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DISTRIBUTION AND THE ROLE OF *HYDROBIIDAE* ON THE MIDDLE POMERANIAN (DARŁOWO-WŁADYSŁAWOWO)

Krystian Obolewski, Zbigniew Piesik

Department of Ecology and Protection of the Sea,
Pomeranian Pedagogical University,
ul. Arciszewskiego 22b, 76-200 Słupsk, Poland
e-mail: obolewsk@pap.edu.pl

Abstract

A population of *Hydrobia* sp. (*Hydrobia ulvae* Pennant and *Hydrobia ventrosa* Montagu) was studied in the Polish coastal zone (up to 3 nautical miles) of the Baltic Sea within the open coast of Polish Middle Pomerania. Abundance, wet biomass, and the frequency of *Hydrobia* were determined in the coastal waters, including estuaries of the Wieprza, Słupia, Łupawa, Łeba rivers and open coastal in the vicinity of Czołpino (Słowiński National Park) and Władysławowo. The frequency (F) of *Hydrobia* in the open coast of the Middle Pomerania amounted to 39%, while in the coastal zone of the open sea (Czołpino and Władysławowo) there were no snails. The abundance of *Hydrobiidae*, in the coastal zone surveyed, ranged from 0 to 398 specimens per m^{-2} of the bottom ($\bar{x}$ = 33.7 spec. m^{-2}). Wet biomass of this bivalve ranged from 0 to 12.0 g_{ww} m^{-2} ($\bar{x}$ = 1.0 g_{ww} m^{-2}). Apparently *Hydrobia* sp. has found better conditions for living and development in the estuary Middle Pomerania coast compared to open coastal. The abundance of this gastropods in the estuary zone was 27-fold higher than in the open coast and the wet weight was about 1.5-fold higher, respectively. *Hydrobiidae* plays an important role in the monitoring of benthos of the Baltic Sea, not constitutes a distinct food base of animals (fish and other hydrobionts).

Key words: Polish coastal zone of Baltic, estuary, *Hydrobia* sp., abundance and biomass

INTRODUCTION

Hydrobia ulvae and *Hydrobia ventrosa* (Gastropoda: Prosobranchia) are a species widely distributed in the seas and oceans of the Northern Hemisphere (North America, Europe, Asia), (Grudemo and Johannesson 1999). In the Baltic Sea it is a characteristic species of the macrozoobenthos, inhabiting the bottom down to some 30--50 m deep (Warzocha 1994). *Hydrobia* sp. for its not large size don't gain a substantial biomass and it may become a dominant macrozoobenthos species while *Mytilus edulis* or *Mya arenaria* are absent or poorly represented. The biomass of

Hydrobia sp. constitutes also a food base for fish including commercially important fish species (Krzykawski and Załachowski 1983, Mulicki 1947). The species surveyed has been studied as a component of Baltic benthos (Demel and Mulicki 1954, Grudemo and Johannesson 1999, Mulicki and Żmudziński 1969, Schulte-Oehlmann et al. 1997, Warzocha 1994, Woźniak 2004). More detailed studies were carried out in the Pomeranian Bay and in the Gdańsk Bay (Bąk 1997, Herra and Wiktor 1985, Osowiecki 2000, Kube et al. 1996, 1997, Masłowski 2001, Witek 1995, Żmudziński and Ostrowski 1990, Żmudziński and Andrulewicz 1997). In addition to the abovementioned authors, *Hydrobia* as a component of the macrozoobenthos, was studied also by Kotwicki 1997, Żmudziński 1982 a and b, Haque et al. 1997, Żmudziński and Andrulewicz 1997 who concentrated on the Polish territorial waters, particularly the shallowest zone subjected to wave action. These snails are an important species enabling determination of macrozoobenthos' changes in monitoring of the Baltic Sea. The coastal zone, due to a direct contact with land and receiving waters of predominantly polluted and eutrophied rivers, is along the deepest areas, the most endangered zone of the Baltic Sea.

The aim of the present study was to determine the distribution and structure (abundance, wet weight and size) of the population of *Hydrobia* sp. in the 3-mile Polish coastal zone within the stretch of Darłowo-Władysławowo. The data acquired will help to determine in the future the quantitative changes indicating trends in development of *Hydrobia* in our Middle Pomeranian coastal zone exposed to various factors of human activity. This paper is also intended to outline the distribution and abundance of *Hydrobiidae* as a food base for animals, in this number also fish species of economical importance.

MATERIAL AND METHODS

Hydrobia sp. was studied from 1998 throughout 2002, within the 3-mile Polish coastal zone of the Baltic stretching from Darłowo to Władysławowo (Fig. 1). The gastropods were sampled from a total of 10 sites with a Van Veen bottom sampler, covering the area of 0.1 m^2. A double sample was taken from each site, which translates to a total of 44 samples. The precise location of the profiles and the sampling sites was determined using the Global Positioning System (GPS) and a radar bearing. A total of 6 bottom profiles perpendicular to the shoreline were designated within the coast stretch studied. The profiles were 3-nautical-mile-long (in Darłowo additionally on 4 Nm), except for Władysławowo, where the profile was only 2-mile-long.

Within the latter, two additional sites were designated 1 mile from the shore and 1 mile to the west and to the east. Also the type of substrate and the depth were noted on the individual sites (Tab. 1). Fig. 1 and table 2 present the location and the distance from the shore (in nautical miles) and the number of sampling sites on individual profiles. The material collected was strained on a benthic sieve with a 1-mm mesh size and subsequently fixed in a 4-% formaldehyde solution. In the laboratory, the material was sorted (not classified to species) and the number of the gastropods was related to 1 m^2. The wet weight of *Hydrobia*, dried on a filter paper (including

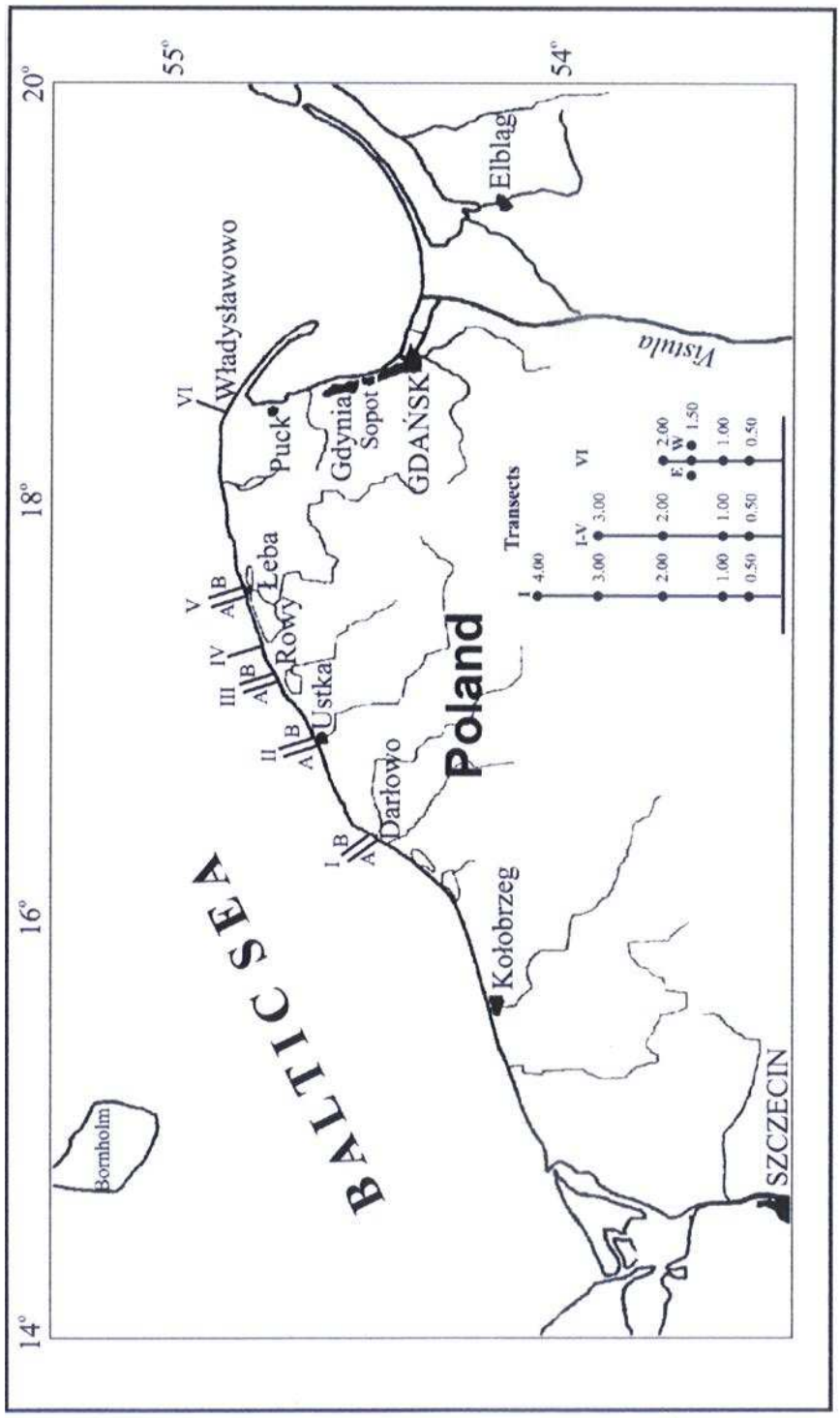

Fig.1. Location of sampling stations and transects

Table 1

Depth and substrate type on the sampling sites in the coastal zone of the Middle Pomerania

Region Location	Transect	Nautical miles											
		0.5		1.0		1.5		2.0		3.0		4.0	
		A	B	A	B	A	B	A	B	A	B	A	B
Wieprza estuary Darłówko West	IA	9.0	fgs	13.5	mgs	---	---	14.7	mgs	19.3	fgs	20.0	mgs
Darłowo East	IB	8.2	fgs	15.0	mgs	---	---	17.0	mgs	19.5	cgs	21.0	gs
Słupia estuary Ustka West	IIA	11.0	fgs	14.6	gs	---	---	16.5	fgs	18.0	gs	---	---
Ustka East	IIB	6.7	g	12.5	gs	---	---	18.5	gs	20.0	gs	---	---
Łupawa estuary Rowy West	IIIA	5.7	fgs	16.5	ss	---	---	20.0	gs	22.4	gs	---	---
Rowy East	IIIB	6.4	fgs	12.7	fgs	---	---	22.4	gs	20.0	gs	---	---
Open coastal Czołpina	IV	5.5	fgs	10.8	fgs	---	---	16.7	ss	18.9	gs	---	---
Łeba estuary Łeba West	VA	5.1	g	14.0	fgs	---	---	17.7	ss	18.2	fgs	---	---
Łeba East	VB	3.0	fgs	11.2	fgs	---	---	18.2	fgs	---	fgs	---	---
Open coastal Władysławowo	VI	8.0	g	13.0	ss	IW 12.0	IE 13.0	IW ss	IE ss	15.4	g	---	---

g – gravel, fgs – fine-grained sand, mgs – medium-grained sand, cgs – coarse-grained sand, ss – silty sand, gs – gravelly sand, s – stons

Table 2

Comparison of the abundance, biomass, and the frequency of *Hydrobia* sp. in the coastal zone of river estuaries (first order estuary) and the Czołpino and Władysławowo

Region	Estuary		Open coast		Estuary			Open coast		
	abundance ind. m^{-2}				biomass g_{ww} m^{-2}		F	biomass g_{ww} m^{-2}		F
	range	$\bar{x}$	range	$\bar{x}$	range	$\bar{x}$	(%)	range	$\bar{x}$	(%)
Polish Baltic coastal zone	0-398	27.3	0	0	0-12.0	1.0	39	0	0	0

the water present in the mantle cavity) was determined on a laboratory balance to the nearest 0.001 g and related to the $1m^2$ of the bottom. The size of *Hydrobia* sp. was determined through measuring the shell width (from its apex to the shell base) using a slide calliper to the nearest 0.1 mm. A total of 283 specimens of *Hydrobiidae* were measured.

RESULTS

In macrozoobenthos Mollusca the dominated four species bivalves, presently observed in the studied stretch of the Polish coastal zone (Darłowo-Władysławowo) were *Macoma balthica* (L.), *Mytilus edulis* L., *Mya arearia* L., and *Cardium glaucum* Petersen, however Gastropods represented two species *Hydrobia ulvae* and *Hydrobia ventrosa*, all of them typical representatives of shallow areas of the Baltic Sea. *Hydrobiidae* in the searched 3-mile-long coastal zone by the density and biomass were replaced by bivalvia representatives. The abundance of *Hydrobia sp.* in the studied zone was significantly diversified (from 0 to 398 specimens per m^2) and in the profiles Darłówko East (I B), Rowy West (III A), Łeba East (V b) and the open coastal zone Czołpino (IV) and Władysławowo (VI) no gastropods was found (Tab. 2). The abundance of Hydrobia on the bottom of the coastal zone of the Middle Pomerania was on the profiles Łeba (transect n^o V A): $\bar{x}$ = 107 ind. m^{-2}. The highest mean densities of analysed snails in the waters of middle Pomerania were recorded on profiles II B (Ustka East) and V A (Łeba West) and they amounted to 102 and 107 ind. per m^2, respectively.

Detailed data relating to *Hydrobia* sp. density in studied profiles on certain sites (in different distance from the shore, Fig. 1) are showed in table 3. It is noticed that the highest density on all researched profiles are noted in 2 Nm distance from the shore ($\bar{x}$ = 6.01 ind. m^{-2}). *Hydrobiidae* rarely inhabit the most shallow and the deepest coastal zones (above 20 m) an exeption was Wieprza river, mouth where *Hydrobia* appeared only in the deepest localized state. Analysing *Hydrobia* distribution on profiles situated in the areas of river-mouths (estuaria) it is stated that average snail density is 1.5 times higher on western profiles ($\bar{x}$ = 50.6 ind. m^{-2}) than on eastern ones ($\bar{x}$ = 33.6 ind. m^{-2}), on exeption is Łupawa river-mouth.

Table 3

Abundance and frequency (F) of *Hydrobia* sp. in the studied Polish coastal zone of the Baltic (Darłowo-Władysławowo)

Region Location	Transect	Abundance (ind. m^{-2})							F (%)
		Nautical Mile (Nm)						$\bar{x}$	
		0.5	1.0	1.5	2.0	3.0	4.0		
Middle Pomerania									
Wieprza estuary Darłówko West	IA	320	0	-	0	0	0	64.0	20
Darłowo East	IB	0	0	-	0	0	0	0	0
Słupia estuary Ustka West	IIA	0	5	-	120	0	-	31.3	50
Ustka East	IIB	0	0	-	90	318	-	102.0	50
Łupawa estuary Rowy West	IIIA	0	0	-	0	0	-	0	0
Rowy East	IIIB	0	130	-	0	0	-	32.5	25
Open coastal Czołpino	IV	0	0	-	0	0	-	0	0
Łeba estuary Łeba West	VA	0	0	-	398	30	-	107	50
Łeba East	VB	0	0	-	0	-	-	0	0
Open coastal Władysławowo	VI	0	0	1W: 0 / 1E: 0	0	0	-	0	0

Table 4

Wet weight and frequency of *Hydrobia* sp. in the studied Polish coastal zone of the Baltic (Darłowo-Władysławowo)

Region Location	Transect	Biomass (in: g_{ww} m^{-2})							F (%)
		Nautical Mile (Nm)						$\bar{x}$	
		0.5	1.0	1.5	2.0	3.0	4.0		
Middle Pomerania									
Wieprza estuary Darłówko West	IA	12	0	-	0	0	0	2.4	20
Darłowo East	IB	0	0	-	0	0	0	0	0
Słupia estuary Ustka West	IIA	0	0.05	-	4.5	0	-	1.1	50
Ustka East	IIB	0	0	-	2.5	8.1	-	2.7	50
Łupawa estuary Rowy West	IIIA	0	0	-	0	0	-	0	0
Rowy East	IIIB	0	5.2	-	0	0	-	1.3	25
Open coastal Czołpino	IV	0	0	-	0	0	-	0	0
Łeba estuary Łeba West	VA	0	0	-	9.99	0.9	-	2.7	50
Łeba East	VB	0	0	-	0	-	-	0	0
Open coastal Władysławowo	VI	0	0	1W: 0 / 1E: 0	0	0	-	0	0

Transformed raw data indicate that the abundance of *Hydrobia* increases along with the distance from the shore, up to 2.0-2.5 Nm:

Distance from shore line [Nm]	0.5	1.0	1.5	2.0	2.5	3.0
Abundance [spec. m^{-2}]	3	1	0	6	3	0

More detailed data on the mean wet weight of *Hydrobia* on the entire area studied and the full range of depths covered confirms in general terms the increase of the mean biomass along with the growing distance from the shore, which is associated with the depth increase:

Depth	biomass
2.0-4.9 m	0 g_{ww} m^{-2}
5.0-9.9 m	1.50 g_{ww} m^{-2}
10.0-14.9 m	0.44 g_{ww} m^{-2}
15.0-19.9 m	1.28 g_{ww} m^{-2}
20.0-24.9 m	1.16 g_{ww} m^{-2}

The statistically significant correlation, however, was demonstrated between the abundance and the wet weight of *Hydrobiidae* and the depth of its occurrence in the coastal zone. The wet weight of *Hydrobia*, similarly as the abundance and frequency were higher in the estuary compared to the open coastal zone. The value of the mean wet weight was about 1.5-fold higher in the bay ($\bar{x}$ = 1.28 g_{ww} m^{-2}) compared to the wet weigh of researched snails in the studied open coastal zone of the Middle Pomerania (Tab. 4). Similarly as the abundance, the values of the wet weight varied within a wide range (0.0-9.99 g_{ww} m^{-2}). The highest wet weight of *Hydrobiidae* was observed in the area of Ustka, Łeba and the Darłowo lighthouse (transects: I, II, IV, Fig. 1, Tab. 4). The lowest wet weight of that gastropods (at sites in *Hydrobiidae*) was observed on transect II a (Ustka East), (Tab. 4). Except for two transects (IX A and XI B) where *Macoma* was absent, the lowest value of the wet weight of this bivalve was observed on profile IX B (Darłówko East) (Tab. 4). The highest of the wet weight of the researched snails was noted in 2 Nm distance from the shore ($\bar{x}$ = 0.53 g_{ww} m^{-2}). Analysing Hydrobia biomass distribution on profiles situated in the areas of river-mouth (estuaries) it is stated that the average wet weight value of the researched snails is 1.5 times higher on western profiles than on eastern ones.

The frequency (F) of *Hydrobiidae* was distinctly not higher in the coastal waters of the Middle Pomerania (19.5%). Not transect where were that's gastropods at all sites (F = 100%). The highest frequency (F = 50%) of *Hydrobia* ware stated in the areas of Ustka and Łeba estuary (transects II A and B, V A, tables 3, 4).

The study of the size structure (shell width, measured from the apex) of *Hydrobia* sp. demonstrated that those snails in the coastal zone of the Middle Pomeranian attained up to 3.9 mm of width. It is interesting that the in general, the mean width of *Hydrobia* shell grew from the west (Darłowo) to the east (Tab. 5). Similarly as the mean width of *Hydrobia*, also grew the mean weight of individual specimens.

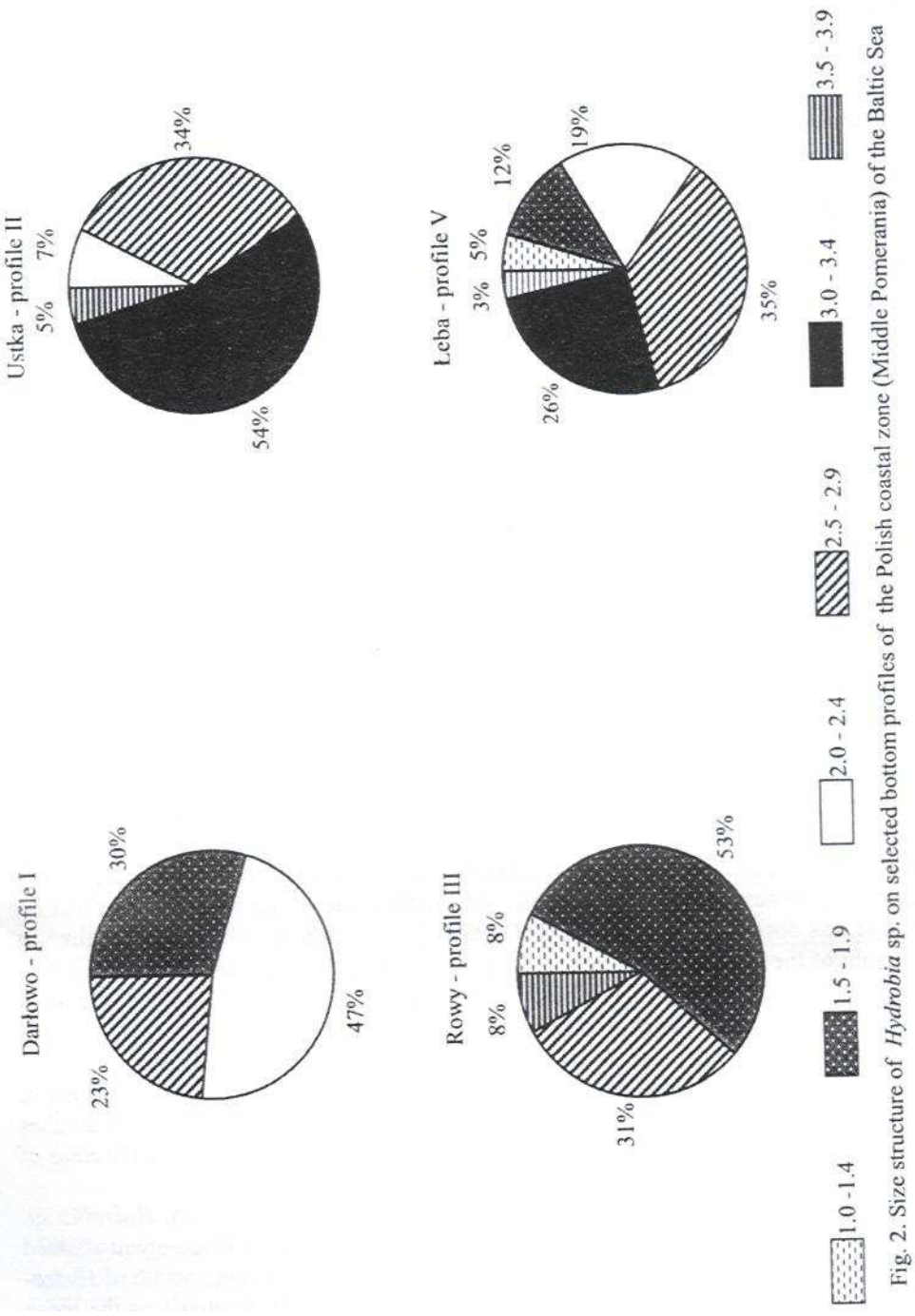

Fig. 2. Size structure of *Hydrobia* sp. on selected bottom profiles of the Polish coastal zone (Middle Pomerania) of the Baltic Sea

Table 5

Shell width, mean wet weight of individual specimens, and the dominant age groups of *Hydrobiidae* in the studied coastal zone of the Baltic

Area	Shell width [mm]		Dominant width class [mm]	Mean wet weight of individual specimen in: g_{ww} m^{-2}
	Range	$\bar{x}$		
Darłowo	2.0-2.9	2.5	2.4	0.002
Ustka	2.1-3.9	2.8	3.0	0.003
Rowy	1.0-3.9	2.7	1.8	0.005
Łeba	1.0-3.9	2.7	2.5	0.005

The most numerous group are snails with their shell size of 2.5-2.9 mm, stating to 31.8% of generally researched *Hydrobia* population. Also a significant port take *Hydrobiidae* representatives from another group 3.0-3.4 mm (28.3%) very few found the biggest representatives (3.5-3.9 mm) only 3% and the smallest ones (1-1.4 mm) only 2% of the whole researched population. The most different profiles considering the size were localized in Łeba river-mouth (estuarium), but the least different were in the areas of Wieprza river-mouth (Fig. 2).
On profiles situated by the Słupia river-mouth (profile II) and Łeba (profile V) dominated bigger *Hydrobia* sp. representatives but by the Wieprza and Łupawa river-mouths the smallest.

DISCUSSION

The surveyed coastal zone of the Baltic Sea (Fig. 1) is the most extensively exposed to the action of frequently unfavourable factors of the proximate land and it is particularly true for the estuary areas. The extent of river impact on the coastal zone is dependant, predominantly on the flow velocity of a river, level of its pollution and eutrophication (Tab. 6). It is also very important if the river estuary contains a larger body of water acting as a sedimentation area. In such bodies of water, substantial amounts of abiseston, heavy metals, PCBs and other substances harmful to hydrobionts are eliminated. On the other hand those bodies of water (Gardno Lagoon, Łebsko Lagoon) promote an intense increase of primary production (development of bacterioplankton, phytoplankton) and secondary production e.g. zooplankton. For example the chlorophyll "a" content in the waters of the Szczecin Lagoon was very high and it reached 57 mg m^{-3}, whereas in the nearby waters of the Pomeranian Bay (Baltic) receiving Odra River waters from the lagoon the content of Chlorophyl "a" was 16 times lower and amounted to as little as 3.6 mg m^{-3} (Niemkiewicz 1999). Intensely developing plankton (bioseston) from those areas is carried out to the coastal zone of the sea. It substantially enriches the food base of a number of hydrobiont species, in this number also benthic forms, for example gastropods. Some,

Table 6

A checklist of pollutants load (tons/year or in kgs/year) in the estuary areas of rivers according to "IMGW Gdynia (1999)"

	Wieprza River	Słupia River	Łupawa River	Łeba River
BOD_5	1 160.0	1 708.3	795.8	1 337.4
COD Mn	19 774.9	11 150.8	4 375.4	10 793.7
Chlorides	5 666.0	6 590.0	2 199.0	5 311.0
Seston	10 214.0	8 923.0	3 741.0	8 057.0
T-N	1 244.6	1 114.0	636.3	1 083.6
$N\text{-}NH_4$	147.7	41.4	26.2	81.8
$N\text{-}NO_x$	696.7	643.3	433.3	517.3
N-org.	398.9	429.6	176.6	484.6
T-P	119.4	77.9	32.7	72.0
$P\text{-}PO_4$	38.7	48.2	19.5	48.0
Calcium (Ca)*	30 872.6	30 101.7	13 304.8	25 179.4
Chromium total (Cr)*	0.606	0.565	0.251	0.430
Zinc (Zn)*	1.11	11.48	4.30	10.55
Cadmium (Cd)*	0.606	0.056	0.025	0.043
Copper (Cu)*	0.940	0.846	0.430	0.639
Lead (Pb)*	0.87	1.26	0.55	1.58

* in: kgs/year

typically freshwater plankters, in contact with more salty waters (7-8 PSU) of the Baltic die off in bulk, enriching the bottom in organic matter, which in turn may be utilised by benthos. Rivers bring mineral salts to the coastal zone, in this number nutrients, promoting increase of primary production, through increased development of autochthonous Baltic planktonic algae (Friedrich and Wilamski 1985; Niemkiewicz 1999, Pollution status... 1999). Substantial amounts of organic seston (high BOD_5, Tab. 6) and allogenous biogenic substances enhancing primary production in the marine areas of estuaries influence development of macrozoobenthos, in this number gastropods. For example, near the Rowy estuary mouth, the wet weight of *Hydrobia* sp. reaches 269.5 g m^{-2}. Comparing the data from tables 6 and 7 we can conclude that *Hydrobia* developed most extensively in the estuary area of the coastal zone Ustka and Łeba, where the rivers waters bring the similar amounts of bioseston and nutrients, lowest than Wieprza River and highest than Łupawa River. The presently determined mean values on the abundance and wet weight of *Hydrobiidae* in

Table 7

Abundance, wet weight and frequency of *Hydrobia* sp. in the studied Polish coastal zone of the Baltic

Region Location	Transect	Abundance (ind. m^{-2})		Wet weight (g_{ww} m^{-2})		F (%)	Source
		range	$\bar{x}$	range	$\bar{x}$		
Strait of Stara Świna		0-144	1.6	0-7.87	0.1	5.3	Bąk 1997
Wieprza estuary Darłowo West	IA	0-320	64.0	0-12.0	2.4	15	present paper
Darłowo East	IB	0	0	0	0		
Słupia estuary Ustka West	IIA	0-120	31.3	0-4.5	1.1	50	
Ustka East	IIB	0-318	102.0	0-8.1	2.7		
Ustka		9-667	251.9	0.05-1.08	0.4	100	Woźniczka 2004
Łupawa estuary Rowy	IIIA	0	0	0	0	12.5	present paper
Rowy East	IIIB	0-130	32.5	0-5.2	1.3		
Open coastal Czołpino	IV	0	0	0	0	0	
Czołpino		0	0	0	0	0	Woźniczka 2004
Łeba estuary Łeba West	VA	0-398	107	0-10.0	2.7	28.6	present paper
Łeba East	VB	0	0	0	0		
Łeba		18-5 182	2 577.8	0.05-6.45	3.3	100	Woźniczka 2004
Open coastal Władysławowo	VI	0	0	0	0	0	present paper
Bay of Puck			1 075.0		5.7	100	Wenne, Wiktor 1982
Gulf of Gdańsk			459.0	0.01-2.8	10.2		
Wisła estuary Wiosłoujście			2.0				

the estuary zones of the coastal waters and in the areas of open shore do not enable to draw an explicit conclusion on the gross effect of rivers (trophic conditions) on supposedly more extensive development of *Hydrobia*. It is possible, however, that bigger rivers such as the Słupia and Łeba may enhance development of macrozoobenthos, in this number *Hydrobia* (Tab. 7). In places where water heats fast and which are not exposed to pollution influence *Hydrobiidae* develop themselves much better (Cardoso et al. 2002, Osowiecki 2000, Wenne and Wiktor 1982, Żmudziński and Ostrowski 1990). Also hydrological factors may be important (transfer of sediments by benthic water currents), as well as the type of substrate, and biotic factors (predation), (Andersen et al. 2002, Haubois et al. 2004).

Hydrobia ulvae and *Hydrobia ventrosa* for many reasons constitutes an important component of macrozoobenthos inhabiting the floor of the Baltic Sea, down to 50 m depth (Warzocha 1994, et al.). In the coastal zone *Hydrobia* sp. is frequently a dominant form, considering its biomass (Wenne and Wiktor 1982, Warzocha 1994, Witek 1995). In the Puck Bay, depending on the distance from the discharge points of the Reda River waters, which is associated with detritus enrichment of the bottom, the dominant species are *Theodoxus fluviatilis* and *Lymnea peregra f. balthica* (Mueller), (Wenne and Wiktor 1982).

It is evident from the data of Obolewski and Piesik (unpublished) that in the 3-mile coastal zone of the Middle Pomerania, the research snails was the only gastropods species in the macrozoobenthos community. Their existence is relevant to cold sea current washing out the Middle Pomeranian.

The size structure of the population *Hydrobia* sp. in the research coastal zone Middle Pomeranian (Fig. 1) was not different. In west of that's zone was only big gastropods $\geq$ 2.0 mm, while in the zone localisation in the east the bottom inhabiting also little size *Hydrobia* $\geq$ 1.0 mm (Fig. 2). Such atypical size structure of the population studied was possibly linked to a specific predation. *Hydrobia* sp. constitutes probably a local food base for fish (*Platichtys flesus* (L.), *Platessa platessa* (L.), *Psetta maxima = Scophthalmus maxismus* (L.), *Zoarces viviparus* L.), particularly eagerly in warm seasons (Krzykawski and Załachowski 1983, Mulicki 1947, Stepniewicz and Meissner 1999, Witek 1995). Large specimens of research snails are probably intensively eaten up also by turbot, *Scophthalmus maximus*, attaining the length of 55 cm in the Baltic Sea. Turbot and other predatory flatfishes or water birds feed on *Hydrobia* in the entire Polish coastal zone of the Baltic and they do not cause such strong reduction in the abundance of great size groups ($\approx$ 5.0 mm).

It is interesting that the coastal area in the proximity of the Świna mouth is inhabited by another big crustacean, a crayfish, *Orconectes limosus* (Raf.) (Świerczyński unpublished). Piesik (1974) demonstrated in his study that this crayfish species unintentionally introduced to European waters from North America feeds also on smaller Mollusca, e.g. on *Dreissena* shorter than 12 mm (in the Szczecin Lagoon). The above-mentioned data indicate that the estuary area of the Baltic coastal zone affected by freshwater with its salinity periodically decreasing down to 3 PSU is inhabited by three additional euryhaline species of predators (*Orconectes*, and *Rutilus*) generally absent from the remaining part of the coastal area studied, though yet not researched this process in estuary of the Middle Pomeranian. Roach (*Rutilus rutilus*),

after attaining the size of 10-12 cm acquires capability of crushing with its pharyngeal teeth, molluscs. Therefore if they are present in the habitat, they constitute a principal part of their diet. Also juvenile specimens of flatfishes, particularly in summer, feed on the bottom in warmer waters close to the shore.

The presently acquired data on the occurrence, abundance, and the biomass of *Hydrobia* sp. in the studied Polish coastal zone of the Baltic, indicate that those gastropods are affected in different intensity by abiotic factors (water current, type of bottom) and biotic (autochthonous and allochthonous bioseston content, predation). *Hydrobia* sp. occurred commonly and its frequency (F) ranged from 25 to 100%. In individual coastal zones, research snails encountered variable conditions for their development, which is confirmed by variable abundance, and by the size structure. The data acquired indicate that *Hydrobiidae* finds more convenient conditions for its development in the estuary, compared to the open coastal zone of the Middle Pomerania (Tab. 7). Compared to the data of Wenne and Wiktor (1982) presenting mean values for the abundance of *Hydrobia* in Puck Buy and Gulf of Gdańsk waters (suitably 1075 and 459 specimens per m^{-2}), the presently determined values for the Middle Pomeranian were 32- and 14-fold lower (34 specimens m^{-2}). But in the Odra estuary subjected to strong pollution influence of that river researched *Hydrobia* sp. appear sporadically restricting its appearance to the reed area (Bąk 1997, Kube et al. 1996, 1997). In the studied stretch of the Middle Pomerania, the abundance of *Hydrobiidae*, were as many as 25-fold lower (943 specimens per m^{-2}) in relation to the data of Woźniczka (2004).

Analysis of the wet weight of *Hydrobiidae* indicates that the food base for aquatic fauna, including commercially important fish species, provided by these gastropods develops the most intensively in the coastal zone in the area of Ustka and Łeba (Transect II and V) in the Middle Pomeranian.

CONCLUSIONS

1. *Hydrobia sp.* is a gastropods not commonly occurring in the studied 3-mile Polish coastal zone of the Baltic. The frequency (F) of this species ranged from 0 to 50%. The highest frequency was recorded in the areas of estuary Ustka (100%). The frequency for the coastal zone of the Middle Pomeranian was low and it amounted to 39% (on the average), while this factor for the open coastal zone of the Middle Pomeranian not was that's gastropods.
2. The abundance of *Hydrobiidae* was diversified (from 0 to 398 specimens per m^{-2}) ($\bar{x}$ = 33.7 spec. per m^{-2}). In the coastal zone of the Middle Pomeranian it not was higher and it amounted to 42.1 ind. m^{-2}.
3. The wet weight of *Hydrobia* sp. in the coastal zone studied (Darłowo-Władysławowo) ranged from 0 to 12.0 g_{ww} m^{-2} ($\bar{x}$ = 1.0 g_{ww} m^{-2}).
4. The mean value of shell width of *Hydrobia* specimens studied shown a growing tendency from the west (2.5 mm) to the east (2.7 mm).
5. The analysis of the mean abundance, wet weight, and the frequency points out that *Hydrobia* to the areas of the Middle Pomerania exhibited more intensive

qualitative growth, which was probably caused by more convenient trophic conditions (Odra River estuary), weakened, and selective pressure of flatfishes.

6. Considering little quantity on the studied *Hydrobia ulvae* and *Hydrobia ventrosa* area we can think about using this organism as an indicator of unfavourable changes happening in the environment.

REFERENCES

Andersen T. J., Jensen K. T., Lund-Hansen L., Mouritsen K. N., Pejrup M., 2002. Enhanced erodibility of fine-grained marine sediments by *Hydrobia ulvae. Journ. of Sea Research*, 48, 1, 51-58.

Bąk M., 1997. Macrozoobenthos of the Stara Świna area. *Balt. Coast. Zone*, 1, 55-66.

Cardoso P. G., Lillebø A. I., Pardal M. A., Ferreira S. M., Marques J. C., 2002. The effect of different primary producers on *Hydrobia ulvae* population dynamics: a case study in a temperate intertidal estuary. *Journal of Experimental Marine Biology and Ecology*, 277, 2, 173-195.

Demel K., Mulicki Z., 1954. Quantitative investigations on the biological bottom productivity of the South Baltic. Pr. Mor. Inst. Ryb., 7, 75-126, (in Polish).

Friedrich M., Wilamski J., 1985. Variations in the chemical composition of surface waters transported to the Baltic Sea with the Rega River in the years 1964-1975. *Oceanologia*, 20, 69-83.

Grudemo J., Johannesson K. 1999. Size of mudsnails, *Hydrobia ulvae* (Pennant) and *H. ventrosa* (Montagu), in allopatry and sympatry: conclusions from field distributions and laboratory growth experiments. Journal of Experimental Marine Biology and Ecology, 239, 2, 167-181.

Haubois A., G, Guarini M. J., Richard P., Hemon A., Arotcharen E., Blanchard G. F., 2004. Differences in spatial structures between juveniles and adults of the gastropod *Hydrobia ulvae* on an intertidal mudflat (Marennes–Oléron Bay, France) potentially affect estimates of local demographic processes. *Journ. of Sea Research*, 51, 1, 63-68.

Haque A. M., Szymelfenig M., Węsławski J. M., 1997. Spatial and seasonal changes in the sandy littoral zoobenthos of the Gulf of Gdańsk. *Oceanologia*, 39, 3, 299-324.

Herra T., Wiktor K., 1985. Composition and distribution of bottom fauna in coastal zone of the Gulf of Gdańsk proper. *Stud. Mater. Oceanol.*, 46, 115-142, (in Polish).

Kotwicki L., 1997. Macrozoobenthos of the sandy littoral zone of the Gulf Gdańsk. *Oceanologia*, 39, 4, 447-460.

Krzykawski S., Załachowski W., 1983. Feeding habits of flounder (*Platichthys flesus*) on coastal grounds in Ustronie Morskie region during the years 1974 and 1975. *Zesz. Nauk. Akademii Rolniczej w Szczecinie*, 103, 3-16.

Kube J., Powilleit M., Warzocha J., 1996. The importance of hydrodynamic processes and foot availability for the structure of macrofauna assemblages in the Pomeranian Bay (Southern Baltic Sea). *Arch. Hydrobiol*., 138, 2, 213-228.

Kube J., Gosselck F., Powilleit M., Warzocha J., 1997. Long-term changes in the benthic communities of the Pomeranian Bay (Southern Baltic Sea). *Helgoländer Meeresunters*., 51, 399-416.

Masłowski J., 2001. Temporal changes in the Pomeranian Bay macrozoobenthos biomass: chance events and regular trends. *Folia Univ. Agric. Stetin, Piscaria*, 218, 28, 97-104.

Mulicki Z., 1947. Odżywianie się storni (*Pleuronectes flesus* L.) w Zatoce Gdańskiej. (Food and feeding of flounder (*Pleuronectes flesus* L.) in the Gulf of Gdańsk). *Arch. Hydrobiol. Ryb*., 13, 221-252, (in Polish).

Mulicki Z., Żmudziński L., 1969. Zasoby zoobentosu południowego Bałtyku (w latach 1956--1957). (Zoobenthos resources of the southern Baltic within 1956-1957). Pr. Mor. Inst. Ryb., Gdynia, 15A, 77-100, (in Polish).

Niemkiewicz E., 1999. Fitoplankton. W: Warunki środowiskowe polskiej strefy Południowego Bałtyku w roku 1998. (Phytoplankton. In: Environmental conditions of the Polish zone of the Southern Baltic in 1998). IMGW Gdynia, 181-198, (in Polish).

Osowiecki A., 2000. Kierunki wieloletnich zmian w strukturze makrozoobentosu Zatoki Puckiej. (Directions in long-term changes of the macrozoobenthos structure of the Puck Bay), *Crangon*, 3, 1-134, (in Polish).

Oug E., 2001. Polychaetes in interlidal rocky and sedimentory habitats in the region of Tromso, Northern Norway. *Sarsia*, 86, 75-83.

Piesik Z., 1974. The role of the crayfish *Orconectes limosus* (Raf.) in extinction of *Dreissena polymorpha* (Pall.) subsisting on steelon-net. *Pol. Arch. Hydrobiol*., 21, 401-410.

Piesik Z., 1998. Macrozoobenthos of the coastal zone in the region of Słowiński National Park, *Balt. Coast. Zone*, 2, 47-60.

Raffaelli D., 2000. Interactions between macro-algal mats and invertebrates in the Ythan estuary, Aberdeenshire, Scotland. *Helgoland Marine Research*, 54, 2-3, 71-79.

Schulte-Oehlmann U., Oehlmann A. J., Fioroni A. P., Bauer A. B., 1997. Imposex and reproductive failure in *Hydrobia ulvae* (Gastropoda: Prosobranchia). *Marine Biology*, 128, 2, 257-266.

Pollution status of rivers, lakes and the Baltic Sea. Bibl. Monitoringu Środowiska, Warszawa 1999, 1-115.

Stepniewicz L., Meissner W., 1999. Assessment of the zoobenthos biomass consumed yearly by diving ducks wintering in the Gulf of Gdańsk (Southern Baltic Sea). *Ornis Svecica*, 9, 143-154.

Trzosińska A., 1990. Seasonal fluctuations and long-term trends of nutrient concentrations in the Polish zone of the Baltic Sea. *Oceanologia*, 29, 27-50.

Warzocha J., 1994. Spatial distribution of macrofauna in the Southern Baltic in 1983. *Biul. Mor. Inst. Ryb*., 1, 131, 47-59.

Warzocha J., 1995. Clasification and structure of macrofaunal communities in the Southern Baltic. *Arch. Fish. Mar. Res*., 42 (3), 225-237.

Wenne R., Wiktor K., 1982. Fauna denna przybrzeżnych wód Zatoki Gdańskiej. (Benthic fauna of the inshore waters of the Gdańsk Bay). *Stud. Mater. Oceanolog*., 39, *Biologia Morza*, 6, 137-171, (in Polish).

Witek Z., 1995. Produkcja biologiczna i jej wykorzystanie w ekosystemie morskim w zachodniej części Basenu Gdańskiego. (Biological production and its utilization within a marinr ecosystem in the western Gdańsk basin). MIR, Gdynia, 145, (in Polish).

Woźniczka A., 2004. Makrozoobentos osadów piaszczystych strefy przybrzeżnej Bałtyku Połudiowego. (Macrozoobenthos of bottoms sandy zones of the coastal midday Southern Baltic). AR, Szczecin, (in Polish).

Żmudziński L., 1982 a. Bentos płytkich wód bałtyckich. (Baltic shallow water zoobenthos). Słupsk, 5-38, (in Polish).

Żmudziński L., 1982 b. Baltic shallowwater zoobenthos. In: Baltic Sea zoobenthos of the sixties). WSP, Słupsk, 39-79, (in Polish).

Żmudziński L., Andrulewicz E., 1997. Preliminary studies on sandy littoral macrofauna at protected areas of the Polish open Baltic Sea coast. *Balt. Coast. Zone*, 1, 33-43.

Żmudziński L., Ostrowski, J., 1990. Zoobenthos in Gdańsk Bay. ed., A. Majewski. Wyd. Geologiczne, Warszawa, 402-430, (in Polish).

ROZMIESZCZENIE I ROLA ŚLIMAKÓW Z RODZAJU *HYDROBIIDAE* W POLSKIEJ STREFIE PRZYBRZEŻNEJ BAŁTYKU (DARŁOWO–WŁADYSŁAWOWO)

Streszczenie

Badano populację ślimaków *Hydrobia* sp. (*Hydrobia ulvae* Pennant i *Hydrobia ventrosa* Montagu) w polskiej strefie przybrzeżnej Bałtyku (max. do 3 Mm) w otwartym wybrzeżu Pomorza Środkowego. Określono zagęszczenie, biomasę mokrą oraz frekwencję *Hydrobia* sp. w wodach przybrzeżnych, w tym w rejonach ujść rzek Wieprzy, Słupi, Łupawy i Łeby oraz otwartego wybrzeża w pobliżu Czołpina (Słowiński Park Narodowy) oraz Władysławowa. Frekwencja *Hydrobia* w strefie przybrzeżnej Pomorza Środkowego wynosiła – F = 39%, natomiast nie wystąpiły one w strefie przybrzeżnej otwartego morza. Zagęszczenie wodożytek w badanej strefie przybrzeżnej wahało się w granicach od 0 do 398 osobn. m^{-2} dna ($\bar{x}$ = 33,7 osobn. m^{-2}). Wartość masy mokrej tego gatunku małża wahała się od 0 do 12,0 g_{mm} m^{-2} ($\bar{x}$ = 1,0 g_{mm} m^{-2}). *Hydrobia* sp. znajdowała dogodniejsze warunki do rozwoju w strefie przybrzeżnej Pomorza Środkowego w porównaniu ze strefą otwartego morza. Zagęszczenie tych ślimaków było 27-krotnie, a masa mokra 1,5-krotnie wyższa w strefach przyujściowych niż na otwartym wybrzeżu. *Hydrobiidae* odgrywają ważną rolę w monitoringu bentosu Morza Bałtyckiego, natomiast nie są preferowaną bazą pokarmową dla zwierząt (ryb i innych hydro-
biontów).