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DISTRIBUTION AND THE ROLE OF MACOMA BALTHICA (L.) IN THE POLISH BALTIC SEA COAST

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Abstract

A population of *Macoma balthica* was studied in the Polish coastal zone (up to 3 Nautical miles) of the Baltic Sea within the Pomeranian Bay and in the open coast of Polish Middle Pomerania. Abundance, wet biomass, and the frequency of *Macoma* were determined in the coastal waters, including estuaries of the Odra River (Świna and Dziwna canals), Wieprza, Słupia, Łupawa, and Łeba rivers. The frequency (F) of *Macoma* in the coastal zone of the Pomeranian Bay was 77.4%, whereas in the open coast of the Middle Pomerania it was lower and amounted to 39.8%. The abundance of *Macoma*, in the coastal zone surveyed, ranged from 0 to 304 specimens per m^{-2} of the bottom ($\overline{x}$ = 46.2 spec. m^{-2}). Wet biomass of this bivalve ranged from 0 to 99.2 g_{ww} m^{-2} (x = 17.6 g_{ww} m^{-2}). Apparently *M. balthica* has found better conditions for living and development in the Pomeranian Bay compared to the Middle Pomerania coast. The abundance of this mollusc in the bay was 4.5-fold higher than in the open coast and the wet weight was 2.5-fold higher, respectively. *M. balthica* plays an important role in the monitoring of benthos of the Baltic Sea, constitutes a distinct food base of animals (fish, birds), and takes part in the process of purification of waters of the coast stretch studied (biofiltration, biosedimentation).

Key words: Polish coastal zone of Baltic, estuary, *Macoma balthica*, abundance and biomass

INTRODUCTION

Baltic tellin, *Macoma balthica* is a species widely distributed in the seas and oceans of the Northern Hemisphere (North America, Europe, Asia)(Wanne and Klusek 1985). In the Baltic Sea it is a characteristic species of the macrozoobenthos, inhabiting the bottom down to some 90 m deep (Warzocha 1994). Macoma gains a substantial biomass and it may become a dominant macrozoobenthos species while *Mytilus edulis* or *Mya arenaria* are absent or poorly represented. Baltic tellin, because of its common occurrence in different zones of the bottom was used by Warzocha (1995) for characterising benthic communities in the Baltic (e.g. *Macoma balthica-Mya arenaria*). Macoma plays also an important ecological role in the Baltic constituting a component of hemiplankton (larval stages) and benthos (Gunther et al. 1998). Those molluscs, as deposit feeders, contribute to elimination of seston (including bacteria), phyto- and zooplankton from the supra benthic layer and their biosedimentation in a form of agglutinates and faeces. The biomass of *M. balthica* constitutes also a rich food base for fish and water birds 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, Mulicki and Zmudzinski 1969, Warzocha 1994). More detailed studies were carried out in the Pomeranian Bay and in the Gdańsk Bay (Herra and Wiktor 1985, Osowiecki 2000, Kube et al. 1996, 1997, Masłowski 2000, Ostrowski 1996, Witek 1995, Żmudziński and Ostrowski 1990). In addition to the above-mentioned authors, *Macoma* as a component of the macrozoobenthos, was studied also by Kotwicki 1997, Zmudziński 1982a, Haque et al. 1997, Żmudziński and Andrulewicz 1997 who concentrated on the Polish territorial waters, particularly the shallowest zone subjected to wave action. Baltic tellin is an important species enabling determination of changes in macrozoobenthos 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, size, and age) of the population of *Macoma balthica* in the 3-mile Polish coastal zone within the stretch of Świnoujście-Władysławowo. The data acquired will help to determine in the future the quantitative changes indicating trends in development of *Macoma* in our coastal zone exposed to various factors of human activity. This paper is also intended to outline the distribution and abundance of *Macoma* as a food base for animals, in this number also fish species of economical importance.

MATERIALS AND METHODS

Macoma balthica was studied from 1994 throughout 2001, within the 3-mile Polish coastal zone of the Baltic stretching from Świnoujście to Władysławowo (Fig. 1). The bivalves were sampled from a total of 92 sites with a Van Veen bottom sampler, covering the area of 0.0625 m^2 (profiles I trough VII) and another one covering 0.1 m^2 (profiles IX trough XIII). A double sample was taken from each site, which translates to a total of 184 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 17 bottom profiles perpendicular to the shoreline were designated within the coast stretch studied. The profiles were 3-nautical-mile-long, except for Władysławowo, where the profile was only 2-mile-long.

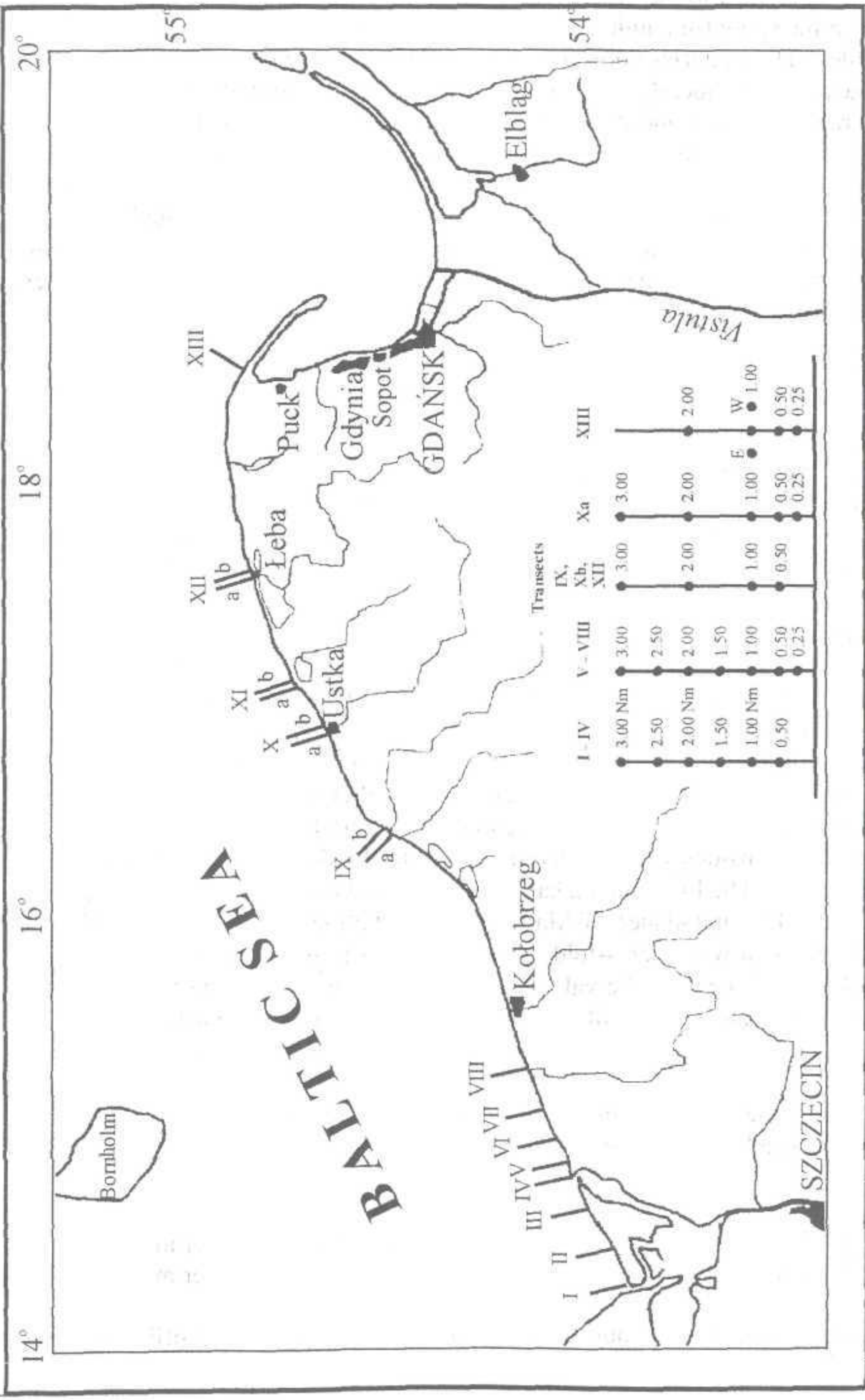

Fig. 1. Location of sampling stations and transects

Within the latter, two additional sites were designated 1 mile from the shore and 1 mile to the west and to the east. 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 and the number of the bivalves was related to 1 m^2. The wet weight of *Macoma*, dried on a filter paper (including 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 *M. balthica* was determined through measuring the shell width (from its apex to the shell base) using a slide calliper to the nearest 0.5 mm. A total of 983 specimens of *Macoma* were measured. The age of the tellin were determined through reading distinct age rings on their shell. Also the type of substrate and the depth were noted on the individual sites (Table 1).

RESULTS

The dominant four species, presently observed in the studied stretch of the Polish coastal zone (Świnoujście-Władysławowo) were *Macoma balthica* (L.), *Mytilus edulis* L., *Mya arearia* L., and *Cardium edule* Petersen, all of them typical representatives of shallow areas of the Baltic Sea. The leading species - Baltic tellin (*M. balthica*) was surpassed in its abundance and biomass, only locally by the blue mussels, *Mytilus edulis* (in the Pomeranian Bay, except the areas of Świnoujście and Mrzeżyno and in the areas of Darłówko and Rowy in the Middle Pomerania). The abundance of *M. balthica* in the studied zone was significantly diversified (from 0 to 304 specimens per m^2) and in the profiles Darłówko West (IX a) and Rowy East (XI b) no tellin was found (Table 2). In the Pomeranian Bay, the mean abundance of tellin was 78.3 specimens per m^2. The highest mean abundance of macoma in the bay, amounting to 133.3 spec per m^2 was recorded on the profile Swinoujscie (transect No I). High mean densities were observed on profile II (Międzyzdroje, III (Kikut), and IV (pobierowo). The lowest abundance was observed on profile IV (Dziwnów): 34.7 spec. per m^2. The abundance of Macoma on the bottom of the coastal zone of the Middle Pomerania was over 4-fold lower compared to their abundance in the Pomeranian Bay and it reached the value of 17.6 ind. per m^2. The highest mean densities of tellin in the waters of middle Pomerania were recorded on profiles X b (Ustka East) and XIII (Władysławowo) and they amounted to 36.2 and 45.0 ind. per m^2, respectively.

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

	Distance from shore line [Nm]
Pomeranian Bay	Abundance [spec. per m^2]
Middle Pomerania	Abundance [spec. per m^2]

Detailed data on the abundance of *Macoma balthica* on the profiles studied are shown in Table 2.

Tab. 1

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

Locality	Transect	Nautical miles													
		0.25		0.5		1.0		1.5		2.0		2.5		3,0	
		A	B	A	B	A	B	A	B	A	B	A	B	A	B
Pomeranian Bay															
Świnoujście	I	---	---	5.5	fsg	8.8	fsg	8.9	fgs	9.2	fgs	9.0	fgs	9.6	fgs
Międzyzdroje	II	---	---	10.2	fgs	11.3	fgs	10.2	fgs	11.0	fgs	11.3	fgs	10.8	fgs
Kikut	III	---	---	11.5	fgs	12.0	fgs	12.0	fgs	12.5	fgs	13.0	fgs	14.5	fgs
Dziwna estuary Dziwnów	IV	---	---	10.1	g	11.4	g	11.7	g	11.5	g	12.7	g	12.7	g
Dziwna estuary Dziwnówek	V	8.5	fgs	10.5	g	11.5	-	13.2	gs	13.6	gs	15.5	-	13.4	---
Pobierowo	VI	3.0	fgs	15.0	mgs	14.7	cgs	15.0	mgs	16.0	ss	18.0	cgs	16.5	cgs
Niechorze	VII	7.2	gs	11.2	gs	16.0	-	17.5	ss	18.6	ss	16.2	ss	18.6	cgs
Rega estuary Mrzezyno	VIII	8.8	fgs	10.5	fgs	9.0	fgs	10.5	fgs	11.0	fgs	15.5	ss	11.5	ss
Middle Pomerania															
Wieprza estuary Darłówko – West	IXa	---	---	9.0	fgs	13.5	mgs	---	---	14.7	mgs	---	---	19.3	fgs
Darłowo – East	IXb	---	---	8.2	fgs	15.0	mgs	---	---	17.0	mgs	---	---	19.5	cgs
Słupia estuary Ustka – West	Xa	6.5	fgs	11.0	fgs	14.6	gs	---	---	16.5	fgs	---	---	18.0	gs
Ustka – East	Xb	---	---	6.7	g	12.5	gs	---	---	18.5	gs	---	---	20.0	gs
Łupawa estuary Rowy – West	XIa	2,3	fgs	5.7	fgs	16.5	ss	---	---	20.0	gs	---	---	22.4	gs
Rowy – East	XIb	2.1	fgs	6.4	fgs	12.7	fgs	---	---	22.4	gs	---	---	20.0	gs
Łeba estuary Łeba – West	XIIa	---	---	5.1	g	14.0	fgs	---	---	17.7	ss	---	---	18.2	fgs
Łeba – East	XIIb	---	---	3.0	fgs	11.2	fgs	---	---	15.0	fgs	---	---	---	---
Open coastal Władysławowo	XIII	7,2	ss	10.8	g	11.5	ss	---	---	15.5	g	---	---	---	---

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

Tab. 2

Abundance and frequency (F) of *Macoma balthica* in the studied 3-mile Polish coastal zone of the Baltic (Swinoujście-Władysławowo)

Locality	Transect	abundance (ind. m^{-2})								F (%)
		Nautical Mile (Nm)							$\bar{x}$	
		0.25	0.5	1.0	1.5	2.0	2.5	3.0		
Pomeranian Bay Odra estuary										
Świnoujście	I	–	0	64	80	192	272	192	133.3	83
Międzyzdroje	II	–	144	48	16	112	144	80	90.7	100
Kikut	III	–	80	80	160	0	16	176	85.3	83
Dziwna estuary Dziwnów	IV	–	96	0	48	0	32	32	34.7	67
Dziwna estuary Dziwnówek	V	0	32	304	112	112	48	48	93.7	86
Pobierowo	VI	128	32	0	0	240	208	80	90.3	71
Niechorze	VII	0	0	0	0	128	176	64	52.6	43
Rega estuary Mrzeżyno	VIII	0	64	0	48	128	64	16	45.7	86
Middle Pomerania										
Wieprza estuary Darłówko – West	IXa	–	0	0	0	0	0	0	0	0
Darłowo – East	IXb	–	0	0	–	16	–	0	4.0	25
Słupia estuary Ustka – West	Xa	0	10	10	–	20	–	0	8.0	60
Ustka – East	Xb	–	0	25	–	30	–	90	36.2	75
Łupawa estuary Rowy – West	XIa	0	0	0	-	39	-	67	21.2	40
Rowy – East	XIb	0	0	0	-	0	-	0	0	0
Łeba estuary Łeba – West	XIIa	–	0	0	–	110	–	0	27.5	25
Łeba – East	XIIb	–	0	50	–	0	–	–	16.7	33
Open coastal Władysławowi	XIII	20	25	1 Nm 30	1W 1E 60 90	45	–	–	45.0	100

More detailed data on the mean wet weight of *Macoma* 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:

2.0 - 4.9 m gł. - 5.13 g_{ww} m^{-2}
5.0 - 9.9 m gł - 10.58 g_{ww} m^{-2}
10.0 - 14.9 m gł - 23.31 g_{ww} m^{-2}
15.0 - 19.9 m gł - 18.50 g_{ww} m^{-2}
20.0 - 24.9 m gł - 34.40 g_{ww} m^{-2}

No statistically significant correlation, however, was demonstrated between the *abundance and the wet weight of Macoma - and the depth of its occurrence in the* coastal zone. The wet weight of *Macoma*, similarly as the abundance and frequency were higher in the Pomeranian Bay compared to the Middle Pomerania. The value of the mean wet weight was 2.5-fold higher in the bay ($x = 22.89$ g_{ww} m^{-2}) compared to the wet weigh of tellin in the studied coastal zone of the Middle Pomerania (9.00 gww m^{-2})(Table 3). Similarly as the abundance, the values of the wet weight varied within a wide range (0.0-86.4 g_{ww} m^{-2}). The highest wet weight of *M. balthica* was observed in the area of Świnoujście, Międzyzdroje and the Kikut lighthouse (transects: I, II, III, Fig. 1) of the Pomeranian bay as well as in the area of Władyslawowo (transect XIII) on the Middle Pomerania (Table 5). 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) (Table 3).

The frequency (F) of *Macoma balthica* was distinctly higher in the Pomeranian bay (77.4%) compared to the frequency of tellin in the coastal waters of the Middle Pomerania (39.8%). *Macoma* was recorded at all sites (F = 100%) only in the area of Międzyzdroje and Władysławowo (transects II and XIII). The lowest frequency of *Macoma* ware stated in the areas of Darłówko, Rowy, and Łeba (transects IX a and b, XI a and b, XII a and b, Tables 3, 5).

Age structure of *Macoma balthica* was studied on selected profiles. It is evident from the present study that in the Polish coastal zone, tellins live up to 6 years (which is perhaps affected by a special way of reading age rings on the shell). According to other authors *Macoma balthica* in the Baltic Sea live up to 12 years (Ostrowski 1976). From the data presented on Fig 2, it is visible that *Macoma* lives shortest lives in the sea part of the Odra River estuary (profiles: Świnoujście, Międzyzdroje, Kikut, Dziwnów), in the coastal zone between the mouths of the Świna and Dziwna. In those areas tellins live up to 3 years (2+) and the dominant group is 1+. In the coastal areas to the east of the Dziwna mouth *Macoma* live up to 5 and 6 years (age groups 4+ and 5+) with the domination of age groups from 1+ to 4+ depending on the profile studied (Fig. 2). In the area of the Middle Pomerania the age structure of *Macoma balthica* was studied on the Ustka profile, where dominated older bivalves , the group 3+ being the most abundant (50% of the population) (Fig. 2). Those data indicate substantial differences in the age structure of *Macoma* on different stretches of the Polish coastal zone, which is probably caused by predation impact of: crustaceans, fish, and water birds (*Eriocher sinensis*, *Orconectes limosus* (Raf.), *Rutilus rutilus* (L.), *Platichthys flesus* (L.), *Platessa platessa* (L.), *Scophthalmus maximus* (L.), *Aythya fuligula* (L.) and others).

Table 3

Wet weight and frequency of *Macoma balthica* in the studied 3-mile Polish coastal zone of the Baltic (Świnoujście-Władysławowo)

Region Location	Transect	Biomass (in g_{ww} m^{-2})								F (%)
		Nautical Mile (Nm)							$\overline{x}$	
		0.25	0.5	1.0	1.5	2.0	2.5	3.0		
Pomeranian Bay Odra estuary										
Świnoujście	I	–	0.0	8.6	17.6	35.2	75.2	52.8	31.6	83
Międzyzdroje	II	–	54.4	14.4	1.6	46.4	48.0	17.6	30.4	100
Kikut	III	–	43.2	54.4	97.6	0.0	4.8	86.4	31.8	83
Dziwna estuary Dziwnów	IV	–	59.6	0.0	5.5	0.0	4.2	4.2	12.3	67
Dziwna estuary Dziwnówek	V	0.0	8.5	34.3	38.1	17.7	5.0	11.6	16.0	86
Pobierowo	VI	30.8	9.8	0.0	0.0	45.3	67.3	23.9	25.0	71
Niechorze	VII	0.0	0.0	0.0	0.0	41.7	50.7	34.4	18.0	43
Rega estuary Mrzezyno	VIII	0.0	27.4	0.0	19.5	52.0	21.1	5.8	18.0	86
Middle Pomerania										
Wieprza estuary Darłówko – West	IXa	–	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Darłowo – East	IXb	–	0.0	0.0	–	2.5	–	0.0	0.6	25
Słupia estuary Ustka – West	Xa	0.0	8.7	9.8	–	23.4	–	0.0	8.4	60
Ustka – East	Xb	–	0.0	9.4	–	28.1	–	65.2	25.7	75
Łupawa estuary Rowy – West	XIa	0.0	0.0	0.0	-	18.3	-	52.3	14.1	40
Rowy – East	XIb	0.0	0.0	0.0	-	0.0	-	0.0	0.0	0
Łeba estuary Łeba – West	XIIa	–	0.0	1.6	–	4.8	–	0.0	1.8	25
Łeba – East	XIIb	–	0.0	40.0	–	0.0	–	–	13.3	33
Open coastal Władysławowi	XIII	1.1	12.2	1 Nm 31.0	1W / 1E 14.0 / 84.5	29.7	–	–	28.7	100

Table 4

Comparison of the abundance, biomass, and the frequency of *Macoma balthica* in the coastal zone of river estuaries (first order estuary) and the open coast in the Pomeranian Bay and Middle Pomerania

Region	Estuary		Open coast		Estuary			Open Coast		
	abundance ind. m^{-2}				biomass g_{ww} m^{-2}		F	biomass g_{ww} m^{-2}		F
	range	x	range	x	range	x	%	range	x	F(%)
Pomeranian Bay	0-304	76.8	0-240	79.7	0-75.2	19.5	80	0-97.6	26.3	74
Middle Pomerania	0-110	14.2	0-110	24.5	0-52.3	10.8	32	0-84.5	5.7	60

Table 5

Abundance, wet weight and frequency of *Macoma balthica* in the studied 3-mile Polish coastal zone of the Baltic (Swinoujście-Władysławowo)

Region Location	Transect	abundance (ind. m^{-2})		wet weight (g_{ww} m^{-2})		F (%)	Source
		range	$\bar{x}$	range	$\bar{x}$		
Zatoka Pomorska Odra estuary							Present paper
Świnoujście	I	0 – 272	133.5	0-75.2	31.5	83	
Międzyzdroje	II	16-144	90.7	1.6-54.4	30,4	100	
Kikut	III	0-176	85.3	0-97.6	47.7	83	
Dziwna estuary Dziwnów	IV	0 - 96	34.7	0-59.6	12.3	67	
Dziwna estuary Dziwnówek	V	0 – 304	109.3	0 – 38.51	19.1	83	
Pobierowo	VI	0-240	114.7	0-67.3	29.5	67	
Niechorze	VII	0-176	61.3	0-50.7	21.1	50	
Rega estuary Mrzeżyno	VIII	0-128	53.3	0-52.0	20.9	67	
Wieprza estuary Darłówko	IX	0-10	2.5	0-2.5	0.6	25	
Słupia estuary Ustka	X	0-90	22.1	0-65.2	17.0	66	
Łupawa estuary Rowy	XI	0-67	10.6	0-52.3	7.1	20	
Open coast Czołpino		0-20	4.0	0-37.6	7.5	20	Piesik 1998
Łeba estuary Łeba	XII	0-110	22.8	0- 9.6	1.8	28	Present paper
Open coast Władysławowi	XIII	10-110	45.0	1.0-120.3	28.7	100	
Wisła estuary Wisłoujście		10-24	17.0	3.0-4.7	3.9	100	Herra, Wiktor 1985

The study of the size structure (shell width, measured from the apex) of *Macoma balthica* demonstrated that tellins in the coastal zone of the Pomeranian Bay attained up to 17 mm of width. In the studied zone of the Middle Pomerania the width of shell of *Macoma* reached 19 mm. It is interesting that the in general, the mean width of *Macoma* shell grew from the west (Świnoujscie) to the east(Table 7). Similarly as the mean width of *Macoma*, also grew the mean weight of individual specimens.

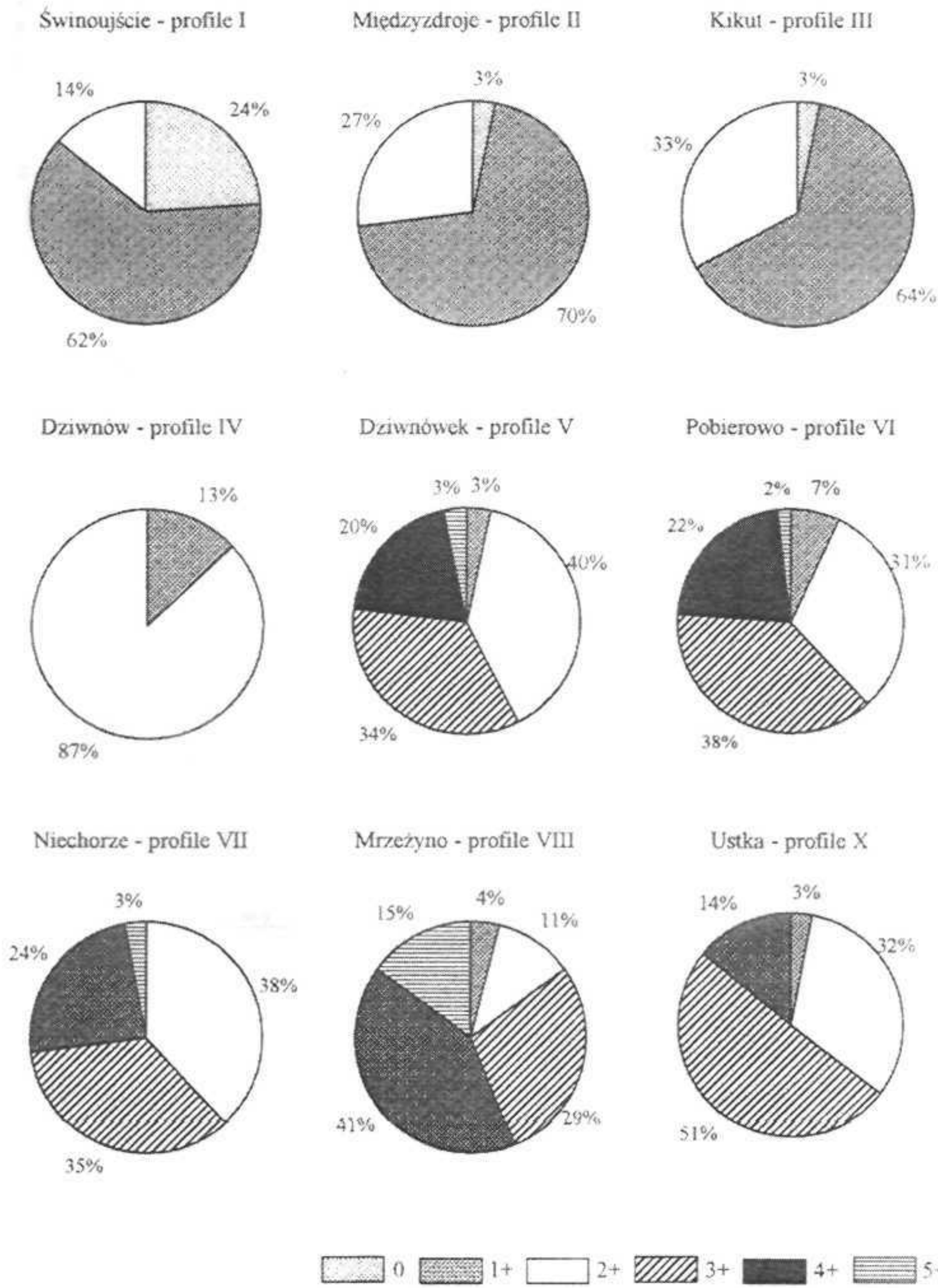

Fig. 2. Age structure of *Macoma balthica* on selected bottom profiles of the Polish coastal zone of the Baltic Sea

Table 6

A checklist of pollutants load (tons/year or in kg/year) in the estuary areas of rivers (according to "Pollution status of rivers, lakes and the Baltic Sea"

	Odra River	Wieprza River	Słupia River	Łupawa River	Łeba River
BOD_5 t/years	71931.0	1910.1	2150.0	843.9	1570.0
COD Mn t/y	106161.0	3704.0	2830.0	1107.4	2789.0
Chlorides t/y	1344957.0	5666.0	6590.0	2199.0	5311.0
Seston	290597.0	10214.0	8923.0	3741.0	8057.0
Total dissolved matter	5994636.0	117668.0	120066.0	117668.0	111745.0
Nitrogen T-N	58269.7	1761.7	1842.3	781.5	1305.0
N-NH4	4787.2	159.3	276.0	37.7	99.9
N-NO2	233.3	9.4	26.9	6.7	8.4
N-NO3	27459.0	740.8	671.3	358.8	500.6
T-P	4593.0	99.2	124.3	40.6	79.0
P-P04	4924.0	152.9	236.5	56.9	112.6
Chromium total (Cr)*	25171.0	310.9	403.7	133.8	356.0
Zinc (Zn)*	483445.0	4720.0	5127.0	1739.0	4466.5
Cadmium (Cd)*	5484.0	535.7	592.1	323.1	1634.0
Copper (Cu)*	104234	729.5	780.0	300.3	1012.4
Lead (Pb)*	59624.9	4583.5	5116.7	2657.7	14236.7

* in: kg/ rok

Table 7

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

Area	Shell width [mm]		Dominant width class [mm]	Dominant age group		mean wet weight of individual specimen in: g_{ww} m^{-2}
	Range	$\overline{x}$		Age	%	
Świnoujście	1 – 13	6.7	4.0 – 4.9	1+	62	0.23
Międzyzdroje	4 – 13	8.7	9.0 – 9.9	1+	70	0.33
Kikut	2 – 15	9.9	12.0 – 12.9	1+	64	0.56
Dziwnów	5 – 13	9.3	9.0 – 9.9	2+	87	0.35
Dziwnówek	1 – 16	10.5	7.0 – 8.9	1+	40	0.17
Pobierowo	2 – 16	10.8	11.0 – 12.9	3+	38	0.25
Niechorze	7 – 17	11.2	8.0 – 8.9	2+	38	0.34
Mrzeżyno	8 – 16	12.3	13.0 – 13.9	4+	41	0.39
Darłówko	6 – 19	12.1	---	3+	--	0.24
Ustka	4 - 17	12.3	12.0 – 12.9	3+	51	0.76
Łeba	6 - 19	--	---	---	--	0.99
Władysławowo	2 - 18	--	---	---	--	0.63

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 (Table 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 (Szczecin Lagoon, Kamień Lagoon, 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, particularly water-filtering bivalves. Some, 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; Poleszczuk and Sitek 1995; Stan 1994). Substantial amounts of organic seston (high BOD_5; Table 6) and allogenous biogenic substances enhancing primary production in the marine areas of estuaries influence development of macrozoobenthos, in this number bivalves. For example, near the Świna mouth, the wet weight of *Mya arenaria* reaches 2 kg m^{-2}. Comparing the data from tables 5 and 6 we can conclude that *Macoma* developed most extensively in the estuary area of the coastal zone between the mouths of Świna and Dziwna, where the Odra River waters bring the highest amounts of bioseston and nutrients, compared to the other estuaries surveyed. The Odra River waters delivered over 290 thousand tons of seston a year, whereas the remaining rivers carried in seston of estimated 3 to 10 thousand tons a year (28 fold less to 78 fold less). The presently determined mean values on the abundance and wet weight of *Macoma* in 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 *Macoma* (Table 4). It is possible, however, that big rivers such as the Odra may enhance development of macrozoobenthos, in this number *Macoma* (Table 5). Also hydrological factors may be important (transfer of sediments by benthic water currents), as well as the type of substrate, and biotic factors (predation).

Macoma balthica for many reasons constitutes an important component of macrozoobenthos inhabiting the floor of the Baltic Sea, down to 90 m depth (Warzocha 1994). Because of its permanent occurrence in defined zones of the bottom of this seas Warzocha (1987) distinguished macrozoobenthos guilds, where the tellin is a component: *Mya arenaria-Macoma balthica*, *Macoma balthica-Mesidotea* (Saduria) *entomon*, and *Scoloplos armiger-Macoma balthica*. Also in other seas e.g. the Norwegian Sea Oug (2001) distinguishes a Macoma "community". In the coastal zone *M. balthica* is frequently a dominant form, considering its biomass (Osowiecki 2000, Warzocha 1994, Witek 1995). In the Pomeranian Bay, depending on the distance from the discharge points of the Odra River waters, which is associated with detritus enrichment of the bottom, the dominant species are *Mya arenaria* and *Mytilus edulis* (cf. Powilliet et all. 1995). According to Piesik and Wawrzyniak-Wydrowska (1997) and Piesik (1998), *Mytilus* presence meant always (except for Świnoujście, transect No. I) its substantially higher abundance and wet weight compared to *Macoma*:

Locality transects		Mytilus edulis			Macoma balthica		
		abundance ind. m^{-2}	biomass g_{ww} m^{-2}	F %	abundance ind. m^{-2}	biomass g_{ww} m^{-2}	F %
Pomeranian Bay							
Świnoujście	I	82	8.6	57	133	31.1	83
Międzyzdroje	II	2679	333.4	100	91	30.4	100
Kikut	III	3523	448.0	100	85	47.7	83
Dziwnów	IV	3672	1137.5	50	35	12.3	67
Dziwnówek	V	294	83.3	57	109	19.1	83
Pobierowo	VI	776	249.5	57	115	29.5	67
Niechorze	VII	1580	158.5	71	61	21.1	50
Mrzeżyno	VIII	0	0.0	0	53	20.9	67
Middle Pomerania							
Darłówek	IX a,b	50	32.3	10	2	0.6	25
Ustka	X a,b	0	0.0	0	22	17.0	66
Rowy	XI a,b	1705	123.0	30	12	10.2	60
Czołpino		0	0.0	0	4	7.5	20
Łeba	XII a,b	6	4.1	28	20	19.8	25
Władysławowo	XIII	0	0.0	0	45	28.7	100

It is evident from the data of Piesik (unpublished) that in the 3-mile coastal zone of the middle Pomerania, the Baltic tellin was the dominant species in the macrozoobenthos community. The exception was the area of Ustka (transect X) where *Cardium glaucum* (= *Cerastoderma lamarcki*) attained 1.5 fold higher biomass and 5-fold higher abundance than *Macoma*.

The age structure of *M. balthica* from the coastal zone of the Pomeranian bay within the estuary area between Swinoujście and Dziwnów (Fig. 1) is distinctly different from the age structure of the population inhabiting the bottom of the coastal zone located to the east, up to Władysławowo. The former zone was inhabited only by smaller tellins aged 0 to 2+ (three-year-olds). The bottom of the latter zone (east of Dziwnówek) was covered mainly by larger *Macoma*, representing older age groups (Fig. 2). Such atypical age structure of the population studied was possibly linked to a specific predation. *Macoma balthica* constitutes probably a local food base for crustaceans (*Eriocher sinensis* Milne Edw., *Orconectes limosus* (Raf.)) and fish (*Rutilus rutilus*). In the entire coastal zone surveyed, *Macoma* is eaten by fishes and water birds. Probably crustaceans utilise *Macoma* as food locally, only in freshwater-diluted part of the Pomeranian Bay. Crab, *Eriocher sinensis* was unintentionally "imported" from China to Europe, including the Odra River estuary. Those crabs are the largest crustaceans in the Baltic and their cephalothorax width reaches 7 cm. The present authors observed in aquaria how *Eriocher* fed on larger (above 15 mm of length) specimens of zebra mussel, *Dreissena*, crushing their shells with strong mandibulae. Large specimens of *Macoma* 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 *Macoma* in the entire Polish coastal zone of the Baltic and they do not cause such strong reduction in the abundance of older age groups as in the Pomeranian Bay (Fig. 2).

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 bivalves, 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 between Świnoujście and Dziwnów, affected by freshwater with its salinity periodically decreasing down to 3 PSU is inhabited by three additional euryhaline species of predators (*Eriocher*, *Orconectes*, and *Rutilus*) generally absent from the remaining part of the coastal area studied. The roach, *Rutilus rutilus*, considered as typically freshwater and known to feed also no bivalves is among the most common fish species in the Pomeranian Bay reaching a high 58 % frequency in the catches (Draganik 1996). Roach, after attaining the size of 10-12 cm acquires capability of crushing with its pharyngeal teeth, molluscs, particularly bivalves. Therefore if they are present in the habitat, they constitute a principal part of their diet. Juvenile specimens of flatfishes, particularly in summer, feed on the bottom in warmer waters close to the shore. During their feeding they may bite off siphons of *Macoma*, protruding above the bottom. The bivalves with missing terminal parts of their siphons are forced to dig up immediately below the surface of the bottom and are this way more vulnerable to predation (flat fishes such as European plaice, *Pleuronectes platessa* or water birds) (Goeij et al. 2000). The presently acquired data on the occurrence, abundance, and the biomass of *M. balthica* in the studied Polish coastal zone of the Baltic, indicate that those bivalves are affected in different intensity by abiotic factors (water current, type of bottom) and biotic (autochthonous and allochthonous bioseston content, predation). *M. baltica* occurred commonly and its frequency (F) ranged from 25 to 100%. In individual coastal zones, tellins encountered variable conditions for their development, which is confirmed by variable abundance, and by the size- and age structure (Table 5). The data acquired indicate that *M. balthica* finds more convenient conditions for its development in the Pomeranian Bay, compared to the coastal zone of the Middle Pomerania (Table 5). Compared to the data of Warzocha 1995) presenting mean values for the abundance of *Macoma* in Polish coastal waters (428 specimens per m^{-2}), the presently determined values for the Pomeranian bay were 5-fold lower (78.3 specimens m^{-2}). In the studied stretch of the Middle Pomerania, the abundance of *Macoma*, were as many as 24-fold lower (17.6 specimens per m^{-2})in relation to the data of Warzocha (1995).

Analysis of the wet weight of *Macoma* indicates that the food base for aquatic fauna, including commercially important fish species, provided by this mollusc develops the most intensively in the coastal zone of Świnoujście and Kikut (tarnsects (I-III) in the Pomeranian bay and in the area of Władysławowo (Tarnsect XIII) in the Middle Pomerania.

CONCLUSIONS

1. *Macoma balthica* is a bivalve commonly occurring in the studied 3-mile Polish coastal zone of the Baltic. The frequency (F) of this species ranged from 20 to 100%. The highest frequency was recorded in the areas of Międzyzdroje and Władysławowo (100%). The frequency for the coastal zone of the Pomeranian Bay was high and it amounted to 77.4% (on the average), while this factor for the coastal zone of the Middle Pomerania was distinctly lower and it reached 38.8%.
2. The abundance of Baltic tellin was diversified (from 0 to 304 specimens per m^{-2}) (x = 46.2 spec. per m^{-2}). In the Pomeranian Bay it was over 4-fold higher (78.3 spec. per m^{-2}) than that in the coastal zone of the Middle Pomerania (x = 17.6 spec. per m^{-2}).
3. The wet weight of *M. balthica* in the coastal zone studied (Świnoujście-Władysławowo) ranged from 0 to 86.4 g_{ww} m^{-2} (x = 17.6 g_{ww} m^{-2}). In the Pomeranian Bay the mean wet weight (22.89 g_{ww} m^{-2}) was 2.5-fold higher in relation to the mean wet weight of this species in the Middle Pomerania (x = 9.00 g_{ww} m^{-2}).
4. Macoma lived up to 6 years (according to the present method of age reading). The age structure of the population of *M. balthica* studied in the Polish coastal zone was strongly diversified. Their life-span was the shortest in the marine part of the Odra River estuary with the dominant age group 1+ (Pomeranian bay, transects I-III). On the remaining profiles, the bivalves lived up to 5, 6 years and the dominant groups were 2+, 3+, and 4+.
5. The mean value of shell width of *Macoma* specimens studied shown a growing tendency from the west (6.7 mm) to the east (12.3 mm)
6. The analysis of the mean abundance, wet weight, and the frequency points out that *Macoma* population in the Pomeranian Bay, compared 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 under the condition of high abundance of *Mytilus edulis* and more favourable hydrological conditions modifying the sandy bottom.

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ROZMIESZCZENIE I ROLA MAŁŻA *MACOMA BALTHICA* (L.) W POLSKIEJ STREFIE PRZYBRZEŻNEJ BAŁTYKU

Streszczenie

Badano populację małża *Macoma balthica* w polskiej strefie przybrzeżnej Bałtyku (do 3 Mm) w Zatoce Pomorskiej (Pomeranian Bay) i otwartym wybrzeżu Pomorza Środkowego (Middle Pomeranian). Określono zagęszczenie, biomasę mokrą oraz frekwencję *Macoma* w wodach przybrzeżnych w tym w rejonach ujść rzeki Odry (cieśnina Świny, cieśnina Dziwny), rzeki Wieprzy, Słupi, Łupawy i Łeby. Frekwencja *Macoma* w badanej strefie przybrzeżnej w Zatoce Pomorskiej wynosiła F = 77.4 % podczas gdy w strefie przybrzeżnej otwartego morza (Pomorza Środkowego) wartość frekwencji była niższa – F = 39.8%. Zagęszczenie *Macoma* w badanej strefie przybrzeżnej wahało się w granicach od 0 do 304 ind. m^{-2} dna ($\bar{x}$ – 46.2 ind. m^{-2}). Wartość masy mokrej tego gatunku małża wahała się od 0 do 99.2 g_{mm} m^{-2} ($\bar{x}$ – 17.6 g_{ww} m^{-2}). *Macoma balthica* znajdowała dogodniejsze warunki dla rozwoju w Zatoce Pomorskiej w porównaniu ze strefą przybrzeżną Środkowego Pomorza, gdzie w zatoce jej zagęszczenie było 4.5-krotnie wyższe, a masa mokra 2.5-krotnie wyższa w porównaniu do otwartego wybrzeża. *Macoma balthica* odgrywa ważną ro-

lę w monitoringu bentosu Morza Bałtyckiego, tworzy znaczącą bazę pokarmową dla zwierząt (ryby, ptaki) oraz uczestniczy w procesie doczyszczania wód badanej strefy przybrzeżnej (biofiltracja, biosedymentacja).