). Most introduced macroinvertebrates have established a permanent existence in estuaries. Nehring (2002) suggested four probable reasons why this has occurred:

1. Salt tolerant limnic species reach the coast via canals from inland waterways boat traffic.
2. Most estuaries are characterised by intercontinental shipping which increases the potential of invasion. This is magnified by the fact that ballast water often has estuarine characteristics.
3. Most introduced species are genuine brackish water species with a high tolerance of changing environmental conditions. They have a better chance of being transported alive than true marine species.
4. Since natural autochthonous species numbers are limited in brackish waters, it is easier for introduced species to find a niche and become established.

The spreading and establishment of aquatic alien species can cause damage to native ecosystems. Species invasion leads to a broad and deep sliding scale of alterations in invaded communities, as well as multiple ranges of societal (industrial, economic, social, recreational, health) impacts (Carlton 2002). Alterations in habitat due to the introduction of alien species may be interpreted as an overall decline in ecological quality, resulting in changes in biological, chemical and physical properties of aquatic ecosystems (Elliott 2003; Reise et al. 2006). A shift of species composition and ecosystem functioning may occur. A recent establishment of a number of alien species populations can be considered as biocontamination (Arbačiauskas et al. 2008). Alien species can also become a serious economic factor, e.g. the United States spend 100 billion US-Dollars per year for the implementation of precautionary measures against alien species (Levine 2008). Nevertheless most non-indigenous species have only a minor impact or may even provide benefits to their new environment. In many cases the determination of the impact by invasive species is complicated (Andersen et al. 2004). International cooperation in exchanging information, research and developing measurements for the management of aquatic alien species is important (Panov et al. 2002).

The European Union enacted the Marine Strategy Framework Directive (MSFD) to implement and coordinate international efforts. This directive demands that all countries of the European Union should assess the ecological status of their associated marine areas and achieve Good Environmental Status (GES) of EU marine waters by 2020. GES is characterized as marine waters that provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive (DIRECTIVE 2008/56/EC). Descriptor 2 of the Directive aims to ensure that non-indigenous species introduced by human activities, such as ballast water or hull fouling, are at levels that do not adversely alter the ecosystem. Each country has to assess the amount and impact of their aquatic alien species. The Helsinki Commission (HELCOM) announced in 2007 that the Baltic Sea Action Plan (BSAP) has a goal to achieve and maintain a GES all over the Baltic Sea before 2021. One of the management objectives of the BSAP is to cease the introduction of all alien species from ships. The biodiversity descriptor includes the target "to prevent adverse alterations of the ecosystem by minimizing, to the extent possible, new introductions of non-indigenous species". After announcing the MSFD, Task Groups for each qualitative descriptor were formed, consisting of experts providing experience related to the four European regional seas (Baltic Sea, North-east Atlantic, Mediterranean Sea and Black Sea). Firstly, approaches were made to interpret descriptors and define key terms (Olenin et al. 2010). Reports included a review of methodologies and scientific literature. The biopollution index was proposed as a method for aggregating indicators for GES assessment. In 2007 Olenin et al. developed a technique to assess the impact of individual invasive species alongside the status of a complete area. In 2011 Borja et al. accomplished an integrated environmental status approach for the first time on the Basque coast. They concluded that many methods, tools or targets for the MSFD are applicable, but often qualitative descriptors have unclear targets or missing reference conditions which make a precise assessment difficult. Interpretation of results obtained was sometimes intricate. The integration and development of indicators and methods is very important. To achieve a universal and applicable appraisal system, it is necessary to develop new methods or scrutinise existing tools. In this paper the biopollution index of Olenin et al. (2007) is applied as an assessment method for non-indigenous species and evaluated on the inner German coastal waters of the Baltic Sea.

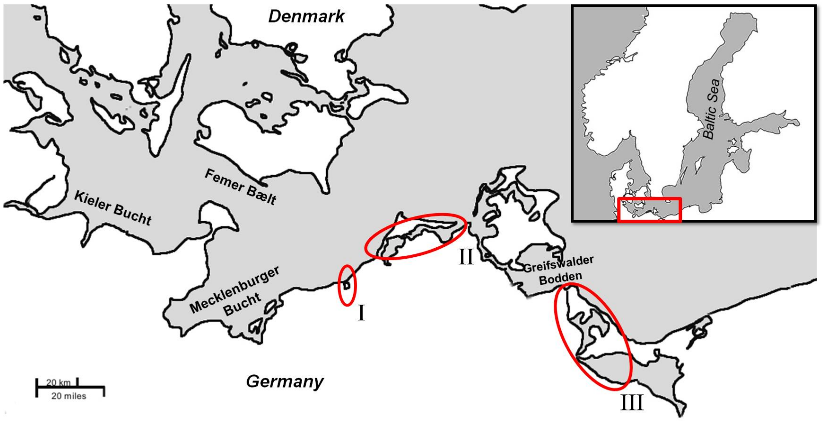
Materials and methods

Study area

Three estuarine and lagoon study sites were investigated. These sites belong to the German Baltic coast and are all characterized by a salinity gradient. The westernmost study area is the estuary of the Warnow, with six sampling stations. The salinity ranged between 0.5 in the innermost stations to 10.0 at the mouth of the river. East of this water body is the Darß-Zingst-Bodden-Chain which also had six sampling sites. The mean salinity varied between 0.5 in the innermost Bodden to 10.0 at the point of discharge to the sea. Bordering Poland, the Szczecin Lagoon had 10 sampling stations (Figure 1). Salinity gradient was less, ranging only from 0.5 and 3.0.

The main infiltration route of Pontocaspian species is via the River Oder. The Szczecin

Figure 1. Investigation area of the southern Baltic Sea. The study areas are circled in red.
I Warnow Estuary (6 stations) (54° 5'31.27"N - 54°10'52.50"N, 12° 5'10.86"E- 12° 9'15.60"E)
II Darß-Zingst-Bodden-Chain (6 stations) (54°14'38.64"N- 54°26'33.86"N, 12°21'22.42"E- 13° 2'25.56"E)
III Szczecin Lagoon (10 stations) (53°41'33.73"N- 54° 9'50.40"N, 13°41'48.44"E- 14°15'59.06"E)



Lagoon was chosen as a study site due to its connection to the Oder River and the Baltic Sea. Apart from transcontinental waterways, large harbours are also exposed to migrating species; hence the Warnow Estuary and the Szczecin Lagoon were investigated. Both these harbours are the largest in Mecklenburg-Western Pomerania (Rostock) and in Poland (Szczecin). The Darß-Zingst-Bodden-Chain was selected as a study area due to its intermediate location between the Warnow Estuary and Szczecin Lagoon. Potential vectors for the spread of non-indigenous species here is limited to small pleasure crafts, boats or active migration.

Data collection

For a sufficient database, the examined areas were investigated on three occasions; early April, end of May, and the beginning of July, 2011. Benthic invertebrates were recorded both qualitatively and quantitatively in water depth ranging from 0.5 m – 1.0 m.

Quantitative sampling:

Triplicate benthic samples were taken at all 22 sampling sites, with a 78.5 cm² core sampler. All samples were sieved through a 1 mm mesh, and invertebrates were preserved in 4% buffered formaldehyde.

Qualitative sampling:

Additional dredge hauls (containing a handnet, mesh size 2 mm) were taken for the collection of larger, mobile or rare species. At each sampling site one haul was taken, over a comparable sampling period (approx. 15 min). Analyses of dredge samples were qualitative only; relative abundance of species was recorded.

Sorting procedures were conducted at the laboratory with a stereo microscope using 10-40x magnification. All macrofauna samples were identified to the lowest taxonomic level whenever possible. Nomenclature was checked on the World Register of Marine Species (WoRMS: http://www.marinespecies.org/index.php) or Biological Library (http://www.biolib.cz/en/).

Biological Pollution Index

For the assessment of non-indigenous species the proposed index of Olenin et al. (2007) was applied. The index does not use a numerical calculation, but follows a specific literal-code. Firstly, the ADR class (abundance and distribution range) for each species in every assessment unit was determined. If the species occurred only in small numbers, its abundance was ranked as "low". Abundance was ranked as "moderate" if the species made up less than a half of the population and "high" where an alien species constituted more than 50% of the native community. The distribution of each species was then analysed. A distribution classification of "one locality" was recorded when the species occurred only in one sampling station of an assessment unit. If the species was distributed in more than one locality but less than half of the stations, its distribution was classified as "several localities". "Many localities" was used when the species was spread over half of the stations. "All localities" was used when the species occurred all over the sampling area.

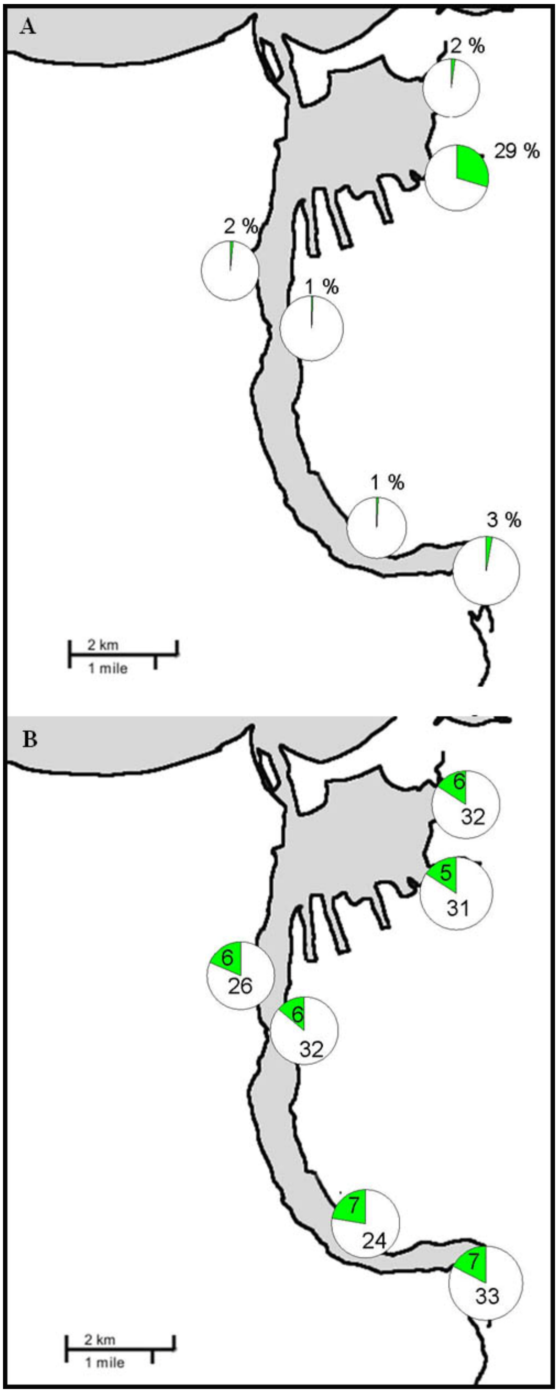


Figure 2. Distribution of non-indigenous species in the Warnow estuary. **A** - relative abundance of non-native species (green). **B - s**pecies number of native (white) and non-native species (green) at the stations.

The combination of the abundance and distribution range leads to 5 classes of the ADR (A-E), classifying the ADR from low numbers in one locality (A) to high numbers in all localities (E). The impact of the species is ranked as no impact (0), weak impact (1), moderate (2), strong (3) and massive impact (4). The possible impacts of alien species are categorized into three groups, namely impact on native species and communities (C0 to C4), impact on habitats (H0 to H4) and the impact on ecosystem functioning (E0 to E4) (see Olenin et al. 2007). The sum of the evaluation of each impact and the ADR class results in a Biopollution Level (BPL), ranging from 0 (No impact) to 4 (Massive impact). The overall BPL for the assessment unit was determined according to the greatest impact level for at least one alien species noted during the evaluation period.

Results

Distribution of invaded species

Overall 90 different macrozoobenthic species were identified in the Szczecin Lagoon. Warnow Estuary exhibited a slightly lower (80) diversity, while Darß-Zingst-Bodden-Chain had the lowest diversity of 55 species. A total of 17 aquatic alien species from 9 different orders were recorded (Table 1). 13 different alien species occurred in the Szczecin Lagoon, 11 in the Warnow Estuary and the Darß-Zingst-Bodden-Chain had only 6 non-indigenous species.

11 alien species in the Warnow Estuary belong to 7 different orders; the majority having their origin in North America. Low abundances of these species were recorded at almost all stations and their relative abundance ranged between 1 and 3% (Figure 2A). Only at one station (near the international harbour) did this percentage reach approx. 29%. Species numbers (native/non-native) ranged between 24–33 and 5–7 respectively (Figure 2B).

The Darß-Zingst-Bodden-Chain had the lowest number of macrozoobenthic species of all three areas assessed. Biodiversity included 6 alien species from 6 different orders, most originating from North America. Comparatively, their relative abundance was very high, ranging from 9 up to 71% (Figure 3A). It appears that the ratio of alien species increases with lower salinity or greater distance from the Baltic Sea. Generally 4 alien species (range 2 to 6) and 25 native species (range 20 to 30) occurred at each station (Figure 3B).

The Szczecin Lagoon supported 90 different species, including 13 non-native species from 7 different orders. Abundances varied greatly

Table 1. Observed non-indigenous species from three German Baltic coastal waters (WE – Warnow Estuary, DZBC – Darß-Zingst-Bodden-Chain, SL – Szczecin Lagoon, x – presence).

Order	Species	Study areas		
		WE	DZBC	SL
Hydrozoa	*Cordylophora caspia* (Pallas, 1771)	x	x	x
Cirripedia	*Balanus improvisus* Darwin, 1854	x	x	
Isopoda	*Proasellus coxalis* (Dollfus, 1892)			x
Amphipoda	*Chelicorophium curvispinum* (G.O. Sars, 1895)	x		x
	Dikerogammarus haemobaphes (Eichwald, 1841)			x
	Dikerogammarus villosus Sowinsky, 1894			x
	Gammarus tigrinus Sexton, 1939	x	x	x
	Obesogammarus crassus (G.O. Sars, 1894)			x
	Orchestia cavimana Heller, 1865	x		x
	Pontogammarus robustoides (Sars, 1894)			x
Mysida	*Limnomysis benedeni* Czerniavsky, 1882			x
Decapoda	*Rhithropanopeus harrisii* (Gould, 1841)	x		
Bivalvia	*Dreissena polymorpha* (Pallas, 1771)	x		x
	Mya arenaria Linnaeus, 1758	x	x	
Gastropoda	*Potamopyrgus antipodarum* (J.E. Gray, 1843)	x	x	x
Polychaeta	*Marenzelleria neglecta* Sikorski and Bick, 2004	x	x	x
	Marenzelleria viridis (Verrill, 1873)	x		
Total	Alien species	11	6	13
	Native species	69	49	77

Table 2. The assessment of the biopollution index level (Olenin et al. 2007) in three study areas [ADR-Class: Abundance and Distribution Range, Impact (Code): C – Community, H – Habitat, E – Ecosystem functioning, BPL: Biopollution level].

Study area	**Species**	**ADR-Class**	**Impact (Code)**	**BPL**
Warnow Estuary	*Balanus improvisus*	C	C0, H1, E1	2
	Chelicorophium curvispinum	A	C0, H0, E0	0
	Cordylophora caspia	A	C0, H0, E0	0
	Dreissena polymorpha	A	C0, H0, E0	0
	Gammarus tigrinus	C	C1, H0, E0	1
	Marenzelleria neglecta	A	C0, H0, E0	0
	Marenzelleria viridis	C	C1, H1, E1	2
	Mya arenaria	C	C1, H0, E0	1
	Orchestia cavimana	A	C0, H0, E0	0
	Potamopyrgus anitpodarum	C	C1, H0, E0	1
	Rhithropanopeus harrisii	A	C0, H0, E0	0
Total				**2 Moderate**
Darß-Zingst-Bodden-Chain	*Amphibalanus improvisus*	A	C0, H0, E0	0
	Cordylophora caspia	C	C0, H0, E0	1
	Gammarus tigrinus	D	C1, H1, E1	2
	Marenzelleria neglecta	D	C2, H2, E2	3
	Mya arenaria	A	C0, H0, E0	0
	Potamopyrgus antipodarum	B	C0, H0, E0	1
Total				**3 Strong**
Szczecin Lagoon	*Chelicorophium curvispinum*	A	C0, H0, E0	0
	Cordylophora caspia	B	C1, H1, E1	1
	Dikerogammarus haemobaphes	A	C0, H0, E0	0
	Dikerogammarus villosus	C	C1, H0, E0	1
	Dreissena polymorpha	C	C1, H1, E1	2
	Gammarus tigrinus	B	C0, H0, E0	1
	Limnomysis benedeni	C	C0, H0, E0	1
	Marenzelleria neglecta	A	C0, H0, E0	0
	Obesogammarus crassus	A	C0, H0, E0	0
	Orchestia cavimana	A	C0, H0, E0	0
	Pontogammarus robustoides	C	C1, H0, E0	1
	Potamopyrgus antipodarum	B	C0, H0, E0	1
	Proasellus coxales	A	C0, H0, E0	0
Total				**2 Moderate**

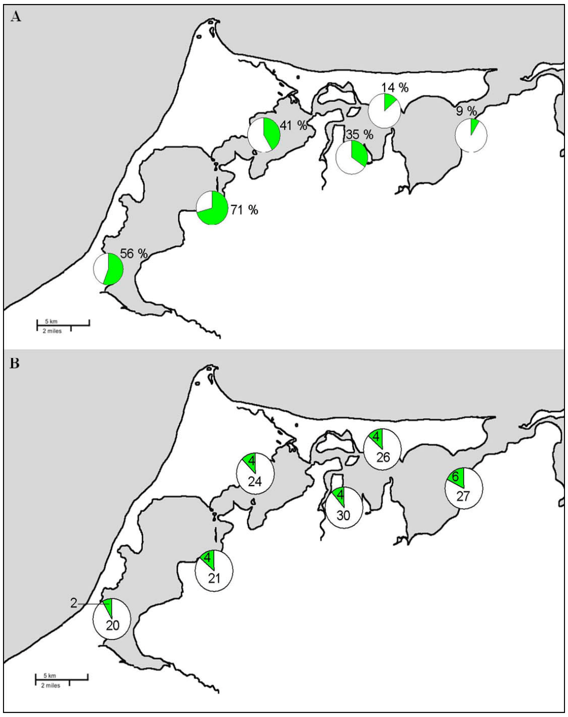


Figure 3. Distribution of non-indigenous species in the Darß-Zingst-Bodden-Chain. **A** - relative abundance of non-native species (green). **B** - species number of native (white) and non-native species (green) at the stations.

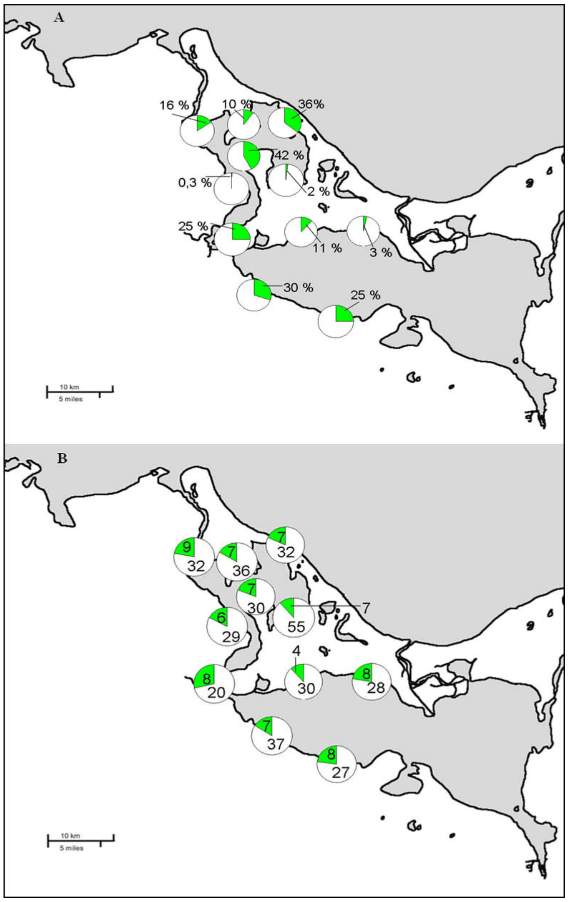


Figure 4. Distribution of non-indigenous species in the Szczecin Lagoon. **A** - relative abundance of non-native species (green). **B** - species number of native (white) and non-native species (green) at the stations

amongst stations. Three stations had a low percentage of alien species (0.3 to 3%), but the majority had a higher percentage ranging between 10 and 42 % (Figure 4A). Most stations were occupied by 7 alien species (range 4 – 9) and 35 native species (range 20 – 55) on average (Figure 4B). Amphipods played an important role both in species number (Table 1) and abundance. The majority of the alien species have their origin in the Pontocaspian region.

Evaluation of the Biological Pollution Index Level

Results are outlined in Table 2. According to the index the Warnow Estuary has a moderate Biological Pollution Level. Determining species included *Balanus improvisus* Darwin, 1854 and *Marenzelleria viridis* (Verrill, 1873), which scored a BPL of two; they exist in moderate numbers in many localities, but overall impact is weak. More than half of the species have no impact on the ecosystem, because they are relatively rare. Only the amphipod *Gammarus tigrinus*, the mussel *Mya arenaria* and the snail *Potamopyrgus anitpodarum* have a weak effect.

The Darß-Zingst-Bodden-Chain had the lowest diversity of alien species but the highest biological pollution of all three study areas. The influence of the species *Marenzelleria neglecta* Sikorski & Bick, 2004 is significant resulting in a strong biopollution. Other species have hardly any or only weak effects with the exception of *Gammarus tigrinus* Sexton, 1939.

Moderate biological pollution is noted for the Szczecin Lagoon due to the high abundance of *Dreissena polymorpha* (Pallas, 1771) and its adverse consequences. No considerable effects were detected by half of the species in the system. Other species had only a weak impact level which resulted in a BPL of one.

Discussion

The number of alien species in the Warnow Estuary is low. This may be due to a healthy natural community (Good Environmental Status) which exists, inhibiting new species from colonizing or where competition is greater in this estuary. The only exception is a station that has 29% non-native species (5 different species). Perhaps the proximity of the industrial harbour to this sampling area is a reason for the high percentage of non-indigenous species; the special habitat (turf) may also play a major role. The last comprehensive macrozoobenthic investigation of the Warnow Estuary (at least partially, only the mouth of the river was considered) was the study of Zettler (1999). Almost all species observed during this survey were also recorded in his previous work. However, the invasive species (e.g. *Gammarus tigrinus* and *Marenzelleria viridis* appear to be more established.

Invasive amphipods in the Szczecin Lagoon make up almost 100 % of total amphipod species diversity. Previous studies in recent decades show that the invasion of 6 amphipod species has altered faunal composition and enriched diversity (Zettler 2008). The majority of alien species have their origin in the Pontocaspian region (personal data, not shown). To date native species (mainly *Gammarus duebeni* Liljeborg, 1852) has not been adversely impacted. The natural occurrence of this native amphipod depends mainly on saltwater intrusions from the Baltic Sea and its range is restricted to stations close to the river mouth.

The Darß-Zingst-Bodden-Chain had the lowest number of species of all three assessed areas with the majority of invaders originating from North America (personal data, not shown). Limited number of invasive species may be as a result of many contributory factors; the isolated location of the sampling station, shallow waters, no harbour for cargo ships or no large inflowing rivers. The only potential entrance for species is via a small opening to the Baltic Sea where only pleasure boats occur. However, *Marenzelleria neglecta* and *Gammarus tigrinus* reached their highest abundance at most stations of this estuary. Two decades since their introduction these species have become dominant. *M. neglecta* colonised the muddy areas in the deeper parts and occurred at greater sediment depths than other species in this area. This colonization of the substrate by the spionid appears to encourage the proliferation of other organisms and acts as an ecological engineer (Zettler et al. 2002).

A fast and consistent assessment of the impact of alien species requires a practical and universally usable index. It is important that results are internationally comparable. The strength of the BPL is that it considers relevant parameters for the assessment of the impact of aquatic alien species, such as abundance, shifts in ecosystem functioning or habitat alteration. An added benefit of the application is that it is not confined to faunal invaders; floral invasives can also be assessed (Olenina et al. 2010). Another advantage of the index is that it directly indicates which species poses the biggest threat to an ecosystem. Specific consequential management measures can be taken.

The biopollution index is applicable to all habitats; however the use of the index has its limitations. A lot of data is required and the evaluation of the impact of species requires a lot of experience. Furthermore, it is difficult to get sufficient historical data to estimate the effect on native species or their extinction, since inadequate detailed monitoring data exists. Unfortunately some ratings are subjective and making a comparison with other assessed areas can be difficult or even impossible, e.g. the assessment of changes in ecosystem functioning. How should such changes be measured or which scale should be used to measure the strength of impacts? Another concern is that the true impact of a species can only be measured if it is well established, since new introduced species are initially low in number and their impact may be underestimated. As a result new invasive species will generally indicate minimal effect. A solution could be including experiences of similar cases. Certain limitations to the index should be reviewed, e.g. the dimension of impacts from different groups (e.g. fish, phytoplankton etc.) (Olenin et al. 2010). For phytoplankton, the index needs further development specific to pelagic life, e.g. the temporally variability of abundance and shifts in trophic levels (Olenin et al. 2010).

A general disadvantage of the index is that it assesses all effects of alien species as ultimately negative. For positive impacts from an invading species no formula exists. An invasive ecological engineer could benefit an area; *Marenzelleria neglecta* could loosen and aerate soil and make it easier for other species to settle in an area (see Zettler 1996; Zettler et al. 2002).

Due to the limitations mentioned, the BPL has been found to be only usable with restrictions as a universal assessment tool for invasive species in the coastal waters of the Baltic Sea.

Acknowledgements

We would like to thank Uwe Jueg for the identification of the leeches and Frank Wolf for his help with the classification of butterfly larvae. In addition, our thanks go to Dr. Ralf Bochert for the identification of Trichoptera larvae. We acknowledge Marina Wigger for preliminary examination of the English translation and Dr. Monica Sullivan as final English editor of the paper. We also thank an anonymous reviewer for critical comments and recommendations on earlier drafts of this paper.

References

Arbačiauskas K, Semenchenko V, Grabowski M, Leuven RSEW, Paunović M, Son MO, Csányi B, Gumuliauskaitė S, Konopacka A, Nehring S, van der Velde G, Vezhnovetz V, Panov VE (2008) Assessment of biocontamination of benthic macroinvertebrate communities in European inland waterways. *Aquatic Invasions* 3: 211–230, http://dx.doi.org/10.3391/ai.2008.3.2.12

Andersen MC, Adams H, Hope B, Powell M (2004) Risk assessment for invasive species. *Risk Analysis* 24: 787–793, http://dx.doi.org/10.1111/j.0272-4332.2004.00478.x

Borja Á, Galparsoro I, Irigoien X, Iriondo A, Menchaca I, Muxika I, Pascual M, Quincoces I, Revilla M, Rodríguez JG, Santurtún M, Solaun O, Uriarte A, Valencia V, Zorita I (2011) Implementation of the European Marine Strategy Framework Directive: A methodological approach for the assessment of environmental status, from the Basque Country (Bay of Biscay). *Marine Pollution Bulletin* 62: 889–904, http://dx.doi.org/10.1016/j.marpolbul.2011.03.031

Carlton JT (2002) Bioinvasion ecology: assessing invasion impact and scale. In: Leppäkoski E, Gollasch S, Olenin S (eds), Invasive Aquatic Species of Europe: Distributions, Impacts, and Management. Kluwer Academic Publishers, Dordrecht, The Netherlands, pp 7–19

David M, Perkovič M, Suban V, Gollasch S (2012) A generic ballast water discharge assessment model as a decision supporting tool in ballast water management. *Decision Support Systems* 53: 175–185, http://dx.doi.org/10.1016/j.dss.2012.01.002

Elliott M (2003) Biological pollutants and biological pollution – an increasing cause for concern. *Marine Pollution Bulletin* 46: 275–280, http://dx.doi.org/10.1016/S0025-326X(02)00423-X

European Parliament and Council (2008) DIRECTIVE 2008/56/EC. Establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). *Official Journal of the European Union* 164: 19–40

DAISIE (2009) Handbook of alien species in Europe. Invading Nature – Springer Series in Invasion Ecology, Vol. 3, Springer, Dordrecht, pp 400

Genovesi P, Shine C (2004) European strategy on invasive alien species. Nature and Environment 137. Council of Europe, Strasbourg, pp 66

HELCOM (2007) The HELCOM Baltic Sea Action Plan. Helsinki Commission

IUCN (1999) IUCN Guidelines for the prevention of biodiversity loss due to biological invasions. *Newsletter of the Species Survival Commission IUCN - The World Conservation Union* 31: 28–42

Levine JM (2008) Biological invasions. *Current Biology* 18: 57–60, http://dx.doi.org/10.1016/j.cub.2007.11.030

Nehring S (2002) Estuaries: The habitat for alien macro invertebrates in German coastal waters. *Aliens* 15: 14–15

Occhipinti-Ambrogi A, Galil BS (2004) A uniform terminology on bioinvasions: a chimera or an operative tool? *Marine Pollution Bulletin* 49: 688–694, http://dx.doi.org/10.1016/j.marpolbul.2004.08.011

Olenin S, Minchin D, Daunys D (2007) Assessment of biological pollution in aquatic ecosystems. *Marine Pollution Bulletin* 55:379–394, http://dx.doi.org/10.1016/j.marpolbul.2007.01.010

Olenin S, Alemany F, Cardoso C, Gollasch S, Goulletquer P, Lehtiniemi M, McCollin T, Minchin D, Miossec L, Occhipinti-Ambrogi A, Ojaveer H, Jensen KR, Stankiewicz M, Wallentinus I, Aleksandorv B (2010) Marine Strategy Framework Directive –TaskGroup 2 Report. EUR 24342 EN Non-indigenous species. Office for Official Publications of the European Communities, Luxembourg 2010, pp 44

Olenina I, Wasmund N, Hajdu S, Jurgensone I, Gromisz S, Kownacka J, Toming K, Vaiciute D, Olenin S (2010) Assessing impacts of invasive phytoplankton: The Baltic Sea case. *Marine Pollution Bulletin* 60: 1691–1700, http://dx.doi.org/10.1016/j.marpolbul.2010.06.046

Panov V, Gollasch S, Leppäkoski E, Olenin S (2002) International cooperation in aquatic invasive species research, information exchange and management in Europe. *Aquatic Invaders* 13 (4): 1–5

Reise K, Olenin S, Thieltges DW (2006) Are aliens threatening European aquatic coastal ecosystems? *Helgoland Marine Research* 60(2): 106–112, http://dx.doi.org/10.1007/s10152-006-0024-9

Zettler ML (1999) Untersuchungen zum Makrozoobenthos des Breitlings (südliche Ostsee) unter besonderer Berücksichtigung der Crustacea. *Rostocker Meeresbiologische Beiträge* 7: 79–90

Zettler ML (1996) Successful establishment of the spionid polychaete *Marenzelleria viridis* (Verrill 1873), in the Darss-Zingst estuary (southern Baltic) and its influence on the indigenous macrozoobenthos. *Archive of Fishery and Marine Research* 43: 273–284

Zettler ML, Daunys D, Kotta J, Bick A (2002) History and success of an invasion into the Baltic Sea: The polychaete *Marenzelleria cf. viridis*, development and strategies. In: Leppäkoski E, Gollasch S, Olenin S (eds), Invasive Aquatic Species of Europe: Distributions, Impacts, and Management. Kluwer Academic Publishers, Dordrecht, The Netherlands, pp 66–75

Zettler ML (2008) Veränderungen einer litoralen Amphipoden-Gemeinschaft am Beispiel einer Langzeitstudie im Oderhaff. *Lauterbornia* 62: 27–32