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Unintended “biological cargo” of ships entering the River Odra estuary: assemblages of organisms in ballast tanks

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Key words: ballast tank water, ballast tank sediment, alien species, River Odra estuary, Szczecin harbour

Abstract
Water and sediment in ships’ ballast tanks provide habitats for various organisms, and thus facilitate alien species introductions. Ballast tank water and sediment of 19 ships docked in the GRYFIA Szczecin Ship Repair Yard (Szczecin, Poland) located in an area connected with the River Odra estuary (Southern Baltic), were sampled in 2009–2011 to find out if the ships could be vectors of species introductions to the estuary, already known for the presence of non-indigenous taxa. This study showed the ballast water of the ships examined to house rotifers, copepods, cladocerans, and bivalve and cirriped larvae – common constituents of zooplankton assemblages in coastal waters. The ballast tank sediment supported meiobenthic foraminiferans, nematodes, harpacticoid copepods, turbellarians, bivalves, polychaetes, and chironomid and cirriped larvae. It is not possible at this stage to judge what meiofaunal taxa constitute an alien component in the estuary biota. Macrobenthos in the ships’ ballast tank sediment examined was represented mainly by nereid polychaetes. Although the unintended “biological cargo” examined proved quite diverse and abundant, it contained few identified alien taxa. It does not seem likely than any of them could pose a threat of a biological invasion in the River Odra estuary. However, numerous species remained unidentified, and therefore assessment of the risk of alien species introduction and invasion contains a large measure of uncertainty. On the other hand, the risk as such remains, since the density of ballast water-borne organisms in all ships exceeded the allowed limits.

Introduction

Ballast tank water and sediment of sea-going ships may provide habitats for a number of pelagic and benthic organisms, thereby facilitating their dispersal and introductions into novel areas [1, 2]. An important role in this respect is played also by biofouling [3], which is of a particular importance for the spread of epibenthic, in most cases Ponto-Caspian, species in inland waterways of the central and western Europe [4, 5]. The River Odra estuary (ROE; Fig. 1) is an area of both marine and inland shipping; therefore, the estuary’s harbours, primarily Szczecin, Police, and Świnoujście, can act as gateways for species’ introductions [6].

ROE consists of three major parts. The Pomeranian Bay, a brackish (salinity about 6–7 psu) Baltic embayment, constitutes the northernmost component. The Bay receives inflows of, usually, oligohaline (about 1 psu) to fresh water from the Szczecin Lagoon, the middle ROE component which intercepts the River Odra water and is periodically affected by seawater incursions from the Bay. The southernmost part of ROE is formed by the downstream reaches of the Odra and the adjacent Lake Dąbie, the salinity there seldom exceeding 0.4 psu [7, 8, 9].

Out of 50+ alien species ever reported from ROE and adjacent waters, about 30 are known to have been introduced into the Baltic Sea, and/or to have spread there, in connection with ships’ traffic (cf. Baltic Sea Alien Species Database http://www.corpi.ku.lt/nemo/mainnemo.html and Alien Species in Poland http://www.iop.krakow.pl/ias/

Default.aspx). Most of those species represent macrobenthos, and could have been brought in by ships operating in inland waters. The presence of as few as 10 alien species known now from ROE can be related to introductions via ballast tanks of the usually sea-going ships [6].

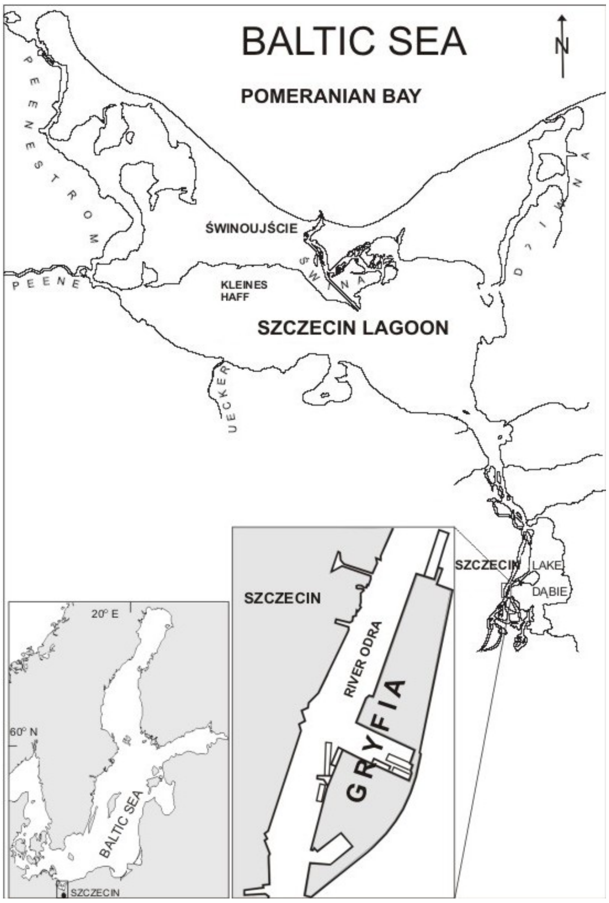

Fig. 1. GRYFIA Ship Repair Yard' location against the background of the River Odra estuary

Introductions of non-indigenous organisms with ships' ballast water and the resultant biological invasions are widely regarded as a considerable threat to the integrity of aquatic (including marine) ecosystems. This threat has been recognised both in scientific literature [1, 10] and in the management practice of the International Maritime Organization (IMO), the latter calling for efficient methods of alien species control [11, 12]. The control measures imply the need to identify potential invaders [13].

In 2009–2011, ballast tank water and sediment biota of a total of 19 ships docked in the GRYFIA Ship Repair Yard, located in the Szczecin harbour (Fig. 1) were examined. This paper is aimed at presenting preliminary data on ballast tank assemblages and at assessing whether the unintended "biological cargo" poses any threat of introducing alien species into ROE.

Materials and methods

The ships whose ballast tank water and sediment were examined included vessels of 1682–38 056 DWT; they were bulk, general cargo, dry cargo and RO-RO carriers, tankers, reefers, a car carrier, and a passenger vessel (Tab. 1). The ships were last ballasted from 1 to 19 days prior to deballasting (and/or sampling) in Szczecin (Tab. 1). Obviously, the ballast tank sediment residence time was longer than that of the water, as usually not all the sediment is removed along with the ballast water during its discharge. Therefore, the sediment residence time in the tanks was impossible to assess.

Upon arrival to the shipyard and prior to docking, some of the ballast water was discharged directly to the shipyard basin adjacent to the docking quay. The remaining water was discharged once the ship was placed in a dry dock. The ballast tank water was then sampled (Fig. 2), and its salinity and pH measured. Whenever possible, at least a 1000 dm^3 sample of water discharged from the ballast tank was collected. In two instances, ballast tanks were not opened after docking, so the ballast water was sampled when pumped to the engine room. The water was filtered through 50 µm (diagonal dimension) mesh size plankton net. The material retained on the net was fixed in 70% ethyl alcohol and examined for the zooplankton.

Fig. 2. Sampling of ballast water on the dry dock

Table 1. Characteristics of ships surveyed, including ballasting history (n.a. – data not available; e – estimated)

Ship No.	Ship type	DWT	Ballasted at (last port of call*)	Last ballasted on	Date of dry-docking / sampling	Amount of ballast released in Szczecin [t]	Days in tank
1	Fall pipe vessel	11546	Norway	18.11.2009	28.11.2009 / 01.12.2009	4000	10
2	General cargo	4234	Wismar, Germany	28.11.2009	30.11.2009 / 02.12.2009	1560	2
3	Reefer	6129	Maloy, Norway (St. Petersburg, Russia*)	22.11.2009	01.12.2009 / 03.12.2009	340	9
4	Passenger/Ro-ro	4655	Rostock, Germany	07.12.2009	09.12.2009 / 11.12.2009	1397	2
5	Ro-ro cargo	4450	Immingham, UK	07.12.2009	15.12.2009	1207	**8**
6	Multiporpose / General cargo	4800	Söråker, Sweden	14.12.2009	17.12.2009	1560	**3**
7	General cargo	11990	Rotterdam, the Netherlands* + Marin + North Sea + Baltic Sea	28.04.2010	10.05.2010 / –	2871	12
8	Tanker	14910	Antwerp, Belgium	03.05.2010	19.05.2010 / 27.05.2010	5497	16
9	Bulk carrier	38056	Rotterdam, the Netherlands	25.07.2010	27.07.2010 / 28.07.2010	5100	**3**
10	Bulk carrier	28115	Lübeck, Germany	12.01.2011	17.01.2011	9572	**5**
11	Bulk carrier – self unloader	18964	Rostock, Germany	08.01.2011	16.01.2011 / –	7203	8
12	Reefer[1]	6333	St. Petersburg, Russia	04.02.2011	07.02.2011 / 22.02.2011	258	**18**
13	Tanker	36993	Sines, Portugal	14.02.2011	21.02.2011	12513	**7**
14	Dry cargo	3495	Szczecin, Poland (Halsvik, Norway*)	20.02.2011	26.02.2011 / –	672	6
15	Dry cargo	3120	Åhus, Sweden	23.02.2011	28.02.2011 / 01.03.2011	930	5
16	Chemical tanker	9494	Antwerp, Belgium	26.02.2011	03.03.2011	3988	**6**
17	General cargo[2]	1682	Tilbury, UK	03.04.2011	07.04.2011	300	**4**
18	Bulk carrier	26264	Liverpool, UK	01.04.2011	20.04.2011 / 15.04.2011	7250	19
19	General cargo	1800	Rhine and Meuse delta (Dordrecht) the Netherlands	? 17.04.2011	29.04.2011	540	**<12**
20	Reefer	7763	St. Petersburg, Russia	23.04.2011	02.05.2011 / 17.05.2011	800	9
21	General cargo	6260	Świnoujście, Poland	21.06.2011	22.06.2011	2438	**1**
22	Car carrier	3347	Ust' Luga, Russia* + Grimsby + Malmö	30.07.2011	01.08.2011 / 02.08.2011	1390	**2**

[1)] 1106 l of water sampled (pumped) in engine room, [2)] 42 l of water sampled (pumped) in engine room

Once the ballast tank was emptied of water, the sediment accumulated on the tank bottom was collected (Fig. 3) for the study of meio- (5 samples of 50 cm^3 sediment each, collected with 2.73 cm i.d. plastic liners) and macrobenthos (5 samples of 1 dm^3 sediment each, collected into plastic jars of appropriate size). The sediment samples were sieved on 0.500 mm (macrofauna) and 0.063 mm (meiofauna) mesh size sieves. The sieving residue was preserved in 10% buffered formalin, and the meiofauna samples were stained with Rose Bengal for the ease of examination. The fish were collected from the bottom of the dry dock during or shortly after the discharge of ship's ballast water.

Fig. 3. Sampling of sediment in a ballast tank

Results

Water

The ballast tank water salinity ranged from 0.3 to 35.2 psu; based on the Venice system [14], the water was classified as ranging from fresh (2 ships) to oligo- (6) to meso- (9) to polyhaline (3) to seawater (euhaline) (1) (Tab. 2). Most of the water discharged was meso- to polyhaline (Fig. 4).

The ballast tank zooplankton was found to consist of taxa regarded as members of holo-, mero-, and tychoplankton (Tab. 3), the latter consisting of organisms (e.g. harpacticoid copepods) which were transferred to the water accidentally, most probably by disturbance of the tank water sediment. The holoplankton was represented by 4 higher taxa (Rotifera, Copepoda, Cladocera, Mysida), whereas the meroplankton consisted of larval forms of polychaetes, cirripeds, decapods, bivalves, and gastropods. Most holoplanktic taxa showed a fairly high frequency of occurrence (5.3 – 63%; Table 3), copepods being the most common among them (63%). The meroplankton occurred at a frequency of 5.3 – 31%, bivalve larvae being the most common organisms (Tab. 3).

Table 2. Characteristics of ballast water and sediments form the ships studied

Ship No.	Water			Sediments	
	pH	PSU	Classification acc. to Venice System*	Sediment type	Organic matter content (%)
1	7.3	2.5	O	fine sand	12.9
2	9.1	16.6–21.8	M	silt/clay	10.5
3	7.2–7.9	1.2	O	–	–
4	–	0.9	O	very fine sand	35.2
5	7.5	2.4–2.8	O	fine sand	13.5
6	7.8	6.7	M	–	–
7	–	–	–	very fine sand	15.4
8	7.5	13.7	M	fine sand	9.2
9	8.2	24.3–25.3	P	silt/clay	10.6
10	7.8–7.9	10.8–11.0	M	–	–
11	–	–	–	very fine sand	31.0
12	8.6	0.3	F	–	–
13	7.2–7.5	33.0–35.2	E	–	–
14	–	–	–	medium sand	3.2
15	8.1	9.3	M	–	–
16	8.3	2.8	O	very fine sand	24.0
17	8.6–8.7	16.4–18.3	M/P	very fine sand	54.5
18	8.4	29.0	P	silt/clay	54.2
19	7.8	0.4	F	very fine sand	31.5
20	8.3	8.9	M	medium sand	10.3
21	8.4	4.1	O	very fine sand	8.6
22	8.7	11.5	M	very fine sand	19.0

* code describing Venice System classification: F – freshwater; O – oligohaline; M – mesohaline; P – polyhaline; E – euhaline (marine).

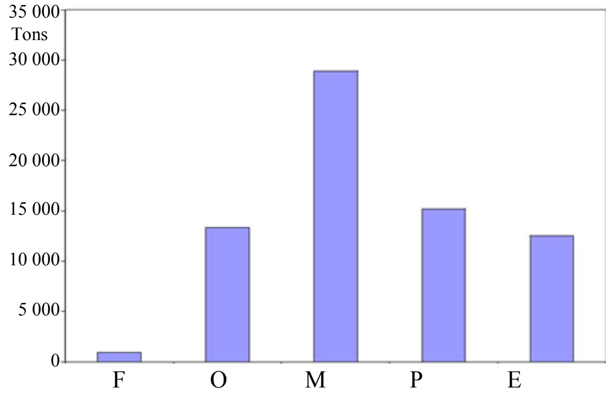

Fig. 4. Amount of ballast water [t] released from ships studied in Szczecin ($n = 21$) grouped in salinity classes according to Venice system (see Table 2 for explanation of symbols)

Table 3. Occurrence of major taxa in ballast tank water and sediment of ships surveyed

Habitat / taxon	Frequency (%)	No. of identifiable lower taxa	No. of alien taxa
Ballast water (n = 19)			
Rhizaria	15.8	unknown	unknown
Rotifera	15.8	13	0
Polychaeta	5.3	unknown	unknown
Copepoda	63.2	26	4
Cladocera	26.3	10	0
Cirripedia	26.3	unknown	unknown
Mysida	5.3	1	0
Decapoda	5.3	unknown	unknown
Bivalvia	31.6	unknown	unknown
Gastropoda	5.3	unknown	unknown
Actinopterygii	5.3	6	1
Ballast sediments (n = 17)			
Rhizaria	76.5	unknown	unknown
Turbellaria	35.3	unknown	unknown
Rotifera	23.5	unknown	unknown
Nematoda	100.0	13	3
Gastrotricha	17.6	unknown	unknown
Kinorhyncha	5.9	unknown	unknown
Oligochaeta	11.8	unknown	unknown
Polychaeta	23.5	2	1
Copepoda	88.2	9	2
Cladocera	5.9	unknown	unknown
Ostracoda	29.4	unknown	unknown
Cirripedia	11.8	2	1
Isopoda	5.9	unknown	unknown
Insecta	17.6	2	0
Halacaroidea	5.9	unknown	unknown
Tardigrada	11.8	unknown	unknown
Bivalvia	35.3	1	1

Not all the planktic taxa could be identified to lower taxonomic levels (genera and species). Overall, the number of ballast water-borne taxa identified to a lower taxonomic level ranged from 0 to 21 per ship (Fig. 5). Those taxa that could be identified further included rotifers (13 species and genera), adult and sub-adult copepods (26 species and genera), cladocerans (10), and mysids (1) (Tab. 3). Most of the identifiable species and genera represented taxa common in coastal and/or estuarine waters of the Baltic Sea, and the non-indigenous species were few only. These included the copepods *Saphirella* cf. *indica* and *Oncaea* spp. which occurred at a very low frequency (2 and 1 ships, respectively). However, none of the meroplankters could be identified to the genus / species level, and hence the non-indigenous species incidence could not be determined. On the other hand, the decapod crab zoeae present in the ballast tank water can be regarded as non-indigenous in the Baltic Sea and its adjacent coastal water bodies (including ROE). Among the 3 tychoplanktic taxa identified to lower level (3 genera of harpacticoid copepods), 1 (the harpacticoid genus *Dactylopsia*) had not been reported earlier from the Baltic Sea and its adjacent water bodies (including ROE).

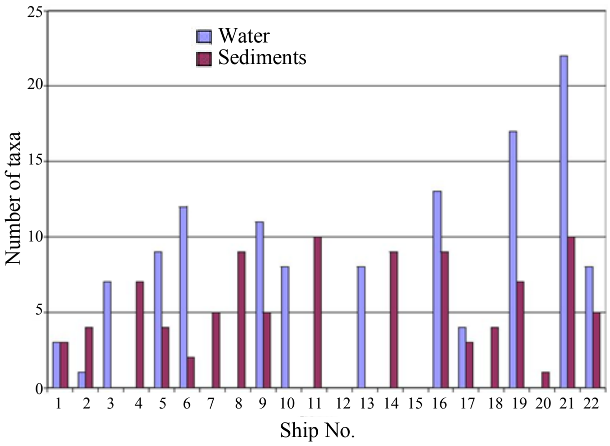

Fig. 5. Number of identified taxa found in ballast water (n = 13 ships) and sediments (n = 17 ships) from ballast tanks of ships sampled in GRYFIA Szczecin Ship Repair Yard in 2009–2011

The ballast water of two ships did not yield any organisms; the total densities of animals found in the quantitative ballast water samples collected from the 10 ships were found to range from 62 to about 643,400 ind./m^3 (Fig. 6). Copepods were the most abundant zooplanktic component. The non-indigenous taxa *Saphirella* cf. *indica* and *Onceaea* spp. occurred at densities of 2–300 and 13 ind./m^3, respectively.

The ballast water discharged by a ship arriving to ROE from Antwerp was found to carry 6 freshwater fish species. Nearly a half of the 60+ individuals retrieved from the ballast water were made up by the ruffe (*Gymnocephalus cernuus*), a species common in ROE. On the other hand, the sample revealed also the bullhead (*Cottus perifretum*), a riverine species [15] that does not inhabit the Odra.

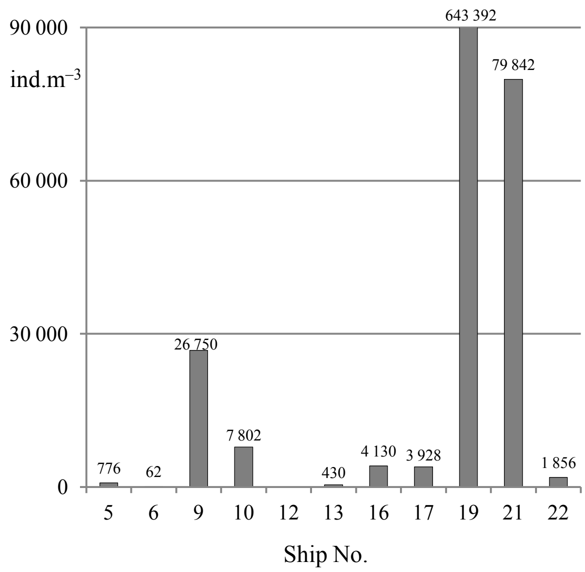

Fig. 6. Total abundance of organisms in m^3 (> 50 microns in minimal dimension), found in water released form ballast tanks upon dry-docking (except ship No. 12 and 17)

Sediment

The ballast tank sediments of most ships were classified as very fine to medium sand; two ships only carried silt / clay in their tanks (Tab. 2). Consequently, the sediment-dwelling fauna, summarised in table 3, is typical of fine sediment habitats. Organisms found in the sediment consisted of the meiobenthos and the macrofauna. Among the benthic meiofauna (organisms smaller than 0.5 mm), the ballast tank sediment supported a total of 8 major taxa (meiobenthic foraminifers, nematodes, harpacticoid copepods, turbellarians, bivalves, polychaetes, and chironomid and cirriped larvae). Only the nematodes and harpacticoid copepods could be identified to lower taxonomic levels (genus). Among the first, the genera *Deontolaimus*, *Rhabditis*, and *Southerniella* had not been reported from the area before, whereas among harpacticoids, 2 taxa (*Asellopsis intermedia* and *Paralaophonte* sp.) proved to be unreported before. Identification of other meiobenthic taxa to lower taxonomic level was not possible, hence the incidence of non-indigenous taxa remains unknown. It may be contended, however, that the foraminifers present in the sediment can be regarded as non-indigenous for ROE, since they were represented by calcareous taxa absent from the coastal Baltic waters and the Odra estuary [16].

The number of sediment-occurring taxa identified to a lower level ranged from 0 to 29 per ship (Fig. 5).

Meiobenthic organisms occurred in the sediment at average abundances of 14 to $107.8 \cdot 10^3$ ind./dm^3 sediment. They were dominated by nematodes (up to 100% of the total meiobenthos in a ship's sediment) and foraminifers (up to 89%).

The macrobenthic organisms were found to inhabit the ballast tank sediment of 6 ships. The macrofauna, wherever present, consisted mainly of annelids: unidentified oligochaetes and the nereid polychaetes *Alitta succinea* and *Hediste diversicolor*. While the first occurs in the western part of the Baltic Sea, the other is a polychaete common in the sandy bottoms of the Baltic Sea proper. The annelids were accompanied by large nematodes. The macrobenthos occurred at average abundances of 0.3 to 7.6 ind./dm^3 sediment.

Discussion

The ballast tank water in the ships surveyed were found to support quite diverse assemblages of organisms (altogether 11 major taxa and at least 57 lower level ones; cf. Tab. 3). For comparison, other studies revealed from 9 major and 12 lower taxa [17] to 25 major taxa [18] in the ballast tank water. In their summary of 25 years (until 2000) of European research on the life in ballast tanks, Gollasch et al. [19] reported up to 18 major taxa and 135 identifiable lower taxa (data from 131 ships). When the comparison is restricted to faunistic lists from the ballast tank water of ships surveyed in Baltic ports, it is only Walk and Modrzejewska [20, 21] who provided relevant data; they found 15 major taxa and 34 lower-level ones in ballasted ships in the Polish Baltic ports of Gdańsk and Gdynia. In their interesting study, Olenin et al. [22] examined en-route the faunistic composition of the ballast water plankton of ships travelling from the Baltic Sea to European ports on the open Atlantic coast and recorded the presence of 9 major zooplanktic taxa and at least 27 species.

Although the taxonomic richness of the ballast tank water assemblage in the present study was comparable to data reported elsewhere, the number of non-indigenous taxa was very low. There were only two non-indigenous copepods, *Saphirella* cf. *indica* and *Oncaea* spp. While both are known to be marine copepods [23, 24], *Saphirella* sp. has been reported (even as a zooplankton dominant) from estuarine waters of the North American Atlantic coast [25]. In view of ecological requirements of both taxa, their chances of tolerating reduced salinity typical of ROE (particularly in its upper reaches where the GRYFIA shipyard is located) are rather slim. Besides, both occurred at few ships only, although in one of them copepodites of *Saphirella* sp. occurred at a considerable density. Although Gollasch and Leppäkoski [26] quoting Carlton [1], contend that the probability of colonisation of brackish recipient areas by organisms from a marine donor region is high, the two copepods do not seem, at present, to be posing a threat of invasion in ROE or the Baltic Sea in general. The differences in environmental conditions between the donor (fully marine regions and North American estuaries) and receiver (ROE) areas should make it impossible for those taxa to survive in the latter [18]. On the other hand, the overall densities of the ballast tank water fauna proved, for all the ships examined, higher (or even substantially so) than the highest acceptable levels (i.e. not more than 10 viable organisms, greater than or equal to 50 micrometres in minimum dimension, per cubic metre) as given in Regulation D-2 of the IMO International Convention for the Control and Management of Ships' Ballast Water and Sediment of 2004 [11], which is noteworthy in itself.

The ballast tank sediment assemblages, in this study comprising 17 major meiobenthhic taxa (with 13 nematode and 8 harpacticoid copepod genera) and 6 macrobenthic ones, were generally less diverse, compared to other studies. The number of higher taxa (meiobenthos and macrofauna combined) reported by other authors amounted to 18 [27], with 89 species and genera; Gollasch et al. 2002, with 139 species and genera, those studies involved a much higher number of ships. In the Baltic Sea, the only published study dealing with ballast tank sediment concerned the meiobenthos [28] examined in a single ship, also docked in the GRYFIA shipyard. The analysis revealed the presence of 7 major meiofaunal taxa, the number of nematode genera being 11. It is not possible at this stage to judge which meiofaunal taxa constitute an alien component in the ROE biota. Although 3 of the 13 nematode genera and 1 harpacticoid copepod identified have not been reported from the meiobenthos of ROE and southern Baltic coastal waters before, the poor general knowledge on the taxonomic diversity of the Baltic meiobenthos cf. [29] precludes any conclusion as to the non-indigenous status, and invasion potential, of any of these genera and the species they represent.

Of the two polychaete species found in the ballast tank sediment, *H. diversicolor* is common in the sandy bottoms of the Baltic Sea, including the northern part of ROE. *A. succinea* is typical of the western part of the Baltic, and has been reported from the north-western part of ROE [30]. The habitat preference of the two nereids is convergent with that of the invasive spionid polychaete *Marenzelleria neglecta* [30], one of two alien species (known in ROE since 1986) whose appearance in ROE can be attributed to the ship-mediated introduction.

All but one fish species, including the most abundant ruffe (*Gymnocephalus cernuus*), found in the ballast tank, are common in ROE. The bullhead (*Cottus perifretum*) has not been reported from the River Odra so far.

Szczecin is a freshwater harbour, so the highest risk of alien species introduction should be connected with ballast water originating from freshwater or oligohaline port located within short distance (requiring short time voyage) [26]. The risk assessment for ballast water mediated species introductions based on voyage pattern analysis of ships calling at Polish harbours (except Gdynia) in 2007–2009, carried out by Jóźwiak [31], showed that Szczecin was among the recipient ports with the highest, or extreme, risk (12% in Szczecin) of alien species introductions. This risk category included also Antwerp and Rotterdam, the ports of call from which some of the ships surveyed in this study arrived.

Conclusions

Although the unintended “biological cargo” of ballast tank water and sediment carried by the ships surveyed proved quite diverse and abundant, it comprised few identified alien taxa. It does not seem likely at present that any of them could pose a threat of a biological invasion in the River Odra estuary. However, numerous species had to remain unidentified, and therefore the assessment of the risk of alien species introduction and invasion involves a large measure of uncertainty. On the other hand, the risk as such remains, since the density of ballast water-borne organisms in all ships exceeded the allowed limits.

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