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QUANTITATIVE STRUCTURE OF *HEDISTE DIVERSICOLOR* (O.F. MÜLLER) IN ESTUARY ZONES OF THE SOUTHERN BALTIC SEA (POLAND'S CENTRAL COASTLINE)

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Abstract

This study concerns the distribution of nereid *Hediste diversicolor* in the Middle Pomerania, near the estuaries of five rivers (Parsęta, Wieprza, Słupia, Łupawa and Łeba). The highest density of *Hediste* was observed in the vicinity of the Wieprza estuary while the lowest (7-fold lower) in the estuary of the Łeba River. As for biomass, it was the highest in the river mouth of Parsęta and the lowest in the Wieprza estuary. Frequency in the studied estuaries was low and amounted to 32%. Using standard statistical methods (significance tests) we indicated differences in average *Hediste* density and biomass between the eastern and western transects. Nereid's density was 2-fold higher in the eastern transects while biomass in western. The applied multivariate regression and classification tree method (MR&CT) revealed that the density of *Hediste* was determined only by the depth of a sampling site while biomass by the distance from the coast. The Spearman's correlation coefficient analysis indicated significant ($p < 0.05$) dependence of biomass and density on depth and distance from the shore. Due to ecological role of *H.diversicolor* as a food source for benthivorous fish, including valuable and endangered species (cod, flatfish), the analysis of food supply can be important in the identification of fish feeding grounds.

Key words: *H. diversicolor*, benthofauna, estuary, Middle Pomerania

INTRODUCTION

Hediste diversicolor (O.F. Müller 1776) is a cosmopolitic species, typical to coastal waters of Europe and North America along the Atlantic coast (Smith 1977). Its occurrence area in Europe extends from the north of the continent and the Baltic Sea to

Morocco, the Mediterranean Sea, the Black Sea and the Caspian Sea (Fauvel 1923, Clay 1967, Smith 1977). *Hediste* is a eurythermic and euryhaline species, therefore is not observed in very saline waters and freshwaters (Bogucki 1954, Wolff 1973, Neuhoff 1979). In the Baltic Sea the discussed organism occurs from the Bay of Kiel to the eastern part of the sea and from the Finland Bay to the Botnicka Bay, including estuaries and coastal waters (Demel 1976, Żmudziński 1978, Żmudziński and Ostrowski 1982). The presence of *Hediste* is connected with various bottom types but mostly with sand and silt, which can constitute a substrate for submerged meadows (Clay 1967, Demel 1976, Warzocha 1995, Żmudziński 1990, Żmudziński and Ostrowski 1982). Nereids bore in the bottom material where they find food by swallowing sand with organic remains and attack encountered small benthic animals, particularly crustaceans and weaker representatives of their own species (Fauchald and Jumars 1979). The other important factor influencing the presence of *Hediste* is water oxygenation and food supply. Appropriate oxygenation occurs mostly in the shallow-water zones and therefore nereid density reaches there the highest values (Demel 1976, Reise 1981, Żmudziński and Ostrowski 1982).

Hediste, as one of the few benthofauna representatives in the Baltic Sea, is resistant to water pollution and abundant in highly eutrophicated waters and estuaries with high content of zinc and copper (Davey and Watson 1995, Grant et al. 1989, Hateley et al. 1989, Piesik et al. 1994). Therefore, it can be treated as an indicator species of contaminated estuaries in Europe (Ozoh 1992).

Hediste is an important element of the food chain. Due to its common occurrence, availability and small size, nereids are food for fish, mainly benthivorous, like flatfish, cod (young individuals) and others (Ciąglewicz et al. 1972, Demel 1976, Żmudziński 1957, Żmudziński and Ostrowski 1982). Some research revealed vertical migration of nereids at night to the surface, where they can be eaten by eels (Żmudziński 1957).

Jażdżewski (1962) during his research in the Puck Bay found jaws and bristle of *Hediste* in the chyme of brown shrimp (*Crangon crangon* L.) in Jama Kuźnicka. It is probable, that freshwater fish seasonally feeding in the Baltic estuaries also eat nereids (Piesik et al. 1994).

The aim of our study was to determine the distribution and structure (density, wet biomass) of *Hediste diversicolor* population in the estuary zone of five rivers in the Middle Pomerania. The obtained data can contribute to the assessment of quantitative changes and trends in the abundance of *Hediste* in the Polish coastal zone, which is influenced by anthropogenic pressure. This paper also presents the distribution and abundance of nereids as food supply for fish important from the economic point of view.

MATERIALS AND METHODS

The population of *Hediste diversicolor* was studied in years 2000-2004 on a 3-mile-long section of the coast, near the river mouths of five rivers located in the Middle Pomerania (Parsęta, Wieprza, Słupia, Łupawa and Łeba) (Fig.1). Polychaetes were

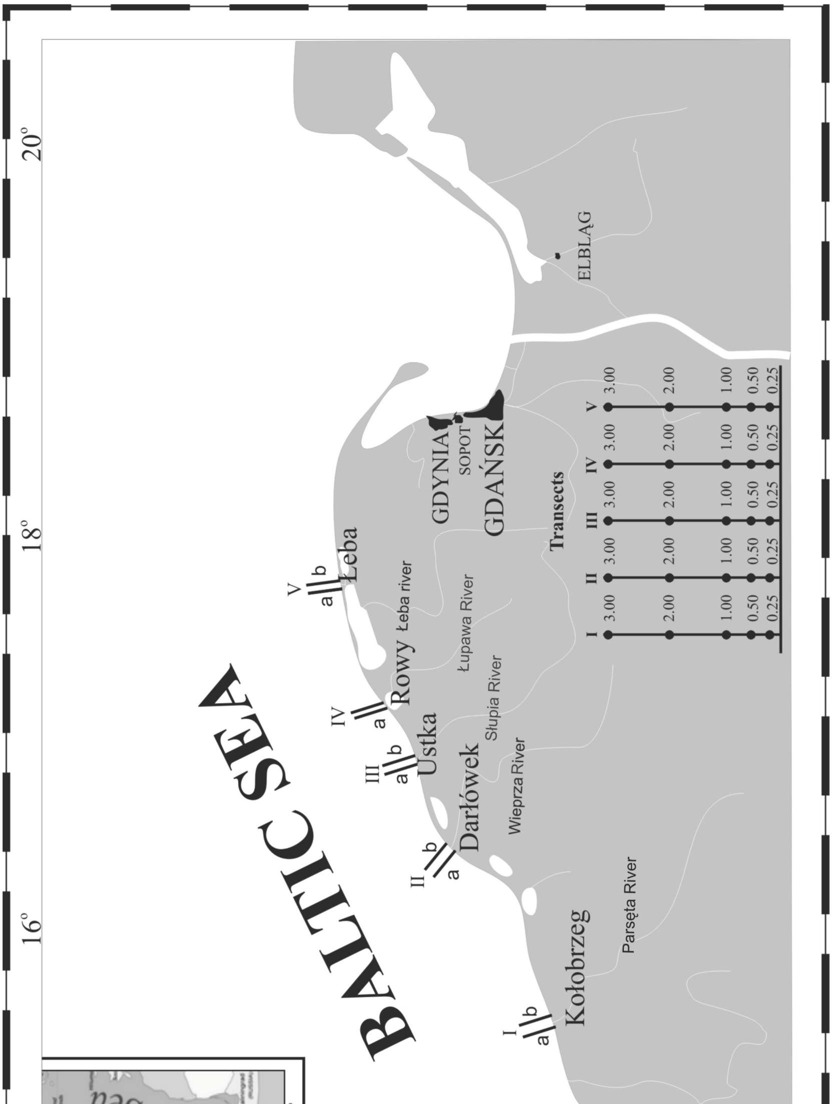


Fig. 1. Localisation of sampling sites

collected using a Van Veen grab with the area of 0.0625 m^2 (transects I-VI). Altogether 50 sampling sites were selected and at each 2-3 grabs were taken (135 samples). The sites constituted 10 transects located crosswise to the shore. The transects were situated 1 Nm to the east (E) and 1 Nm to the west (W) from a river mouth. Each transect was formed by 5 sampling sites (Fig. 1).

The collected material was sieved on a benthos sieve of 1-mm mesh size and then conserved in a 4-% formaldehyde solution. In a laboratory it was analysed and then the abundance of *Hediste* was related to 1 m^2 of bottom area. Wet mass, after prior drying on a filter paper, was determined using a laboratory scale with 0.01 g accuracy and also related to 1 m^2 of bottom area.

The obtained data set was analysed with common statistical methods: descriptive statistics (average value ($\bar{x}$), median (Me), standard deviation (SD), standard error (SE), coefficient variation (CV)), the U Mann-Whitney test (variable distributions significantly differed from the normal distribution), Spearman's rank correlation between density/biomass and environmental factors. Additionally multivariate regression and classification tree method (MR&CT) was applied (Breiman et al. 1984, De'ath and Fabricus 2000, De'ath 2002). The overall fit of the tree was specified as relative error (RE; SSD – sum of squared Euclidian distances – in clusters divided by SSD of the undivided data) and the predictive accuracy was assessed by cross-validated relative error CVRE (Breiman et al. 1984, De'ath and Fabricus 2000). In this study, the finally selected tree was the most complex model within one standard error (1 SE) of the best predictive tree (Breiman et al. 1984), using 2000 multiple cross validations to stabilize CVRE.

MR&CT analyses were carried out in R 2.1.1 (R Development Core Team, 2004) using the mvpart (Multivariate Partitioning) package. The distribution of *Hediste* in the studied area was analysed with Surfer ver. 8.01 and the remaining analyses were performed in Statistica ver. 7.0.

RESULTS

In the studied estuary zones of the Middle Pomerania *Hediste* representatives occurred with the highest abundance near the river mouth of the Wieprza River (Darłowo), where it reached density at the level of 136 indiv. m^{-2}, while in the Łeba estuary *Hediste* was rather a rare species (Tab. 1). The analysis of average density excluding places omitted by *Hediste* revealed that this species was the most abundant near Darłowo while the least near the Słupia estuary. However, its frequency was the highest in the river mouth of the Słupia River (F = 60%) and the lowest near Parsęta, Łupawa and Łeba estuaries (Tab. 1).

In the eastern transects *Hediste* density reached its maximum in the vicinity of Darłowo and Rowy, while much lower values were observed in the remaining sections (Fig. 2). In case of western transects the highest nereid density was found near Kołobrzeg, Darłowo and Rowy. However, differences between the eastern and western transects as well as between the consecutives estuaries were insignificant ($p < 0.05$). In general, the highest *Hediste* density was observed in the central part of the Middle Pomerania coast.

Table 1

Comparison of *Hediste diversicolor* density in the studied zones: range, average abundance ($\bar{x}$), excluding places omitted by this species ($\bar{x}_z$), standard deviation (SD), coefficient of variability (CV) in coastal and open coastal zones with different level pollution; (W, E) – coastal zone west and east from the studied river mouths

Localisation	Kołobrzeg (Parsęta River)	Darłowo (Wieprza River)	Ustka (Słupia River)	Rowy (Łupawa River)	Łeba (Łeba River)	Transects West (W)	Transects East (E)
Coast type	Estuary	Estuary	Estuary	Estuary	Estuary	Estuary	Estuary
abundance range (ind. m^{-2})	0-292 n = 10	0-912 n = 10	0-110 n = 10	0-385 n = 10	0-180 n = 10	0-292 n = 25	0-912 n = 25
min-max abundance (ind. m^{-2})	27-292	80-912	5-110	80-385	20-180	5-292	20-1136
$\bar{x}$ – average abundance (indiv. m^{-2})	31.9 n = 10	136.0 n = 10	24.5 n = 10	46.5 n = 10	20.0 n = 10	35.0 n = 25	68.5 n = 25
$\bar{x}_z$ – excluding places omitted by this species (ind. m^{-2})	159.5 n = 2	340.0 n = 4	40.8 n = 6	232.5 n = 2	100.0 n = 2	109.5 n = 8	214.1 n = 8
SD_z	187.38	385.86	42.36	215.67	113.14	110.11	305.63
CV (%)	28.8	20.8	15.4	26.1	28.3	22.6	28.3
$\bar{x}$ – wet mass (gWW m^{-2})	0.31	0.04	0.13	0.14	0.29	0.23	0.13
$\bar{x}_z$ – excluding places omitted by this species (gWW m^{-2})	1.53	0.10	0.21	0.70	1.44	0.72	0.41
Median (Me)	159.5	184.0	30.0	232.5	100.0	80.0	87.5
F (%)	20	40	60	20	20	32	32

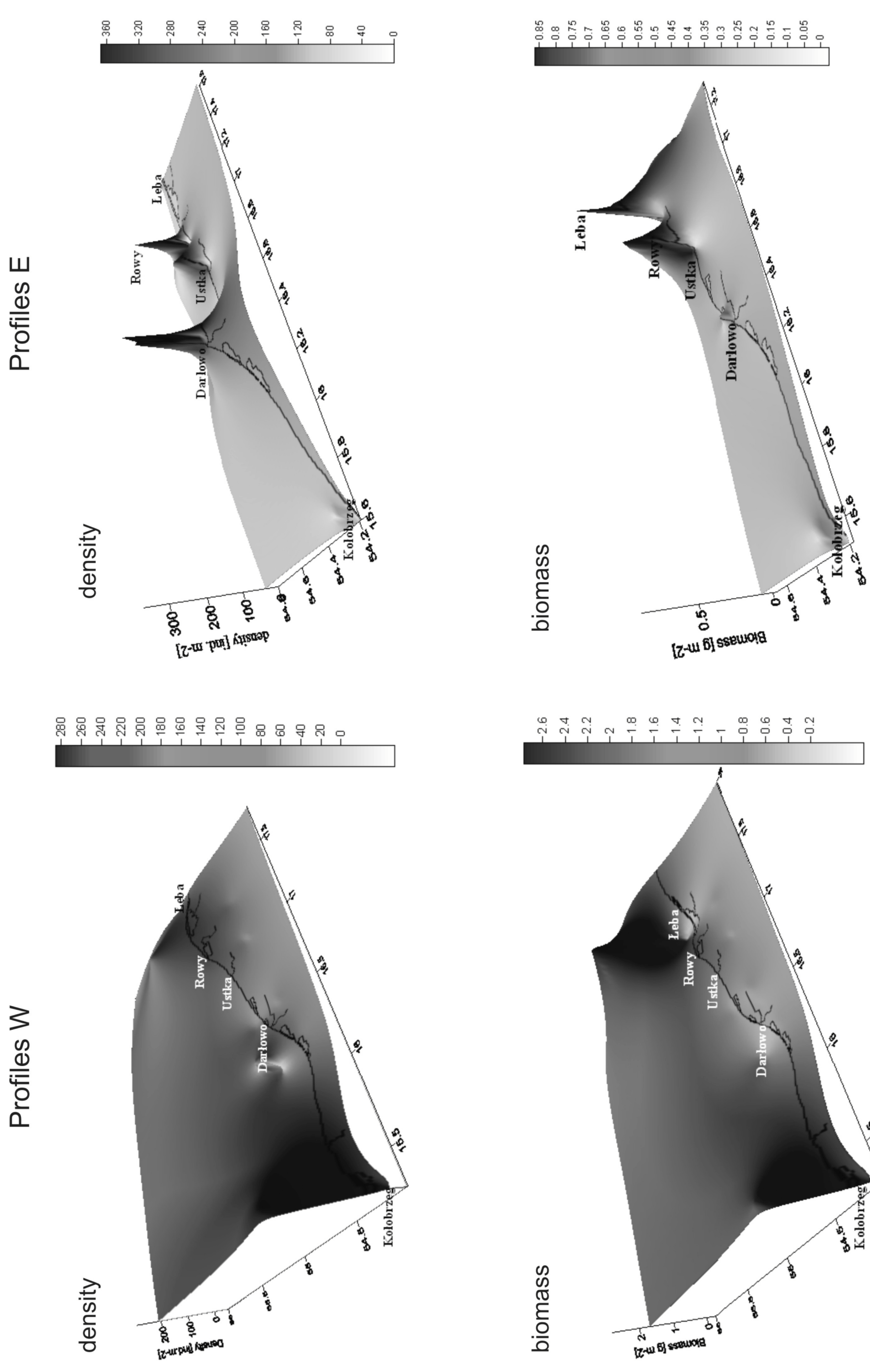


Fig. 2. Distribution of *Hediste diversicolor* density and biomass in the estuary zones of the Middle Pomerania

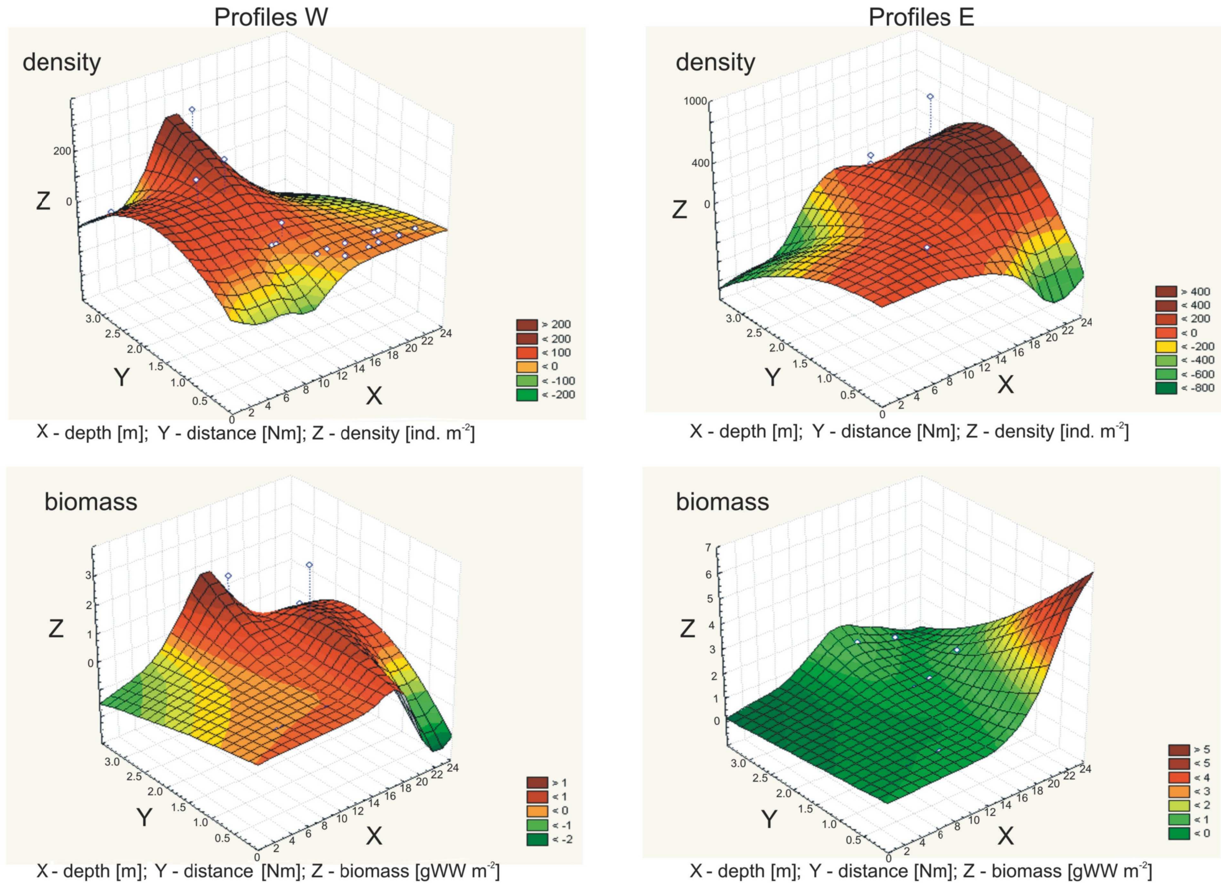
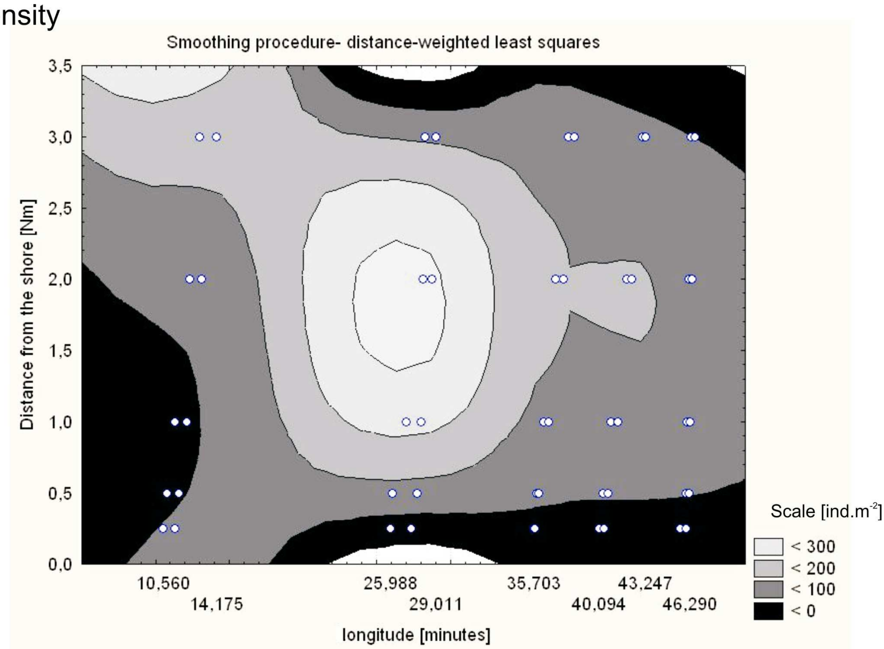


Fig. 3. Distribution of *Hediste diversicolor* density and biomass at sites forming transects located to the east and west from the studied estuaries in the Middle Pomerania

density



biomass

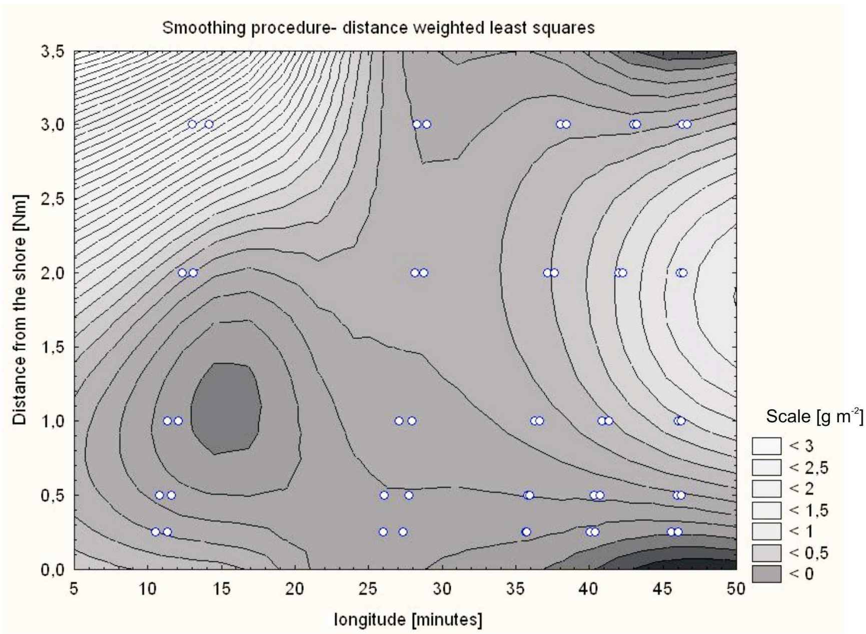


Fig. 4. Distribution of *Hediste diversicolor* biomass and density in the studied estuary zones of the Middle Pomerania

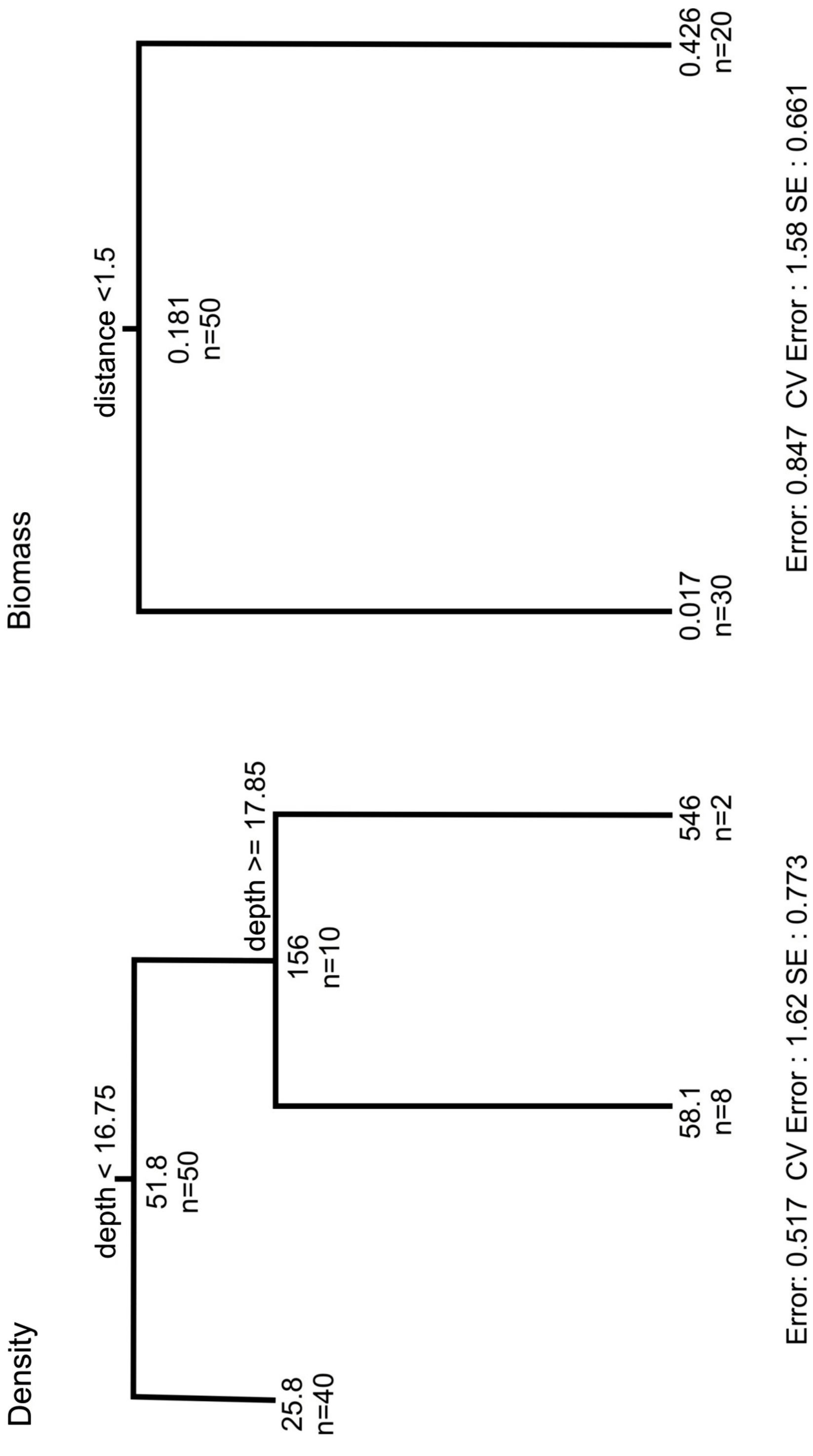


Fig. 5. MR&CT trees for *Hediste diversicolor* density and biomass in the studied estuary zones of the Middle Pomerania

Nereids in the studied area preferred sites located 2 Nm from the coast ($\bar{x}$ =185.6 indiv. m^{-2}) and avoided shallow zones (0.25 Nm), where no *Hediste* representatives were observed. Concurrent analysis of density, depth and distance from the coast revealed, that at the western transects *Hediste* preferred sites far from the shore (3 Nm) at the depth of 14 m while at the eastern transects maximum density was observed at higher depth, 2 Nm from the shore (Fig. 2). Distribution of the studied species was determined by its preferences towards eastern sites (Tab. 1).

The wet mass of nereids reached the highest level near Kołobrzeg. That maximum was followed by a rapid fall near the Wieprza estuary, where *Hediste* biomass was 8-fold lower (Tab. 1). In the next estuaries the wet mass slowly increased up to 0.29 g m^{-2} and was comparable to biomass near the Parsęta estuary. Average *Hediste* biomass in the consecutive estuaries was influenced by the western transects, particularly near the river mouths of Parsęta and Łeba (Fig. 2). Nereid weight at eastern profiles decreased from Kołobrzeg to Ustka while at western profiles it fluctuated (Fig. 2). However, differences in the average biomass between eastern and western transects and the consecutive estuaries where insignificant ($p < 0.05$).

The analysis of *Hediste* biomass dependence on depth and distance from the coast indicated that at eastern transects the wet mass increased with both of those parameters (Fig. 3). At western transects *Hediste* biomass was the highest far from the coast at the depth of 14 m and decreased with depth (Fig. 3).

The Spearman's correlation analysis revealed the dependence of *Hediste* density on depth (correlation coefficient 0.39) and distance from the coast (0.36). Localisation of a site, expressed by longitude, turned out to be an insignificant factor. As for biomass, it also correlated with the depth of a site (0.40) and distance from the coast (0.38).

The distribution of *Hediste* density in the studied area showed, that it was the highest 1-2 Nm from the shore (Fig. 4) in the vicinity of Darłowo and at sites the most distant in Kołobrzeg. Similar dependencies were observed for biomass but with the highest level of density situated 3 Nm from the shore in Kołobrzeg.

MR&CT analysis indicated depth as the most important factor influencing *Hediste* density (Fig. 5). Its average value at the depth equal to or higher than 16.75 m amounted to 156 indiv. m^{-2} while in shallower zones it was 7-fold lower. The next split of the MR&CT tree separated sites with depth higher or equal to 17.85 m (58.1 indiv. m^{-2}) and those with depth between 16.75 and 17.85 (over 500 indiv. m^{-2}). In case of biomass only distance from the shore turned out to be an important factor and indicated *Hediste* preference toward more distant sites (Fig. 5).

DISCUSSION

Macrozoobenthos in the Polish part of the Baltic Sea has been studied by many researchers. However there is little information on that formation in estuary zones of the Middle Pomerania (Piesik 1998, Szlamińska 1976, Warzocha 1995).

Coastal zone is inhabited by complexes of macrofauna but with the decrease in depth the bottom life becomes more monotonous. The most abundant representatives of benthic organisms in the southern Baltic Sea are polychaetes and crustaceans. They occur at every depth, from the coast to more deep zones (Żmudziński 1978).

A typical representative of polychaetes is *Hediste diversicolor*, which prefers depth 5-20 m (Warzocha 1995) and avoids shallow zones down to 2 m (Żmudziński 1982). Thanks to the salinity tolerance, *Hediste* also occurs in estuaries (Koszteyn 1973, Piesik et al. 1994, Szlamińska 1976), where it usually is of a bigger size and achieves higher density and biomass comparing to open coast (Piesik et al. 1994, Żmudziński 1967). In a section of the Świna Właściwa strait the wet mass of *Hediste* reached 86 g m^{-2} (Piesik et al. 1994) and in the Puck Bay 58 g m^{-2} (Żmudziński 1982). According to Warzocha (1995) the average *Hediste* density in the open coastal zone amounts to 166 indiv. m^{-2} while its wet mass range from 1.91 to 5.87 g m^{-2}.

In the studied 3-mile-long coastal zone of the Middle Pomerania the average density amounted to 52 indiv. m^{-2} (0-912 indiv. m^{-2}), which was 2-fold lower comparing to the average density of nereids in the Pomeranian Bay and 1.9-fold lower than in the Gulf of Gdańsk (Wenne and Wiktor 1982). However, in other regions of the Baltic Sea (Tvörminne – Finland) the density given by Smith (1955) was almost 10-fold higher.

Studies on the distribution of *H.diversicolor* in other European estuaries revealed, that its density range observed in the Middle Pomerania (20-136 indiv.m^{-2}) was much lower than in Scotland (Chambers and Milne 1975), England (Ratcliff 1979), Netherlands (Essink et al. 1985), France (Gillet 1990) or Spain (Clavero et al. 1991). Low density of *Hediste* in the estuary zone of the Middle Pomerania may indicate lower contamination, particularly with organic substances, than in the Gulf of Gdańsk or the Pomeranian Bay (Piesik et al. 1994, Żmudziński and Ostrowski 1982). Moreover, near the estuaries in the Middle Pomerania the density of nereids increases with depth, opposite to the situation observed in bays (Tab. 2).

Table 2

Comparison of *Hediste diversicolor* density along the Polish coast

Depth [m]	Pomeranian Bay (Piesik et al. 1994)	Estuary zones Middle Pomerania (own research)	Gulf of Gdańsk (Żmudziński 1982)
< 10 m	163 indiv. m^{-2}	8 indiv. m^{-2}	300 indiv. m^{-2}
11-20	101 indiv. m^{-2}	71 indiv. m^{-2}	235 indiv. m^{-2}
21-30	7 indiv. m^{-2}	155 indiv. m^{-2}	35 indiv. m^{-2}

Hediste frequency (F) in the compared zones of the Baltic Sea was diverse and amounted to 69% in the Pomeranian Bay, 80% in the Gulf of Gdańsk and 32% in the studied area of the Middle Pomerania.

The wet mass of *Hediste* is particularly high at a certain distance from the coast: 3.0 Nm near the Odra river mouth and 2.0 Nm in the studied estuary zones of the Middle Pomerania. This situation may be connected with more favourable trophic conditions. Riverine current velocity decreases with the distance from a shore while the sedimentation of organic matter or atrophied freshwater plankton increases. Sedimented seston forms detritus which is basic food for nereids. The zone of intensive riverine seston sedimentation in the sea depends probably on the volume of inflowing water and flow velocity. Therefore, in the Odra estuary (V_Q = 605.2 m^3/s) the highest wet mass of *Hediste* was observed 3.5 Nm from the coast. Flow velocities in the Middle Pomerania rivers (Wieprza – 15.9 m^3/s, Słupia – 15.9 m^3/s and Łeba – 13.6 m^3/s) are much lower comparing to the Odra River (Niemirycz and Borkowski 1996) and that is why the zone of intensive seston sedimentation as well as the highest *Hediste* wet mass is located 2.0 Nm from the shore.

The studies on *Hediste* distribution in other sections of the Polish coastal zone indicate higher average biomass than in the estuaries of the Middle Pomerania. In the Pomeranian Bay the wet mass was over 2-fold higher (Piesik et al. 1994) while in the Gulf of Gdańsk over 5-fold higher (Wenne and Wiktor 1982). Only near Göteborg in Sweden (Möller 1985) the observed wet mass was similar to the Middle Pomerania estuaries, while in Scotland (Chambers and Milne 1975), England (Nithart 1998), Netherlands (Essink et al. 1985), France (Gillet 1990), Spain (Clavero et al. 1991) and Morocco (Gillet 1993) *Hediste* biomass was considerably higher.

Hediste is important as food for benthivorous fish, not only Baltic species as flat fish, young cods and European smelt (Demel 1976, Wultańska 1971, Załachowski et al. 1976) but also freshwater fish feeding in estuaries, for instance roach or bream. Due to vertical migration of *Hediste* at night it is also eaten by eels (Żmudziński 1957).

Constant control of the quantitative structure of nereids in the Polish part of the Baltic Sea can help in the monitoring of sea contamination with organic substances and also in the identification of some fish species fishing grounds.

CONCLUSIONS

1. The highest density of *Hediste diversicolor* was observed near the estuary of Parsęta while the lowest in the vicinity of Łeba.
2. In terms of density, *Hediste* preferred sites located to the east from river mouths while the highest biomass was observed in western transects but average values did not differ significantly between transects ($p < 0.05$).
3. In the whole studied area *Hediste* was the most abundant 2 Nm from the coast and preferred higher depths.
4. The most important environmental factor influencing *Hediste* biomass and density was the depth.

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STRUKTURA ILOŚCIOWA *HEDISTE DIVERSICOLOR* (O.F. MÜLLER) W STREFACH ESTUARIOWYCH BAŁTYKU POŁUDNIOWEGO (WYBRZEŻE ŚRODKOWE POLSKI)

Streszczenie

Przeprowadzono badania nad rozmieszczeniem wieloszczeta *Hediste diversicolor* w częściach estuariowych polskiego Wybrzeża Środkowego, w strefie przyujściowej 5 rzek (Parsęty, Wieprzy, Słupi, Łupawy i Łeby). Największe zagęszczenie *Hediste* obserwowano w okolicach ujścia Wieprzy, a najmniejsze (blisko 7-krotnie niższe) w estuarium rzeki Łeby, natomiast biomasa tego gatunku najwyższe wartości uzyskała w ujściu Parsęty, zaś najniższe – Wieprzy. Frekwencja dla obszarów estuariowych była niewielka i wyniosła zaledwie F = 32%. Przy użyciu klasycznych metod statystycznych (testów istotności) wykazano różnice w średnim zagęszczeniu i biomasie pomiędzy profilami wschodnimi i zachodnimi w estuariach. Nereida osiągała blisko 2-krotnie wyższe zagęszczenie na profilach wschodnich, natomiast biomasa w takim samym zakresie była wyższa na profilach zachodnich. Zastosowana metoda MR&CT (drzewa regresyjne) dla danych z Morza Bałtyckiego wskazała, że na zagęszczenie *Hediste* wpływ ma jedynie głębokość wody w miejscu poboru, natomiast na biomasę odległość od brzegu. Analiza korelacji Spearmana wskazuje na istotną zależność ($p < 0.05$) zagęszczenia i biomasy od głębokości i odległości od brzegu.

Ze względu na ekologiczną rolę *H. diversicolor* jako bazy pokarmowej dla ryb bentosożernych, w tym cennych, a zarazem zagrożonych gatunków (dorsz, płastuga itp.), określenie potencjalnej bazy pokarmowej może być cenną wskazówką co do identyfikacji miejsc ich żerowania.