Comparison of the Composition of Three Polychaete Communities from different Habitats in the Ecosystem Wadden Sea (List, Sylt)

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Abstract
In order to test whether different habitats in the Wadden Sea are characterized by different polychaete communities, we identified all polychaete species from three different habitats in List, Sylt. We chose one habitat which can be categorized as a mudflat, one mixed sediment mudflat and one sand flat. To show the composition of the polychaete communities, we calculated the dominance of species, determined the Shannon-Weaver diversity index for each habitat and compared each habitat with another via the Renkonen index. Our dataset showed different dominant species for each habitat and a varying distribution of polychaete species in general. However, our dataset does not provide the expected results and shows no significance. Therefore, general assumptions about the effect of a different habitat, and a different particle size, can not be made. The diversity in the polychaete communities were not as high as expected. Further studies have to be made which include more samples over a longer period.

Introduction

Polychaetes are an animal group present in all kinds of marine habitats .They expanded into estuaries and meiofauna systems. This class of animals shows a variety of adaptations in order to conquer all kinds of modes of life. Usually, they are the one of the most abundant taxon present in the benthos regarding the number of species and their numerical abundance. Additionally, they can be attached to all kinds of substrates or live within the benthos besides being present as pelagial forms. Those species living in the benthos can be vagile, hemi-sessile or sessile and can therefore contribute to different trophic levels, e.g. utilising sediment or acting as predators or deposit-feeders (Hartmann-Schröder, 1996).

A huge variety of polychaetes can be found in the tidal flats of the North Sea (Hartmann-Schröder, 1996). Here, they are confronted with changing environments, being exposed to different temperatures, salinities and water levels (Reise, 1985; Semeniuk, 2005). The tidal cycle determines the exposure to those rather harsh conditions. The currents generated by this cycle determine the distribution of particles and therefore lead to the assemblage of different kinds of substrate. These substrates can be categorised by their particle size. Particles ranging from 2 to 0.063 mm size are considered to be sand, whereas particles with 0.063 to 0.002 mm in diameter are called silt (Reise, 1985). Due to the currents, these tidal flats are important sedimentation areas and enable the formation of specific endo- and epibenthic communities. With the semi-diurnal tides and the therefore high availability of organic substances, a lot of oxygen is consumed leading to a limitation of oxygen content of the pore water (Ingole, 2005). Particle size and substrate quality are also important limitation factors leading to a distinct distribution and zonation of species (Semeniuk, 2005).

Polychaetes may also be used as indicators for environment disturbance (Samuelson, 2001) and marine pollution (Dean, 2008). Therefore, they are used as model organisms to show effects of pollution and anthropogenic influences (Dean, 2008).

In order to compare the distribution of polychaetes and the species present at one site, a baseline has to be generated to show which species are generally abundant or exist there at all. To give an overview about one particular site and to show the influence of habitats on the species variety, we looked at three different habitats in close proximity to each other which differed in their particle size and can be categorised as sand flat, mudflat and mixed sediment mudflat. Our hypothesis is that the polychaete communities differ in their composition according to the substrate they are living on.

Material und Methoden

Study area

As study site served the Oddewatt at List, Sylt (Germany), which is located in the northern part of the Wadden Sea close to the Danish border (Fig.1). Sylt is part of the cold temperate region with a mean annual air temperature of 8.1 °C, an annual precipitation of 731 mm and a mean wind velocity of 6 m s -1 (Reise, 1985). Mean annual water temperature is about 9°C and salinity is about 30 ‰ (Reise et al., 1994). Tides are semi-diurnal separated by 12.4 h on average (Reise, 1985) with an amplitude of 1.8 m (Reise et al., 1994), while the average difference between neap and spring tide is only about 17 cm (Reise, 1985).

Sampling

Sampling took place from October 5th, 2017 till October 8th, 2017. Three different habitats were chosen: sand flat (55°1’34’’ N 8°26’10’’ O), mudflat (55°1’30’’ N 8°25’25’’ O) and mixed sediment mudflat (55°1’19’’ N 8°26’17’’ O) (Fig. 1). The sand flat is characterized by a grain size of about 0.5 mm, a mean soil temperature of 11.3 °C and a mean depth of the oxidation layer at ca. 4.3 cm below the sediment surface. The mudflat is characterized by a grain size of about 0.25 mm, a mean soil temperature of 12 °C and a mean depth of the oxidation layer at ca. 2.7 cm. The mixed sediment mudflat is characterized by a grain size of less than 0.063 mm, a mean soil temperature of 11 °C and a mean depth of the

Fig. 1. a) Northern area of Sylt. Red dot = Alfred-Wegener-Institut Sylt. b) Location of the three sampled habitats. Yellow circle = mudflat (55°1’30” N 8°25’25” O), yellow square = sand flat (55°1’34” N 8°26’10” O), yellow triangle = mixed sediment mudflat (55°1’19” N 8°26’17” O). Red dot = Alfred-Wegener-Institut Sylt. Source: https://www.google.de/maps/@55.0356298,8.4328897,5403m/data=!3m1!1e3 (adapted)

oxidation layer at ca. 2.5 cm. Per habitat four samples were taken with a box corer (14 cm x 15 cm x 30 cm) at a distance of approximately 1.5 m of each sample. Soil samples were then sieved in the lab (mesh size 1 mm and 0.25 mm) and polychaetes were picked carefully with tweezers and stored in seawater-filled petri dishes for further analysis. For species identification, a dissecting microscope was used.

Since the box corer did not allow for sampling equal sediment volumes throughout, the number of collected individuals from a given volume was extrapolated to ten litres of sediment to compare the data.

Data analysis

Dominance (D)

The dominance measures the relative frequency of a taxon in relation to the total number of taxa in a habitat (Mühlenberg, 1993) and is defined by D (%) = n * 100 / N, where n represents the number of individuals of a taxon and N represents the total number of individuals in a sample. The classification of dominance was categorised according to a logarithmic relation between the number of individuals and taxa (Engelmann, 1987): eudominant = 32,0 – 100 %, dominant = 10,0 – 31,9 %, subdominant = 3,2 – 9,9 %, receding = 1,0 – 3,1 %, subreceding = 0,32 – 0,99 %, sporadic = < 0,32 %.

Shannon index (HS)

The Shannon Index (Shannon & Weaver, 1967) is a widely used measure of biological diversity (Chao & Shen, 2003) and is defined by $HS = -\sum p_i * \ln(p_i)$, where pi is the proportion of taxa in the total population. If the number of individuals is evenly distributed across a high number of taxa HS is high indicating a great diversity, whereas a low index characterizes a small diversity as follows: high = $Hs > 4$, good = $3 < HS \leq 4$, moderate = $2 < HS \leq 3$, poor = $1 < HS \leq 2$, bad = $HS \leq 1$ (Zettler et al., 2007).

Table 1. Abundance [individuals per 10 litres soil] and relative abundance of the polychaete species composition of the intertidal mudflat habitat.

Species	Abundance [per 10 litres soil]	Relative abundance [%]
Arenicola marina	5 ± 1	18
Hediste diversicolor	21 ± 2	71
Phyllodoce maculata	2 ± 1	5
Polydora spec.	2 ± 1	5

Renkonen similarity index (P)

The Renkonen similiarity index compares the congruence of two species communities in different habitats and is defined by

$$P\ (\%) = \sum_{i=1}^{G} min D_{A,B}$$

with D = nA/NA and nB/NB, respectively where minDA,B represents the sum of the smaller dominance value of mutual species of both habitats A and B, i represents one species, G is the number of mutual species in both habitats, nA,B is the number of individuals of species i in habitat A and B and NA,B is the overall number of individuals of habitat A and B (Hübner, 2007). The index ranges from 0 (no mutual species in both habitats) to 1 (same species composition in both habitats) and also considers whether the mutual species occur in the same proportions (Seda & Devetter, 2000).

Statistical analysis

We first performed a Shapiro-Wilk test to evaluate whether the data was normally distributed. Since this was not the case we performed a Kruskal-Wallis test to monitor whether a significant difference between the polychaete communities in the three habitats exists. The programme R (version 3.4.2) was used for statistical analysis.

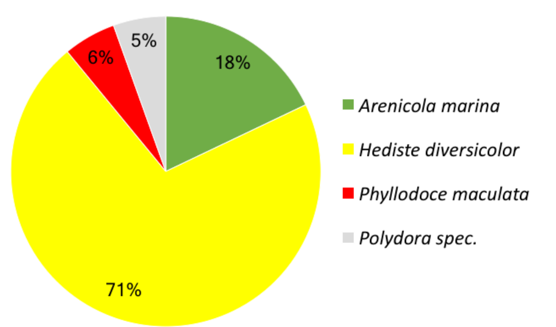

Fig. 2. Dominance (relative abundance) of the polychaete species composition of the mudflat habitat in the Oddewatt at List, Sylt (Germany). In total four species were found. Hediste diversicolor is with 71 % an eudominant species. Arenicola marina is with 18 % a dominant occurring species, while Polydora spec. (5 %) and Phyllodoce maculata (6 %) are subdominant species.

Results

To test whether the polychaete species have different distributions among the three habitats, we calculated the dominance (D) (see materials and methods) of every species present in one habitat. This dominance is synonymous to the relative abundance of a species in correlation to the total amount of individuals found in one habitat. Therefore, it shows which species is most dominant.

In the mudflat we found four species in total. *Hediste diversicolor* was the most dominant species representing approximately 70% of all individuals (Fig. 2). Thus, it is a eudominant species in this habitat. *Arenicola marina* on the other hand only constitutes about 18%, hence it is not eudominant but only dominant (Fig. 2). The remaining two species, *Phyllodoce maculata* and *Polydora* spec. represented about 5% each of all individuals in the mudflat. Therefore, the latter species are subdominant (Fig. 2). Exact values can be seen in Table 1.

In the mixed sediment mudflat, *Capitella capitata* was the most dominant species with about 70% (Fig. 3) making it as dominant as *H. diversicolor* in the mudflats. In the mixed sediment mudflats, *H. diversicolor* was represented by about 18% of all individuals; therefore it is only dominant in this habitat (Fig. 3). *Arenicola marina*, which is one of the most abundant species in the Wadden Sea (Beukema, 1976; Reise, 1985), only yielded about 9% of the individuals; thus this species is subdominant in the mixed sediment mudflats (Fig. 3). The other two species that we found in the mixed sediment mudflats were *Phyllodoce maculata* and *Scoloplos armiger*. These two were quite rare and only represented approximately 1% and 2% of all individuals, respectively (Fig. 3). Therefore, they were categorized as receding. Exact values can be seen in Table 2.

In the sand flat, where we found three species in total, Scolelepis squamata was most abundant representing approximately 77% of all found individuals. Hence, it is a eudominant species like H. diversicolor in the mudflats and C. capitata in the mixed sediment mudflats (Fig. 4). The other two species that we found were H. diversicolor and Eteone longa. H. diversicolor represented about 21% whereas E. longa made up approximately 2%. It can be said that H. diversicolor was a dominant species whereas E. longa was a receding one (Fig. 4). The exact values can be seen in Table 3.

In order to make a statement about the diversity of the three habitats, we calculated the Shannon-Weaver-Index (see materials and methods). Due to the relatively low number of species found, it is evident that these indices were quite low. The diversity index for the mudflat was 0,91 ± 0,79; for the mixed sediment mudflats 1,29 ± 0,51 and for the sand flats 0,56 ± 0,47 (Table 4).

To compare the three habitats to each other, we calculated the Renkonen index which represents the similarity of one habitat to another (see materials and methods). The lowest Renkonen index, i.e. the lowest similarity appeared in the com-

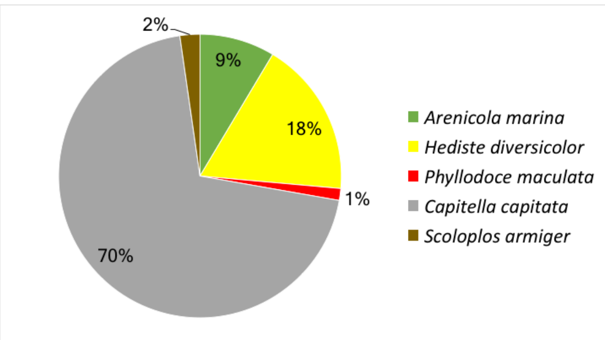

Fig. 3. Dominance (relative abundance) of the polychaete species composition of the mixed sediment mudflat habitat. In total five species were found. Capitella capitata is with 70 % an eudominant species, while Hediste diversicolor (18 %) is categorised as a dominant species. Arenicola marina (9 %) is categorised as a subdominant species. Scoloplos armiger (2 %) and Phyllodoce maculata (1 %) are receding species.

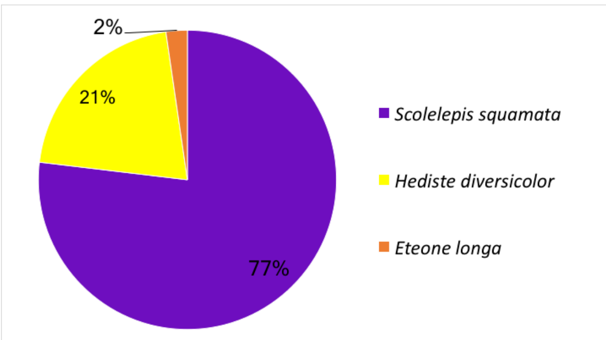

Fig. 4. Dominance (relative abundance) of the polychaete species composition of the sand flat habitat. In total three species were found. Scolelepis squamata is with 77 % an eudominant occurring species, while Hediste diversicolor (21 %) is categorised as a dominant species. Eteone longa (2 %) is a receding species.

parison of the sand flats to the mixed sediment mudflats with a value of about ca. 0.19. For the comparison of the sand flats to the mudflats, the Renkonen index was about 0.23, therefore higher than the previous one. The highest Renkonen index of all three was when the mixed sediment mudflats were compared to the mudflats, about 0.28 (Table 5). The highest score than can be reached with the Renkonen index would be 1 and shows a 100% similarity.

Discussion

According to our dataset, it is obvious that all three habitats only slightly overlapped in their composition of polychaete species. For instance, *Hediste diversicolor* was the only species present in all three habitats whereas species like *Scolelepis squamata* or *Capitella capitata* could only be found in one habitat, respectively (Fig. 3, 4, 5). Additionally, the overall amount of polychaetes species found was differing. For example, in the mixed sediment mudflat, five species were identified whereas in the sand flat only three species were found (Fig. 3, 4, 5).

Every habitat had a eudominant species, e.g. *Hediste diversicolor* in the mudflats. They represented about 70% of all individuals. However, there were several species that were present in a dominant or even receding way (Table 1, 2 and 3). Thus, it can be assumed that one species dominates in one habitat whereas the others were relatively small in number. On the other hand, we did not find any sporadic species whose relative abundance would have been less than 0.32%. But this might be due to our low number of samples and the generally low number of species found with our collection method. It is also quite interesting that we did not find any other predators than *H. diversicolor*, e.g. *Nephthys hombergii* which is one prominent polychaete predator in tidal flats (Gehrmann, 2011; Beukema, 1987). In general, it can be assumed that all three habitats differed in their eudominant species and also in their number of identified species.

Regarding the diversity, it should be noted that the Shannon-Weaver indices for each habitat (Table 4) are relatively low in comparison to the results of e.g. Neumann et al. (2009). This study compared the diversity of epifauna in four habitats and the Shannon-Weaver indices varied from approximately 2 to 3 which is several times higher than what we calculated based on our dataset. The standard deviations for each index are quite high as well. Therefore, it is adamant that our findings should be revised and verified by another group of researchers. It is also possible that our limitation (in time, means and samples) is affecting our measure of diversity on a larger scale than we originally expected. For instance,

Table 2. Abundance [individuals per 10 litres soil] and relative abundance of the polychaete species composition of the mixed sediment mudflat habitat.

Species	Abundance [per 10 litres soil]	Relative abundance [%]
Arenicola marina	30 ± 1	9
Capitella capitata	246 ± 25	70
Hediste diversicolor	63 ± 3	18
Phyllodoce maculata	5 ± 1	1
Scoloplos armiger	8 ± 3	2

Table 3. Abundance [individuals per 10 litres soil] and relative abundance of the polychaete species composition of the sand flat habitat.

Species	Abundance [per 10 litres soil]	Relative abundance [%]
Eteone longa	2 ± 1	2
Hediste diversicolor	20 ± 4	21
Scolelepis squamata	63 ± 1	77

some polychaete species like *Nephtys hombergii* were not found in any sample although this predator is quite abundant (Gehrmann, 2011; Hartmann-Schröder, 1996).

To compare the similarity between all three habitats and to make a statement about whether the different particle sizes have an effect of the distribution of polychaete species, we calculated the Renkonen indices in order to show the congruence between two habitats at once. First of all, we compared the sand flats to the mixed sediment mudflats. Only by considering the species that are present in each habitat, it is obvious that these two habitats are quite dissimilar. This is shown by a Renkonen index of about 0.19 which means that these two habitats overlap in their species distribution only for about 20% (Table 5). The only species present in both habitats is *H. diversicolor*. A similar Renkonen index was calculated when comparing the sand flats to the mudflats. Here, the index is 0.23 which is still very small (Table 5). However, these two habitats are a little bit more similar to each other than the previous two. The highest Renkonen index was reached when comparing the mudflats with the mixed sediment mudflats. Here, the index is 0.28 which is small as well. In general, the Renkonen indices are quite small meaning that all three habitats show small similarity in their species distribution. Therefore, they are distinct from each other and we can assume that the habitat characteristics, especially the particle size, have an effect on the distribution of polychaete species. The particle size correlates with a lot of other characteristics, e.g. the amount of water accessible, the diversity of species, the general biomass and the abundance of species (McLachlan, 1996). Thus, it is not that unlikely that our three different habitats show distinct distribution of polychaete species due to their substrate characteristics.

Table 4. Shannon-Weaver diversity index (Hs) of the three polychaete communities of the differing habitats. The index value ranges from 0 to 4 as follows: high = Hs > 4, good = 3 < HS ≤ 4, moderate = 2 < HS ≤ 3, poor = 1 < HS ≤ 2, bad = HS ≤ 1.

Habitat type	H_s
mudflat habitat	0.91 ± 0.79
mixed sediment mudflat	1.29 ± 0.51
sand flat	0.56 ± 0.47

However, we analysed our data statistically to show whether these differences are significant enough to pose such assumptions. We used a Kruskal-Wallis test to show the significance of the differences between the three habitats. Unfortunately, the significance value, or p-value, was higher than what is normally accepted to be significant. Mostly, a p-value of about 0.05 is quite common to show significance for a dataset. For our dataset, we used the absolute numbers of individuals present in all three habitats, respectively, and calculated a p-value of about 0.2. Hence, the differences that we showed using the Renkonen indices are not reliable or significant to deduce statements about the variety of polychaete communities. Therefore, we cannot confirm our hypothesis that polychaete communities vary according to the substrate that they live on.

Additionally, we may have missed some individuals by using the described extraction methods (see materials and methods) because they were too small and got entangled in the sieve (see also Gage, et al., 2002).Therefore, the total number of individuals per species might be a lot bigger.

In general, our dataset showed that we could identify different dominant species for our three habitats. We identified seven species which differed in their abundance and distribution according to the habitats. Therefore, we can qualitatively assume that mudflats, mixed sediment mudflats and sand flats vary in their composition of polychaete communities. To verify these findings statistically, more wide-spread studies have to be made that include more samples for each habitat.

Table 5. Similarity of the three polychaete communities of the differing habitats according to the Renkonen similarity index (P). The index ranges from 0 (no mutual species in both habitats) to 1 (same species composition in both habitats).

Compared habitat types	P
mudflat habitat - mixed sediment mudflat	0.28
mudflat habitat – sand flat	0.23
mixed sediment mudflat - sand flat	0.19

Literature cited

Beukema, J.J. (1987): Influence of the predatory polychaete *Nephtys hombergii* on the abundance of other polychaetes. Marine Ecology Progress Series, 40: 95-101.

Buchsbaum, R. (1987): Animals Without Backbones, 3rd ed. Univ. of Chicago Press, Chicago.

Chao, A., & Shen, T. J. (2003): Nonparametric estimation of Shannon's index of diversity when there are unseen species in sample. Environmental and ecological statistics, 10(4): 429-443.

Dean, H.K. (2008): The use of polychaetes (Annelida) as indicator species of marine pollution: a review. Revista de Biologia Tropical, 56: 11-38.

Engelmann, H. D. (1978): Zur Dominanzklassifizierung von Bodenarthropoden. Pedobiologia.

Gage, J.D.; Hughes, D.J.; Gonzalez Vecino, J.L.: Sieve size influence in estimating biomass, abundance and diversity in samples of deep-sea macrobenthos. Marine Ecology Progress Series, 225: 97–107.

Gehrmann, S. (2011): Stamm Annelida – Ringelwürmer, in: Die Fauna der Nordsee – Niedere Tiere & Wirbeltiere. ePubli GmbH, 122-134.

Hartmann-Schröder, G. (1996): Allgemeiner Teil, in: Annelida, Borstenwürmer, Polychaeta, 11-23, Jena: Gustav Fischer Verlag.

Hartmann-Schröder, G. (1996): Gattung *Nephtys*, in: Die Tierwelt Deutschlands – Annelida, Borstenwürmer, Polychaeten. 217-232, Jena: Gustav Fischer Verlag.

Hübner, G. (2007). Ökologisch-faunistische Fließgewässerbewertung am Beispiel der salzbelasteten unteren Werra und ausgewählter Zuflüsse. Kassel University Press GmbH, 27: 103.

Ingole, B. (2005): Indian Ocean Coasts, Coastal Ecology, in: Encyclopedia of Coastal Science (ed. M, Schwartz), 546-554, Berlin: Springer Verlag.

McLachlan, A. (1996): Physical factors in benthic ecology: effects of changing sand particle size on beach fauna. Marine Ecology Progress Series, 131: 205-217.

Mühlenberg, M. (1993): „Freilandökologie"; 3. Aufl., UTB, 344 – 345.

Neumann, H; Reiss, H; Rakers, S; Ehrich, S; Kröncke, I: Temporal variability in southern North Sea epifauna communities after the cold winter of 1995/1996. ICES Journal of Marine Science, 1-11.

Reise, K. (1985): Introduction, in: Tidal Flat Ecology: An Experimental Approach to Species Interactions, 1-5, Berlin: Springer Verlag.

Reise, K. (1985): The Tidal Flats of Königshafen, in: Tidal Flat Ecology: An Experimental Approach to Species Interactions, 35-53, Berlin: Springer Verlag,.

Reise, K. (1985): Tides, Sediments and the Distribution of Organisms, in: Tidal Flat Ecology An Experimental Approach to Species Interactions, 9-16, Berlin: Springer Verlag.

Reise, K.; Herre, E.; Sturm, M. (1994): Biomass and abundance of macrofauna in intertidal sediments of Königshafen in the northern Wadden Sea. Helgoländer Meeresuntersuchungen, 48(2): 201-215.

Samuelson, G.M. (2001): Polychaetes as Indicators of Environmental Disturbance on Subarctic Tidal Flats, Iqaluit, Baffin Island, Nunavut Territory. Marine Pollution Bulletin, 42(9): 733-741.

Seda, J., & Devetter, M. (2000): Zooplankton community structure along a trophic gradient in a canyon-shaped dam reservoir. Journal of Plankton Research, 22(10): 1829-1840.

Semeniuk, V. (2005): Tidal Flats, in: Encyclopedia of Coastal Science (ed. M. Schwartz, RW. Fairbridge, M. Rampino), 965-975, Berlin: Springer Verlag.

Shannon, C. E., & Weaver, W. (1967): The Mathematical Theory of Communication by Claude E. Shannon and Warren Weaver. University of Ill. Press.

Zettler, M. L.; Schiedek, D.; Bobertz, B. (2007): Benthic biodiversity indices versus salinity gradient in the southern Baltic Sea. Marine Pollution Bulletin, 55(1): 258-270.