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The phytal fauna of the SW Baltic Sea and its importance as reservoir for fish prey

Die Phytalfauna der SW-Ostsee und ihre Bedeutung als Reservoir von Fischnahrung

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Summary: The phytal fauna of the SW Baltic was investigated at three localities of the German coast: Flensburg fjord (Kiel Bight), Dahmeshöved (Lübeck Bight) and Salzhaff (NW Mecklenburg). The samples comprised five algae species (*Fucus vesiculosus, Ceramium* sp., *Enteromorpha* sp., *Ectocarpus* sp., *Chorda* sp.), two spermatophytes (*Zostera marina, Zannichellia palustris*) and animal aufwuchs by *Mytilus edulis*. Additionally, succession experiments were performed in the *Mytilus* and *Ceramium* belts of Dahmeshöved. The investigations were focused on the organisms living between the substrate and their possible exploitation by fish. Therefore, the question arose what substrate is best suited to be colonized by "invertebrates". At all three localities highest biomass was found in the *Ectocarpus* belt in late spring, in *Ceramium*, *Enteromorpha* and *Mytilus* belts in summer. The *Zostera* belts presented highest values in spring, whereas *Fucus* and *Zannichellia* belts attained relatively low values. Production of fish prey animals was highest in *Enteromorpha* belts followed by *Ceramium* and *Mytilus* belts. *F. vesiculosus* attained low values in Flensburg fjord but clearly higher values in Salzhaff. The index of settlement which expresses the utilization of the substrate by fish prey organisms was highest in *Enteromorpha* belts, followed by *Ceramium*, *Fucus* and *Zostera* belts from Salzhaff. At the end of succession areas biomass of *Mytilus* and *Ceramium* belts was lower than in the control areas but taxa numbers were higher. In these experiments the *Mytilus* belt attained slightly higher biomass values than the *Ceramium* belt. The *Enteromorpha* and *Ceramium* belts proved to be especially suited reservoirs for fish prey organisms.

Key words: SW Baltic, marine aufwuchs, phytal fauna, succession, fish prey reservoir,

Zusammenfassung: Die Aufwuchsfauna an der deutschen Ostseeküste wurde an drei Standorten untersucht: Flensburger Förde (Kieler Bucht), Dahmeshöved (Lübecker Bucht) und im Salzhaff (NW-Mecklenburg). Die Proben umfassten fünf Algenarten (*Fucus vesiculosus, Ceramium* sp., *Enteromorpha* sp., *Ectocarpus* sp., *Chorda* sp.), zwei Spermatophyten (*Zostera marina, Zannichellia palustris*) und tierischen Aufwuchs von *Mytilus edulis*. Ferner wurden Sukzessionsexperimente in den *Ceramium*- und *Mytilus*-Gürteln von Dahmeshöved durchgeführt. Die Untersuchungen konzentrierten sich auf die zwischen den Substraten lebenden „Evertebraten" und deren mögliche Bedeutung als Nahrung für Fische. Daher erhob sich die Frage nach dem am besten geeigneten Substrat für die Besiedlung durch „Wirbellose". An allen drei Probestellen wurde die höchste Biomasse im Frühjahr im *Ectocarpus*-Gürtel, im Sommer in den *Ceramium*-, *Enteromorpha*- and *Mytilus*-Gürteln gefunden. Die *Zostera*-Gürtel wiesen ihre höchste Biomasse im Frühjahr auf, die *Fucus*- and *Zannichellia*-Gürtel wiesen relativ niedrige Werte auf. Die Produktion von Fischnährtieren war am höchsten im *Enteromorpha*-Gürtel, es folgten die *Ceramium*- und *Mytilus*- Gürtel. Der *Fucus*-Gürtel vom Flensburg-Fjord erreichte nur niedrige Werte, diese waren im Salzhaff deutlich höher. Der Besiedlungsindex, der die Ausnutzung des Substrats durch Fischnährtiere ausdrückt, war in *Enteromorpha*-Gürteln am höchsten, gefolgt von den *Ceramium*-, *Fucus*- und, im Salzhaff, von *Zostera*-Gürteln. Am Ende der Sukzessionsexperimente war die Biomasse der *Mytilus*- und *Ceramium*-Gürtel kleiner als die der Kontrollen, allerdings waren die Taxazahlen höher. Dabei erzielte der Muschelgürtel etwas höhere Werte als der Rotalgengürtel. Als besonders geeignete Vorratsspeicher für Fischnahrung erwiesen sich die *Enteromorpha*- und *Ceramium*-Gürtel.

Schlüsselwörter: SW Ostsee, mariner Aufwuchs, Phytalfauna, Sukzession, Reservoir für Fischnahrung

Introduction

The Baltic Sea is the greatest brackish water system in Europe. In contrast to other seas it does not present constant values of lowered salinities but begins in the West from Skagerrak and Kattegat with a marine milieu and continues with slowly decreasing values until fresh water in the Bothnian and Finnish Bays in the North and East. Wind and storms may raise or lower, depending to its direction, the prevailing salinity of the respective locality. The SW Baltic is characterized by salinities of 20 ‰ in Kiel Bight decreasing to 10 ‰ in Mecklenburg Bight (Jansson 1972).

Regarding the faunas of North and Baltic Sea, Remane (1940) created beside the habitats of pelagial and benthal as third category the phytal which regards the floral and faunal epibenthos as a suited substrate for invertebrate communities. This substrate is not only restricted to macroalgae and eelgrass but also consists of colonies of sessile animals such as hydrozoans, bryozoans, mussels or tunicates, thus creating a three-dimensional habitat. In particular, mussel belts (*Mytilus edulis*) can create diverse and specimen rich communities with high biomass and productivity (Kautsky 1981, Zander & Hagemann 1986, 1987, Zander 1991). These studies revealed high biomass and productivity values of invertebrate and algal communities. The genuine phytal is founded on algae and spermatophytes. Especially the belts of *Fucus vesiculosus* (Hagermann 1966, Jansson & Wulff 1977, Anders & Möller 1983), *Cladophora* sp. (Jansson & Kautsky 1977), *Ceramium* sp. (Kautsky 1974, Lüthje 1978) and *Zostera* sp. (Gründel 1982) were formerly investigated. Algae and *M. edulis* exist generally on hard substrate whereas *Zostera* sp. grows on soft bottoms. One can differentiate between leaf-shaped, ramose and button-like phytal organisms (Remane 1940) of which the ramose form, e.g. *Ceramium* sp., seems to harbor the most organisms: as much as 275 g/m² (Lüthje 1978).

The existence of *M. edulis* ceases in the Baltic Sea at salinities of about 5 ‰ in the Bothnian and Finnish Bays, *Fucus vesiculosus* even tolerates 4 ‰ (Jansson 1972). An extreme increase of planktonic and delicate benthic algae appeared in the last decades of the 20th century which was caused by eutrophication (Schwenke 1996). Additionally, the conditions for the existence of macroalgae became disadvantageous by decreasing visibility due to turbidness and oxygen deficiency due to extreme bacterial destruction. As consequence, especially the *Fucus* spp., *Zostera marina* and *Pomatogeton* spp. stocks of the Baltic Sea were reduced or disappeared, whereas in the same time the stocks of *Pilayella littoralis, Ectocarpus siliculosus* and *Ceramium* spp increased enormously (Schramm 1996). Eutrophication promoted also mussels and other epiphyton which settle on the plants and can damage them. This study is focused on the faunas of diverse algae (*Ceramium* sp., *Enteromorpha* sp., *Ectocarpus* sp., *Chorda* sp. and *Fucus vesiculosus*), spermatophytes (*Zostera marina, Zannichellia palustris*) and *Mytilus edulis* belts in the SW Baltic, their efficiency and function as reservoir for "invertebrates" of which several may be prey for fish. Therefore, the biomass, production and ecological efficiency (below: index of settlement) of these organisms, both substrate as well as colonists were investigated. Following this path, differences between these organisms will be pursued and compared. Additionally, identical substrates from three localities of the SW Baltic Sea with diverging salinities were compared and the causes of their differences analyzed. Finally, the importance of the investigated belts as reservoir for fish prey will be discussed.

2. Material and methods

The investigations were performed in three localities along the German coast at the SW Baltic Sea: Salzhaff near Wismar, West Mecklenburg, Dahmeshöved near Neustadt, Lübeck Bight, and Bockholmwik, Flensburg fjord near Glücksburg (fig. 1). Samples were collected monthly or bimonthly between spring and autumn in 1988, 1990, 1992 and 1994 in Dahmeshöved, 1999 and 2000 in Flensburg fjord, and 2000 in Salzhaff.

The primary bottoms were rock, boulders, pebbles or, in the case of eelgrass belts, sand. Several algae belts were investigated like *Fucus vesiculosus, Ceramium* sp. , *Enteromorpha* sp., *Ectocarpus* sp. and *Chorda* sp., spermatophytes like *Zostera marina* and *Zannichellia palustris* and the animal aufwuchs of *Mytilus edulis*. In order to get quantitative samples immediately at the shore a measuring frame with a round opening of 0.125 m² or a measuring rope was laid out on the bottoms. In this area the plants or mussels were detached from the ground by the help of a spatula and transferred to a PVC bottle. In other cases a bottle was tilted several times over the sample area where the epiphyton was scraped off within its opening and immediately collected in plastic bags or bottles. The samples in deeper water were obtained by scuba diving with the same tools. The samples were assorted to relevant taxa (very often to species), counted, dried at 60 °C and weighed to the nearest 10 µg. Shell bearing organisms were dried ash-free at 510 °C. Biomass was calculated of an area of 1 m².

Succession experiments were performed by scraping the total epiphyton off of an area of 1 m² within a greater stock of *Ceramium* sp. or *M. edulis*, respectively.

Production was calculated as minimum production (Kirkegard 1978) in which the difference of the lowest and the largest biomass value during the course of the year was used.

An Index of Settlement (IoS) was calculated as "component (g)/Substrat (g) x 100 (%)". It was used for the evaluation of the capability and usability, i.e. the ecological efficiency of the respective substrate for colonization. As statistical mean the homogeneity test (χ^2-test) was used. The t-test was calculated regarding succession experiments.

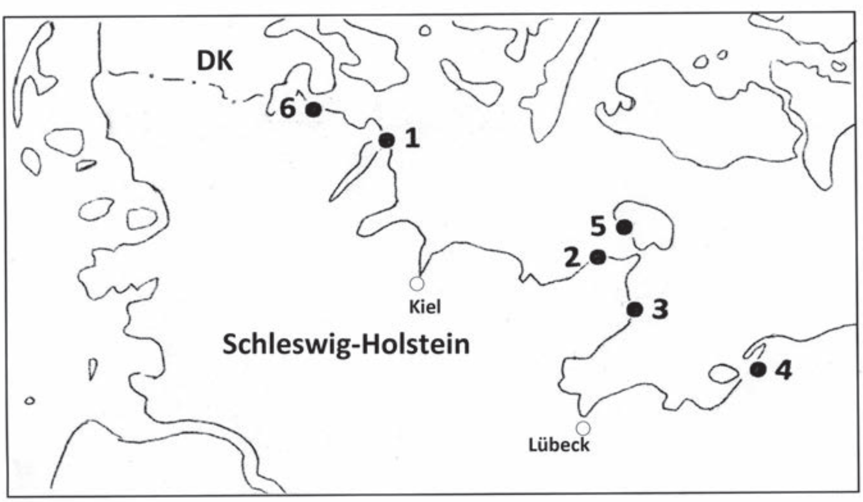

Fig. 1: Map of northern Germany with six locations of investigation. Samples derived from Flensburg fjord (6), Dahmeshöved (3) and Salzhaff (4). Phytobenthos was sampled also in Schlei (1), Westfehmarn (5) and Blank Eck (2) but not regarded in this study (from Zander 2009).

Abb. 1: Karte von Norddeutschland mit sechs Untersuchungsstellen. Proben stammen aus dem Flensburg-Fjord (6), Dahmeshöved (3) und dem Salzhaff (4). Aufwuchs wurde auch in der Schlei (1), Westfehmarn (5) und Blank Eck (2) gesammelt, aber hier nicht berücksichtigt (aus Zander 2009).

3. Results

3.1. Dahmeshöved

The investigations were performed monthly from spring to autumn.

3.1.1. *Mytilus* belt

Total biomass started with 137 g/m² in May 1990 and peaked in July by 185 g/m² but decreases to 123 g/m² in November (tab. 1). The biomass values of *Mytilus edulis* dominated clearly over that of other organisms and attain often two magnitudes higher values than these together. Among other organisms, *Balanus improvisus* were by far the most important taxon followed by Gastropoda on a low level and *Jaera albifrons* which is an object of fish prey (fig. 2). The latter taxon was most abundant in July whereas Gastropoda attained maximal values in October. Isopods played only a minor role.

The succession experiments of the *Mytilus* belt in 1988 revealed that biomass of the succession area did by far not attain that of the control area (tab. 1). Whereas the latter varied between 954 g/m² in early spring to 541 g/m² in autumn, the recovering of the succession area began in April/ May with very low values (2 g/m²), attained maximal values of 155 g/m² in August and decreased thereafter (tab. 1). In both, the control and the succession area, *M. edulis* dominated over all other organisms. During the course of the year the portion of other organism clearly differed in the two investigation samples. The Gastropoda and the crustaceans *Balanus improvisus* and Gammarida made up the greatest part in the control area, in the succession fauna at first Gastropoda and thereafter Hydrozoa were conspicuously abundant but were replaced in June again by Gastropoda (fig. 3). Not earlier than July as an equivalent of Gastropoda Gammarida and sometimes *Idotea* spp.(July) were found. In contrast to the control area *Balanus* sp. was of less importance in the succession fauna. Remarkably, Hydrozoa were very abundant in the succession area in May.

Tab. 1: Taxa numbers and total biomass of mussel belts of the years 1988 and 1990 in the locality Dahmeshöved and comparison of a control (C) and a succession (S) area.

Tab. 1: Artenzahlen und totale Biomasse der Muschelgürtel der Jahre 1988 und 1990 in Dahmeshöved und Vergleich mit einer Kontroll- (C) und Sukzessionsfläche (S).

Mussel belt 1990	**May**	**July**	**Sept.**	**Oct.**	**Nov.**
Taxa numbers	7	7	6	5	5
Total biomass (g/m²)	136,63	185,23	174,37	151,55	123,68
Mytilus edulis	129,58	177,31	169,52	147,09	119,83
Others	7,05	7,92	4,85	4,46	3,85

Mussel belt 1988	**March** C	**April** C	**April** S	**May** C	**May** S	**June** C	**June** S	**July** C	**July** S	**August** C	**August** S	**September** C	**September** S	**November** C	**November** S
Taxa numbers	18	21	11	23	16	26	17	23	23	20	25	21	22	21	21
Total biomass (g/m²)	954,16	606,84	2,11	718,81	7,16	893,53	47,61	707,48	127,09	1114,19	155,34	462,98	88,11	541,69	133,66
Algae	0,41	1,35	0,7	2,61	0,11	0,76	23,12	1,95	79,08	0,32	18,67	1,06	2,2	10,02	5,91
Mytilus edulis	952,24	595,12	1,25	684,08	3,03	773,63	5,12	689,26	42,96	901,83	126,55	442,74	77,38	508,09	113,04
Other	1,51	10,37	0,16	32.12	4,02	119,14	19,37	16,27	5,05	212.04	10,16	19,18	8,53	23,58	14,71

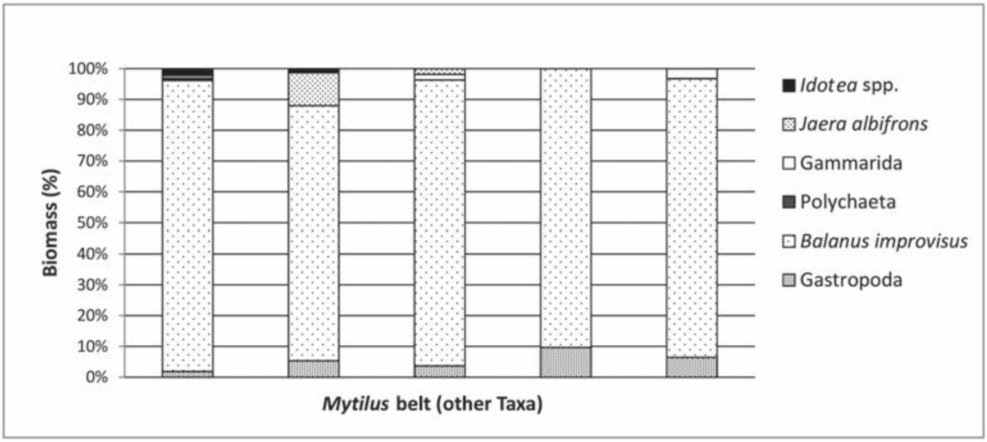

Fig. 2: Biomass of "invertebrates" without common mussels (%) in the *Mytilus* belt of Dahmeshöved during 1990. In this as in the following figures gammarids are marked in white, *Idothea* spp. in black.
Abb. 2: Biomasse von „Wirbellosen" (%) ohne Miesmuscheln im *Mytilus*-Gürtel von Dahmeshöved im Jahr 1990. Hier und in den folgenden Abbildungen sind die Gammariden weiß und die *Idothea* spp. schwarz hervorgehoben.

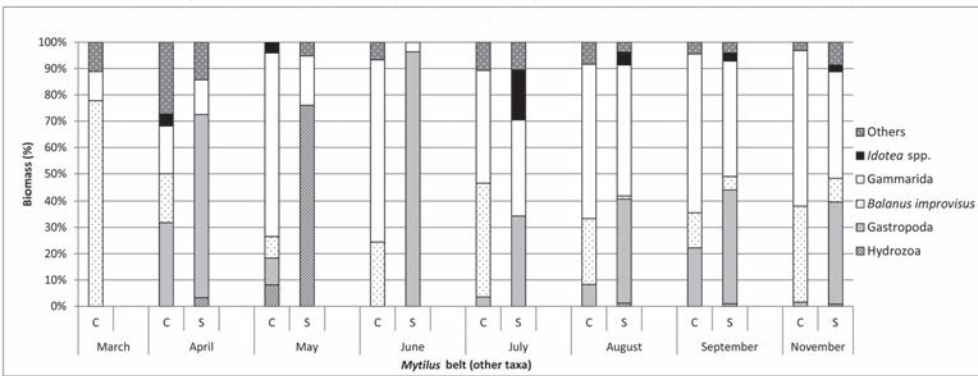

Fig. 3: Biomass of "invertebrates" without common mussels (%) in the *Mytilus* belt of Dahmeshöved during 1988. C = control area, S = succession area.
Abb. 3: Biomasse von „Wirbellosen" (%) ohne Miesmuscheln im *Mytilus*-Gürtel von Dahmeshöved im Jahr 1988. C = Kontrollfläche, S = Sukzessionsfläche.

The varying values of biomass during the investigation period of 1992 and 1994 proved to be significantly different ($p < 0.1$ %), but were homogeneous if mussels were disregarded. This is also valid for the control area. The comparison of control and succession area proved to be not significant.

3.1.2. *Ceramium* belt

The first investigation of the *Ceramium* belt was performed in 1992. Biomass of the fauna attained in June as much as 195 g/m² (tab. 2) of which *Mytilus edulis* attained 60-95 % (fig. 4). The next important components were Gammarida (3-22 %) and *Idotea* spp. (1-17 %). The values in the course of the investigation period were not homogeneous ($p < 0.1$ %) that means a wide range of variation.

During studies in 1994 which comprised several algae the *Ceramium* belt proved to be similar to the biomass values of the *Mytilus* belt and peaked in August 1994 with 116 g/m² (tab. 2). The biomass of mussels attained maximal values in August but was generally lower than in the

Tab. 2: Taxa numbers and total biomass of *Ceramium* belts of the years 1992, 1994 and 1997 in the locality Dahmeshöved and comparison of a control (C) and a succession (S) area.

Tab. 2: Artenzahlen und totale Biomasse des *Ceramium*-Gürtels in den Jahren 1992, 1994 und 1997 in Dahmeshöved und Vergleich mit einem Kontroll- (C) und Sukzessionsgebiet (S).

***Ceramium* belt 1992**	**May**	**June**	**July**	**August**	**September**
Taxa numbers	12	11	15	9	10
Algae biomass (g/m²)	447,39	275,08	124,56	22,16	188,62
Phyton biomass (g/m²)	51,46	195,03	170,45	88,31	19,66
Mytilus edulis	47,16	185,51	116,9	63,69	12,35
Others	4,3	9,52	53,55	24,62	7,31

***Ceramium* belt 1994**	**June**	**July**	**August**	**September**	**October**	**November**
Taxa numbers	3	4	5	13	9	7
Algae biomass (g/m²)	62,87	66,11	139,04	95,16	135,25	128,52
Phyton biomass (g/m²)	20,18	42,21	116,46	82,19	62,44	30,85
Mytilus edulis	19,37	34,09	94,56	45,06	55,26	25,43
Others	1,81	8,12	19,9	37,13	7,18	5,42

***Ceramium* belt 1997**	**May**	**June**		**July**		**August**		**September**		**October**	
Kind of sample	**C**	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**S**
Taxa numbers	17	15	9	22	18	26	19	27	28	**32**	30
Algae biomass (g/m²)	145,53	222,43	9,27	854	139	99,1	122,08	458,13	188,03	183,26	80,14
Phyton biomass (g/m²)	10,23	41,32	0,26	58,86	16,32	47,2	18,67	153,49	75,22	179,45	112,32
Mytilus edulis	7,95	38,04	0,1	55,3	5,27	44,21	8,87	120,96	53,15	160,73	93,22
Other	2,28	3,28	0,16	3,56	11,05	2,99	9,78	32,53	22,07	18,72	19,10

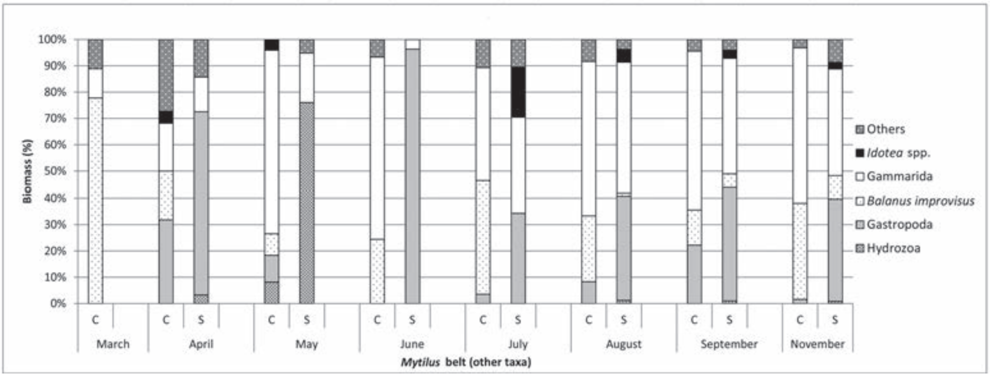

Fig. 3: Biomass of "invertebrates" without common mussels (%) in the *Mytilus* belt of Dahmeshöved during 1988. C = control area, S = succession area
Abb. 3: Biomasse von „Wirbellosen" (%) ohne Miesmuscheln im *Mytilus*-Gürtel von Dahmeshöved im Jahr 1988. C = Kontrollfläche, S = Sukzessionsfläche.

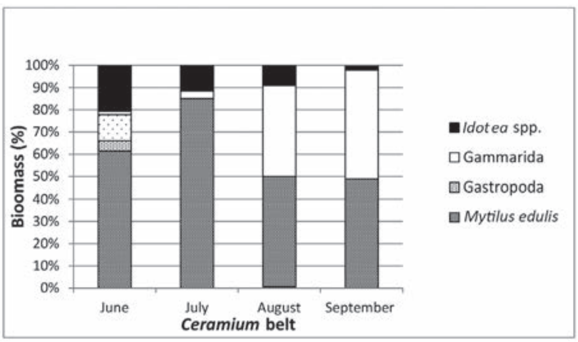

Fig. 4: Biomass of "invertebrates" (%) in the *Ceramium* belt of Dahmeshöved during 1988.
Abb. 4: Biomasse von „Wirbellosen" (%) im *Ceramium*-Gürtel von Dahmeshöved im Jahr 1988.

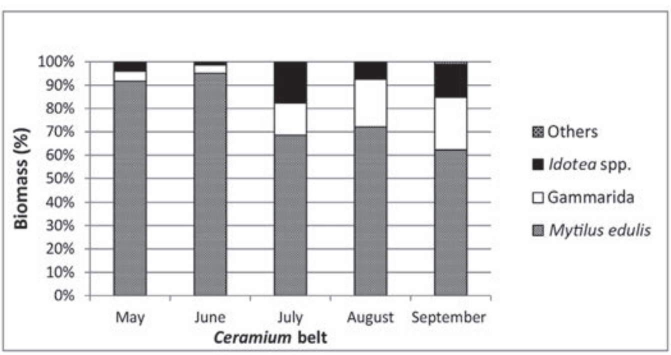

Fig. 5: Biomass of "invertebrates" (%) in the *Ceramium* belt of Dahmeshöved during 1994.
Abb. 5: Biomasse von Wirbellosen (%) im *Ceramium*-Gürtel von Dahmeshöved im Jahr 1994.

Mytilus belt, with 19 g/m² in June and 94 g/m² in August (tab. 2). The other organisms attained highest biomass in September. In August they attained 20 g/m² but were lower in the other months. The most abundant other organisms were *Gammarus* spp. and *Idotea* spp. which both are important prey for fish (fig. 5).

Ceramium sp. biomass dominated in the experiments during 1997 in the control as well succession area and was completed to a lesser part by *M. edulis*. The category 'other organisms' was rather higher in the succession than in the control area (tab. 2). Biomass values increased from May or June until September but decreased in October. Maximal values of the control fauna attained 179 g/m² in October when the values of the succession fauna raised only unto 112 g/m² (tab. 2). The other fauna was similar in both areas and consisted mainly of *Idotea* spp. in June and of Gammarida thereafter. In August Gastropoda appeared in the succession area and dominated in October, in September and October also in the control fauna (fig. 6). Hydrozoa appeared in spring in the succession area such as in the *Mytilus* belt (fig. 3).

The biomass values varied strongly during the investigation time and were, therefore, not homogeneous ($p < 0.1$ %). The comparison of the control and succession proved to be significant of a lower level than 5 %.

3.1.3. Enteromorpha belt

Biomass was below 7 g/m² in June and July but higher in August (more than 130 g/m²) and September 1994 (30 g/m²) (tab. 3). The most abundant fauna were mussels which dominated in June and July and decreased thereafter to 50 % (fig. 7). In June the part of *Idotea* spp. attained 25 %, but they were compensated by *Gammarus* spp. which increased in higher numbers until September up to 50 % of total biomass.

3.1.4. Ectocarpus belt

Biomass of this alga was highest in June (more than 200 g/m²), but low in July and August with 25 g/m² (tab. 3). Mussels dominated in June and August, but were present by only 40 % of the total biomass in July (fig. 7). Whereas *Idotea* spp. appeared only in July, Gammarida became conspicuous in July and August.

3.1.5. Chorda belt

The community of this alga was only investigated in May 1992 and presented biomass values of only 45 g/ m² (tab. 3). Such as in other communities, *Mytilus edulis* dominated but also the isopod *Jaera* albifrons attained 25 % of biomass (fig. 7).

Tab. 3: Taxa numbers and total biomass of Enteromorpha, Ectocarpus, Chorda and Zostera belts in 1992 in the locality Dahmeshöved.
Tab. 3: Artenzahlen und totale Biomasse der Enteromorpha-, Ectocarpus-, Chorda- und Zostera-Gürtel im Jahr 1992 in Dahmeshöved.

	***Enteromorpha* belt**				***Ectocarpus* belt**			***Chorda* belt**	***Zostera* belt**				
	June	**July**	**August**	**September**	**June**	**July**	**August**	**May**	**May**	**June**	**July**	**August**	**September**
Taxa numbers	6	4	9	5	10	14	12	14	12	9	7	8	7
Algae biomass (g/m²)	172,55	163,63	29,39	108,19	233,31	117	28,48	388.25	606,46	592,8	463,9	621,03	700,09
Phyton biomass (g/m²)	7,46	4,09	138,83	29,34	217,7	24,47	25,74	45,53	92,98	44,53	20,48	18,31	27,9
Mytilus edulis	5,2	3,48	68,91	14,38	210,68	9,39	9,87	30,55	86,8	41,73	16,34	13	15,38
Gammarus spp.	0,12	0,14	57,05	14,38	3,39	9,27	5,26	0,53	0,85	0,12	0,59	0,5	0,07
Idothea balthica	1,75	0,47	12,58	0,58	2,97	4,9	6,8	0,37	0,81	0,3	3,43	3,51	6,55
Others	0,39	0	0,29	0	0,66	0,91	3,81	14,08 *	4,52	2,38	0,12	1,3	5,9

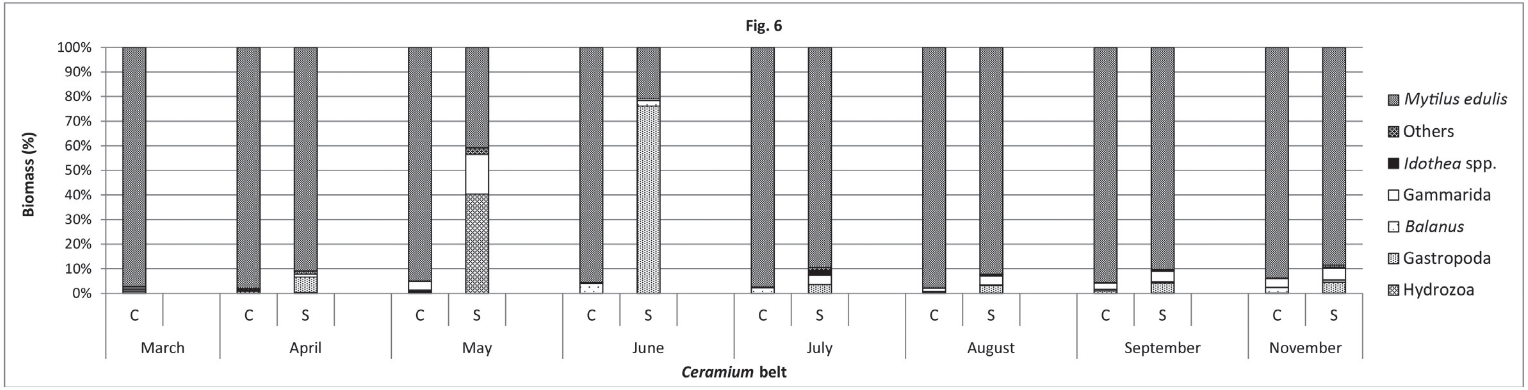

Fig. 6: Biomass of "invertebrates" (%) in the *Ceramium*-belt of Dahmeshöved during 1997. C = control area, S = succession area.
Abb. 6: Biomasse von „Wirbellosen" (%) im *Ceramium*-Gürtel von Dahmeshöved im Jahr 1997. C = Kontrollfläche, S = Sukzessionsfläche.

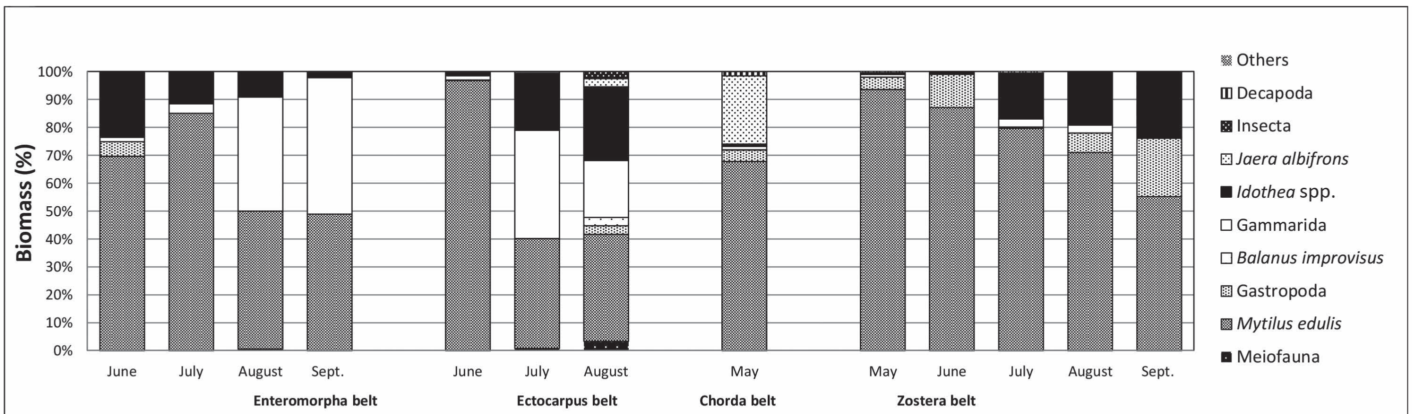

Fig. 7: Biomass of "invertebrates" (%) in the *Enteromorpha, Ectocarpus*, *Chorda* and *Zostera*belts of Dahmeshöved during 1992.
Abb. 7: Biomasse von „Wirbellosen" (%) im *Enteromorpha-, Ectocarpus*-, *Chorda*- and *Zostera*-Gürtel von Dahmeshöved im Jahre 1992.

3.1.6. *Zostera* belt

Biomass values ranged from 92 g/m² in May to 18 g/m² in August and increased again to almost 30 g/m² in September 1994 (tab. 4). Also biomass portions of *Mytilus edulis* decreased from more than 90 % to less than 60 % during the course of the year which was compensated by increasing parts of *Idotea* spp. and *Littorina* spp. (fig. 7). Only in July and August a minor part of Gammarida were present. No homogeneity was found regarding biomass values during the year ($p < 0.1\%$).

The biomass values of *Enteromorpha*, *Ectocarpus* and *Zostera* belts were not homogeneous ($p < 0.1$ %) that means high variability during the investigations time.

3.2. Flensburg fjord

The investigations in the Flensburg fjord were performed bimonthly in 1999 and 2000.

3.2.1. *Fucus* belt

Biomass attained not more than 4 g/m² during the course of the year 1999, in July the lowest value of less than 0.8 g/ m² was found (tab. 4). *Mytilus edulis* was the most abundant component but, regarding biomass, only dominant in September (fig. 8). An important role played also Gastropoda and, until July, Gammarida spp. whereas *Idotea* spp. was only present in July. The appearance of the meiofaunal Harpacticoidea in May and to a less part in March was conspicuous. Two samples which were gained a year later presented higher values of biomass which was caused mainly by an increased colonization of mussels.

3.2.2. *Ceramium* belt

The biomass of colonists increased from less than 0.5 g/m² (March) to almost 14 g/m² in July (tab. 3). *Mytilus edulis* was the most abundant component in March and May, it was substituted in July by other bivalves like *Mya* sp. and *Cerastoderma* sp. (fig. 8). Such as in the *Fucus* belt Harpacticoida (Meiofauna) were of greater importance as were also *Gammarus* spp.and other gammarids. *Idotea* spp. were only present in July as was already found in *Fucus vesiculosus*.

3.2.3. *Zostera* belt

Biomass was highest in March (17 g/m²), decreased in May and July (4 g/m²) and increased again in September onto 11 g/m² (tab. 3). Regarding biomass *Mytilus edulis* was only dominant in September, abundant were *Idotea* spp., Polychaeta and, to a lower extent, Gammarida and other gammarids. In May also Gastropoda and, to a lesser degree, Harpacticoida (Meiofauna) were conspicuous (fig. 8). Insecta (mostly chironomid larvae) and decapods (*Praunus* spp.) were of certain importance.

The *Ceramium* and *Zostera* belts proved to be not homogeneous during the investigation months where variation of biomass was strong ($p < 0.1$ %), whereas the *Fucus* belt varied without significance.

3.3. Salzhaff

3.3.1. *Fucus* belt

The *Fucus* belt of Salzhaff was only investigated two times, in late spring and in summer (fig. 9). Biomass resulted in low values as prevail similarly in Flensburg fjord: 1 g/m² in June and 4.5 g/m² in August (tab. 5). *Mytilus edulis* dominated in spring, but was replaced by *Littorina* spp. in summer. In June the crustaceans *Balanus* spp. ("Others" in fig. 9) and *Palaemon adspersus*, in August *Gammarus* spp. were, additionally, very conspicuous.

3.3.2. *Zostera* belt

This belt was investigated from July to September. Biomass ranged from 2 to 4 g/m² (tab. 5). *Mytilus* dominated in July and August, but decreased to only 10 % in September. This component was substituted by *Hydrobia* spp., *Littorina* spp., several bivalves, gammarids and insects in autumn (fig. 9). These components were already present in lower abundance in the earlier months.

Tab. 4: Taxa numbers and total biomass of *Fucus, Ceramium* and *Zostera* belts in 1999 in the locality Flensburg fjord.
Tab. 4: Artenzahlen und totale Biomasse der *Fucus-, Ceramium-* and *Zostera*-Gürtel im Jahre 1999 im Flensburg-Fjord.

***Fucus* belt**	**March**	**May**	**July**	**Sept.**
Taxa numbers	28	39	35	39
Plant biomass (g/m²)	51	26	30	58
Phyton biomass (g/m²)	1,39	3,78	0,77	2,86
Mytilus edulis	0,65	1,03	0.24	1,96
Littorina spp	0,46	0,97	0,21	0,33
Other molluscs				
Idothea spp.				
Others	0,28	1,78	0.32	0,57

***Ceramium* belt**	**March**	**May**	**July**
Taxa numbers	14	30	25
Plant biomass (g/m²)	233	490	61
Phyton biomass (g/m²)	0,56	9,77	13,7
Mytilus edulis	0,20	4,58	1,76
Littorina spp.			
Other molluscs		1,51	5,68
Idothea spp.			
Others	0,36	3,68	6,26

***Zostera* belt**	**March**	**May**	**July**	**Sept.**
Taxa numbers	35	21	27	24
Plant biomass (g/m²)	185	28	138	376
Phyton biomass (g/m²)	17,2	4,15	4,35	10,88
Mytilus edulis	4,93	0,01	1,16	7,99
Littorina spp.				
Other molluscs				
Idothea spp.	4,47	1,78	1,11	1,24
Others	7,80	2,38	2,08	1,65

Tab. 5: Taxa numbers and total biomass of *Zannichellia, Zostera* and *Fucus* belts in 2001 in Salzhaff.
Tab. 5: Artenzahlen und totale Biomasse der Zannichellia, Zostera und *Fucus*-Gürtel im Jahre 2001 im Salzhaff.

	***Zannichellia* belt**					***Zostera* belt**			***Fucus* belt**	
	May	June	July	August	Sept.	July	August	Sept.	June	August
Taxa numbers	41	33	40	44	41	35	28	37	49	46
Plant biomass (g/m²)	31	71	68	42	35	91	94	76	41,08	115,87
Phyton biomass (g/m²)	8,11	3,63	6,81	3,12	2,53	2,27	3,51	3,99	1,09	4,49
Mytilus edulis	4,47	2,21	0,42	0,80	0,04	1,29	1,08	0,33	0,52	0,56
Gammarida	0,92	0,21	1,42	0,26	0,24	0,21	0,12	0,48	0,03	0,68
Idothea spp.	0,20	0,06	0,46	0,15	0,19	0,11	0,02	0,05	0,11	0,45
Polychaeta	0,90	0,03	0,99	0,06	0,16	0,00	0,04	0,14		
Others	1,26	1,12	3,52	1,85	1,90	0,66	2,25	2,99	0.43	2,8

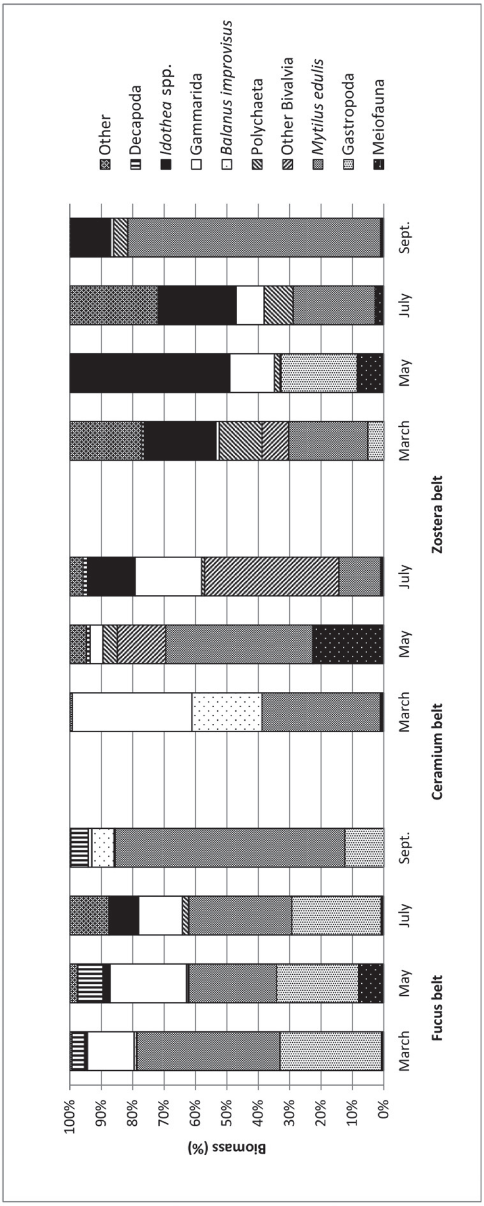

Fig. 8: Biomass (%) of "invertebrates" in the *Fucus*, *Ceramium,* and *Zostera* belt of Flensburg fjord during 1999.
Abb. 8: Biomasse von Wirbellosen (%) im *Fucus*-, *Ceramium*- und *Zostera*-Gürtel vom Flensburg-Fjord im Jahr 1999.

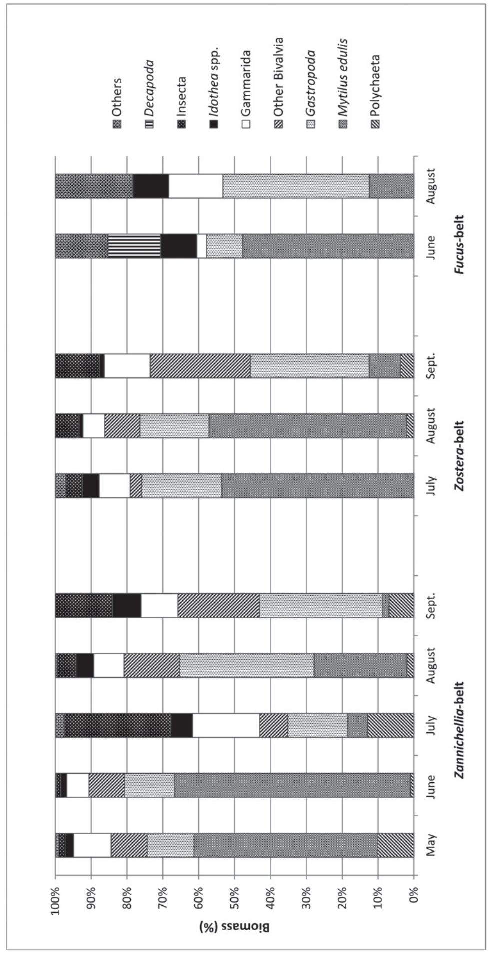

Fig. 9: Biomass of invertebrates (%) in the *Zostera* and *Zannichellia* belt of Salzhaff during 2000.
Abb. 9: Biomasse von „Wirbellosen" (%) im *Zostera*- und *Zannichellia*-Gürtel des Salzhaffs im Jahr 2000.

3.3.3. *Zannichellia* belt

This plant was found monthly from May to September. In May and July biomass was high (7-8 g/ m²), but lower in June, August and September (below 4 g/ m²) (tab. 5). *Mytilus edulis* decreased in *Zannichellia* belt, but decreased in July to August and was without importance in September when these were substituted by Gastropoda, *Balanus* improvisus, insects or gammarids, only to a lesser degree by *Idotea* spp. (fig. 9).

Tab. 6: Production and index of settlement of seven different belts from three localities of the SW Baltic. *According to ZANDER & HAGEMANN.
Tab. 6: Produktion und „Index of settlement“ von sieben verschiedenen Gürteln von drei Örtlichkeiten in der SW-Ostsee. *Nach ZANDER & HAGEMANN.

Production (g/m² × y)								**Index of settlement (%) (component/substrate)**			
		Year	**Substrat**	**Polychaeta**	**Gammarida**	**Isopoda**	**Σ prey org.**	**Polychaeta**	**Gammarida**	**Isopoda**	**Σ**
Mytilus belt	Dahmeshöved	1988	306,71		28,12	1,41	29,53		9,17	0,45	9,62
		1990	150	0,05	0,12	0,49	0,66	0,03	0,08	0,33	0,44
		1986 *	1569,3		22,4	10,3	32,7		1,42	0,66	2,08
		1987 *	584		14,3	10,5	24,8		2,45	1,8	4,25
Ceramium belt	Dahmeshöved	1992	176,67		21,43	26,84	48,27		12,12	16,01	28,13
		1994	76,14	6,62		7,4	14,2	8,69		9,72	18,41
		1997	178,2	3	12,1	14	29,1	1,68	6,79	7,86	16,33
	Flensburg fjord	1999	62,9	0,33	0,75	2,09	3,17	0,52	1,19	3,32	5,03
Fucus belt	Flensburg fjord	1999	32	0,02	1,5	0,32	1,84	0,62	4,69	1	6,31
	Salzhaff	2001	74,04	0,22	12,7	3,5	16,2	0,3	17,15	4,73	21,91
Ectocarpus belt	Dahmeshöved	1992	202,46		2,98	4,51	7,49		1,47	2,23	5,7
Enteromorpha belt	Dahmeshöved	1992	134,24		56,93	12,11	69,04		42,41	9,02	51,43
Zostera belt	Dahmeshöved	1992	71,1		0,47	6,25	6,72		0,66	8,79	9,45
	Flensburg fjord	1999	257	2,61	0,99	3,3	6,9	1,02	0,38	1,28	2,68
	Salzhaff	2001	18	0,96	1,22	0,19	2,37	5,33	6,78	1,06	12,17
Zannichellia belt	Salzhaff	2001	40	0,14	0,35	0,12	0,61	0,35	0,87	0,3	1,25

Variability of biomass was in Salzhaff not significant in all plant belts.

3.4. Production

Production of potential prey organisms of fish (polychaetes, gammarids and isopods) was very variable at all localities as well as in the different substrates (tab. 5). It was highest in the *Enteromorpha* belt (51 g/m² *y) and lowest in a *Mytilus* sample from Dahmeshöved (0.44 g/m² * y). High productivity was especially obvious in the *Ceramium* and *Fucus* belts, whereas the *Mytilus*, *Ectocarpus* and *Zannichellia* belts were of minor importance. The most important organisms were gammarids which peaked in the *Entromorpha* belt, isopods and polychaetes attained important values in the *Ceramium* and *Zostera* belts of Dahmeshöved or Salzhaff, respectively (tab. 5).

The index of settlement (IOS) revealed variable values in the single belts which surpassed 10 % only in the *Ceramium* belt of Dahmeshöved and Flensburg, in *Fucus* and *Zostera* belts of Salzhaff and especially in the *Enteromorpha* belt of Dahmeshöved. A little lower value than 10 % was also attained by the *Mytilus* and *Zostera* belts from Dahmeshöved (tab. 6). Mostly, gammarids contributed to the high values, but in *Ceramium* belts and two of three *Zostera* belts *Idotea* spp. surpassed them. In *Ceramium* sp. from Dahmeshöved in 1994 gammarids played no role, but were substituted by polychaetes. The latter played also an important role in *Zostera* sp. from Salzhaff following after gammarids but before *Idotea* (tab. 5).

4. Discussion

Many hard bottom organisms of the Baltic colonize the phytal as new habitat, because of shortness of suited hard substrates (Remmert 1968). Thus, values of biomass and production attained high values in the investigated belts. The parts of herbivorous crustaceans (primary consumers), which may be prey for small-size fish can often surpass the 10 % mark of the ecological efficiency (Lindemann 1942) unless that snails and bivalves are regarded, which are not preferred prey of fish. This result is the more surprising, because generally the step from producers to primary consumers is marked by a loss of 99 % of energy (Odum 1968). It is to emphasize here that the index of settlement is independent to the productivity of the substrate.

In the following discussion the results of diverse belts will be discussed and compared with respect to different years or localities.

In comparison to other Baltic benthal systems the *Mytilus* belt has proved to be not very productive. This belt is of special interest because the mussel lives as epiphyton on hard substrate but it also provides substrate for the colonization by other organisms. The investigation in 1988 was performed near the surface such as those of Zander & Hagemann (1986), but the production of the former investigation was twice higher (tab. 6). Not so obvious are differences of crustacean production presenting higher values for isopods in 1988 than in 1986 but lower ones for gammarids. In comparison to Zander & Hagemann (1987), where investigations were performed in deeper waters, production values from 1990 were clearly lower but showed the same trend: the biomass of isopods surpassed the biomass of gammarids. In particular, the crustacean production of 1990 was found to be higher than in 1987. Therefore, *Mytilus* belts near the water surface attained larger production values than those of deeper levels. This might be caused by a greater phytoplankton offer in layers near the surface. The same phenomenon was found by Janssen & Kautsky (1977) in a vertical profile until a depth of 32 m with maximal production in 3-4.5 m. In a more recent investigation in 4-8 m depth high biomass could be confirmed in two localities of Lübeck Bight and West Fehmarn (Voce & Zander 2013). Regarding the succession area of the mussel belt *Mytilus* biomass attained only 13 % of the values from the control area in August 1988; other fauna attained only 0.5 % at this time. At the end of the succession experiment mussel biomass was 25 % and biomass of other fauna even 40 % of that in the control area. In contrast to biomass the number of taxa was higher than in the control area in late summer and autumn.

Considering the red algal belt of *Ceramium* sp., productivity was higher than in the *Mytilus* belt whereas productivity of the genuine substrate was in *Ceramium* sp. lower. The former investigation of LÜTHJE (1978) presented a production of utilizable food which corresponds to the organisms defined as fish prey of 71g $*m^{-2} * y^{-1}$. In the present investigation maximal biomass was attained in the locality Dahmeshöved with 48 g $*m^{-2} * y^{-1}$,which was still higher than that from the *Mytilus* belt. Minimal values were found in Flensburg fjord. In Dahmeshöved the productivity of the substrate was similar in the years 1992 and 1997 whereas it decreased in 1994 similar to the value of Flensburg fjord. The production of fish prey organisms was highest in 1992. The colonization density neither correlated to the productivity of the substrate nor to that of fish prey organisms compared to the *Mytilus* belt. Because the biomass values of the *Ceramium* belt are higher than that of the *Mytilus* belt, the succession may run faster. Unexpectedly, from July until the end of the experiment the biomass without mussels was greater in the succession than in the control area of the *Ceramium* belt.

Fucus belts were investigated in two localities, Flensburg Fjord and Salzhaff. In the latter locality similar production values of fish prey organisms were recorded as in the *Ceramium* belt. Whereas production was in Flensburg Fjord very low, the index of settlement was conspicuous low with just a third of the Salzhaff value. In the *Fucus* belts gammarids prevailed before isopods. *Idotea* spp. fed not only on the epiphyton but also directly on this alga as found on *Ceramium* sp. (SALEEMA 1979). In comparison to investigations in Kiel Fjord biomass was higher caused by higher specimen numbers (ANDERS & MÖLLER 1983). Gammarids and especially isopods were present by 95 % of macrofauna in Kiel Fjord whereas in Flensburg Fjord these attained only 27 %; but meiofauna (nematods, harpacticoids) was not included in the former locality. A similar situation was described by ZANDER et al. (2002) in West Fehmarn where *Idotea* spp. dominated on *Fucus vesiculosus* in July/August but on *Enteromorpha* sp. in May. Gammarids were distributed in a more balanced way over the whole vegetation period.

The productivity of fish prey organisms in the *Enteromorpha* belt attained the highest value of all substrates. This result was also supported by the index of settlement. Gammarids played a more important role than isopods. In Western Fehmarn the abundance of isopods was not as high as in Dahmeshöved, but was larger than in gammarids (ZANDER et al. 2002). Thalli structure of the green alga *Cladophora* sp. corresponds to that of *Enteromorpha* sp. and also harbours especially gammarids in Askö, East Sweden. Gammarids preferred such algae, because they are able to feed on the tips of the plant (JANSSON 1974). This explains their lower abundance on other plants like *F. vesiculosus Zostera marina*. or *Zannichellia palustris*, which tips are not as delicate as in the mentioned algae. *Enteromorpha* belts are therefore very important reservoirs for fish prey organisms.

Ectocarpus sp. and *Chorda* sp. so far were not investigated in regard to build a possible reservoir of small crustaceans. Nevertheless, the presented results seem to reveal a minor importance. The two algae present slender thalli in consequence of short vegetation periods and are special habitat and prey for young *Idotea* spp. and *Gammarus* spp. which can be consumed by small and young fish.

The inhabitants of the belts of the angiosperm plants *Zo. marina* and *Za. palustris* reveal another different picture. The productivity of *Z. marina* from three localities was at a lower level than that of *Ectocarpus* sp. and *Chorda* sp. resulting in low population densities of the prey organisms of fish. In Dahmeshöved and Flensburg fjord idoteids prevailed over gammarids, in Salzhaff over polychaetes. In contrast to the *Ceramium* and *Enteromorpha* belts adult *Idotea* spp. dominated here. The indices of settlement of the *Zostera* belt from Flensburg Fjord was low compared with other localities as already found in the *Fucus* and *Ceramium* belts. The *Zannichellia* belt which was investigated only in Salzhaff attained a far lower productivity and a lower index of settlement compared with *Zostera*.

Isopods were more abundant than gammarids, it seems to be a special habitat of juvenile *Idotea* spp. In contrast to productivity, abundance of macrofauna and especially crustaceans was higher on *Za. palustris* than on *Zo. marina*.

The most colonists were found in *Enteromorpha* and *Ceramium* belts. *Fucus* and the *Zostera* belt were an important reservoir of fish prey organisms only in Salzhaff. Thus, the eelgrass beds of the Bothnian Bay were assumed to house the most specimen and species rich communities of the northern Baltic shallow bottoms (Boström & Bonsdorff 1997).

Generally, no regularity was recognized in the investigations of mussel and plant belts and, therefore, the question arises for the causes or complex of causes which are important for differences between localities, substrates or years. Not only seasons but also the specific climate factors of the year of investigation create different sizes and density of the substrate organisms and, thus, offer variable environments. Therefore, in the next part of the discussion the influence of such factors, especially structure of substrate organisms, salinity and eutrophication are discussed.

The structure of sessile substrate organisms can be described according to Remane's (1940) classification of epiphyton, which was defined as plant and animal aufwuchs. He differentiated filament shaped epiphyton like *Ceramium* sp., *Enteromorpha* sp. and *Ectocarpus* sp., leaf shaped epiphyton like *Fucus* sp., *Zostera marina* and *Zannichellia palustris*, and button shaped epiphyton like *Mytilus edulis*. Among the algal belts *Enteromorpha* sp. presented the highest productivity of gammarids, *Ceramium* sp. the highest of isopods. This is probably caused by the delicate ramification of *Ceramium* thalli which offer habitat on the smallest space for these crustaceans, especially for the young specimens. Additionally, microalgae, which grow on *Ceramium* sp., and also the tips of this alga are grazed off by gammarids (Jansson 1966). On the other side, *Ceramium* sp. and *Enteromorpha* sp. are no suited substrates for mussels and snails because these are after growing up too heavy for the delicate thalli.

The difference between the *Ceramium* and *Mytilus* belts may be caused by faster growth of the algae than of the mussel belt which resulted also in a greater settling capacity of *Ceramium* sp. This is clearly evident from the succession experiments (see above). In contrast to productivity, abundance of macrofauna, especially of crustaceans, is higher on *Za. palustris* than on *Zo. marina,* which can be explained by the more structured habit of the former species (von Weber & Gosselck 1997).

Salinity of the investigated localities attains 19 ‰ in Flensburg fjord, 12 ‰ in Dahmeshöved and 8 ‰ in Salzhaff. The latter value is near the threshold of species minimum (5-8 ‰, Remane 1958), where species richness is lowest, but species, adapted to low salinity, increase their reproduction and populations growth as is generally valid in all extreme environments (Margalef 1968). Size of mussel decreases in lower salinities (Remmert 1968) which, in consequence, causes reduced colonization by crustaceans and other organisms (Kautsky 1981). Though in Flensburg fjord higher salinity prevailed than in Salzhaff the index of settlement on *Fucus vesiculosus* and *Zo. marina* is higher in the latter locality. This means that the factor salinity is not very important for the rate of productivity.

The Baltic Sea is polluted by phosphates and nitrates in particular from agriculture. This situation creates different effects for plants, on the one side it enhances the growth of algae but on the other side also the production of an excessive surplus of primary producers which are not consumed by herbivorous animals and, in consequence, leads to azoic wastes (Gerlach 1996, Zander & Blessin 1996). Another effect is water turbidity by plankton algae which hinders deeper growing plants to perform photosynthesis and, therefore, to exist (Schwenke 1996). Also small epiphytic algae may not develop optimally. This may be the reason for lesser colonization of *F. vesiculosus* and *Zo. marina* by crustaceans in Flensburg fjord though substrate biomass and salinity is higher than in Salzhaff. This locality had proved to be heavy polluted (Zander 2002). This phenomenon is also valid for the *Zostera* belts. The *Fucus* stocks of Kiel Bight were drastically reduced since the 1950 (Vogt & Schramm 1991). A similar situation is assumed in Lübeck Bight where in the localities Dahmeshöved, Timmendorf and eastern Fehmarn no *Fucus vesiculosus* has been found since the observation began in 1984 (Zander & Hagemann 1986, Voce & Zander 2013).

Epiphytic algae which grow on *Fucus* spp. can have strong influence on the food chain and, therefore, on fluctuations of the macrofauna (Haage 1976). Whereas young gammarids and isopods consume filamentous algae, adults prefer *Fucus* spp.and *Zostera marina* but also animal organisms (Jansson 1967, Saleema 1979). *Fucus* algae were very important parts of *Idotea* plant prey (Saleema 1979). *Idotea* has a positive effect on the removal of epiphytes on *Fucus* spp. as well as on *Zostera marina* (Leidenberger et al. 2012). Anders & Möller (1983) did not regard fish in Kiel Fjord. In commercially overfished areas of the western Baltic a mutual dependence between different levels of the food chain reveal that a decrease of isopods occurred as consequence of population growth of their main consumers, small-size fish, because population of greater fish decrease (Eriksson et al. 2009). This is a good example for mutual dependences of the members of a food chain and web where top predators can control the whole ecosystem.

Small size fish are represented especially by goby species which can appear in the Baltic in huge swarms (Zander & Hagemann 1986), but also by *Pholis gunellus* and *Zoarces viviparus*.They prefer crustaceans as prey and search for them between the algae and spermatophytes. It turned out that the goby *Pomatoschistus minutus* selects the most abundant category of crustaceans below 7 mm size (Zander 1990). Though the values change monthly, Gammarida gen. spp., *Idotea* spp. and *Jaera albifrons* were regularly selected whereas Polychaeta and *Mytilus edulis* below 5 mm size were avoided.

In conclusion, the investigated plant belts in the SW Baltic are an important reservoir of small crustaceans which find optimal hiding-place on macroalgae and prey by grazing epiphytic algae. The crustacean's role is to clean the thalli to allow an effective photosynthesis. The preference of "soft" plant substrates like *Ceramium* or *Enteromorpha* may have two reasons. The competition for space with mussels, snails, barnacles or bryozoans is not strong because these are too heavy for colonization, and the algae themselves offer prey. "Hard" plant substrates like *Fucus vesiculosus*, *Zostera marina* or *Zannichellia palustris* are prey only for *Idotea* spp., which possesses more robust maxillae. The third level of the food chain is especially represented by small-size fish which mainly prey on these crustaceans, as larvae and young fish do on planktonic copepods (Zander 1991). These small-size fish comprise the gobies *Pomatoschistus microps, P. minutus, P. pictus, Gobiusculus flavescens* and *Gobius niger*, the sticklebacks *Gasterosteus aculeatus, Pungitius pungitius* and *Spinachia spinachia* and the pipefishes *Syngnathus acus* and *Nerophis ophidion* in the mussel belts of Dahmeshöved (Zander 2008). In eelgrass areas of the German Bodden seas also ten small-size fish species were found (Bobsien & Munkes 2004). Cods, turbots, plaice, flounder or sea bulls occur as top predators e.g. in Dahmeshöved (Zander 2008). The importance of phytal biomass is clearly visible when it is compared with the low biomass of sand bottoms (Bobsien & Munkes 2004, Voce & Zander 2013). The rocky habitats are endangered by natural stress like ice which can destruct the plants or mussels, or massive appearance of sea stars which feed on mussels. But the greatest danger originates from stone fishing by humans which bring and use this substrate on land and reduce it in water (Zander 1991, Bock et al. 2003). Beside a restriction of stone fishing the hard bottoms of artificial reefs can help to solve this dilemma, because of its promoting effects on the food chain of commercial fish species (Mohr 2010, Voce & Zander 2013).

Literature

Anders, K., & Möller, H. 1983. Seasonal fluctuations in macrobenthic fauna of the *Fucus* belt in Kiel Fjord (western Baltic Sea). Helgoländer Meeresuntersuchungen 36, 277-283.

Bobsien, M., & Munkes, B. 2004. Saisonale Variation der Fischgemeinschaft und Habitatsstruktur einer Seegraswiese (*Zostera marina* L.) der südlichen Ostsee. Rostocker Meeresbiologische Beiträge 12, 39-59.

Bock, G., Thiermann, F., Rumohr, H., & Karez, R. 2003. Ausmaß der Steinfischerei an der schleswig-holsteinischen Ostseeküste. Jahresbericht Landesamt für Natur und Umwelt des Landes Schleswig-Holstein 2003, 111-116.

Boström, C., & E. Bonsdorff. 1997). Community structure and spatial variation of benthic invertebrates associated with *Zostera marina* (L.) beds in the northern Baltic Sea. Journal of Sea Research 37, 153-166.

Eriksson, B.K., Ljunggren, L., Sandström, A., Johansson, G., Mattila, J., Rubach, A., Råberg, S., & Snickars, M. 2009. Declines in predatory fish promote bloom-forming macroalgae. Ecological Application 19, 1975-1988.

Gerlach, S.A. 1996. 7.3.1 Eutrophierung. pp. 275-282. In: Meereskunde der Ostsee (Rheinheimer, G., Ed.). Springer, Heidelberg, Berlin.

Gründel, R. 1982. Ökosystem Seegraswiese – qualitative und quantitative Untersuchungen über Struktur und Funktion einer *Zostera*-Wiese vor Surendorf (Kieler Bucht, westliche Ostsee). Laboratory report for international circulation – Sonderforschungsbereich 95, Universität Kiel.

Haage, P. 1976. Quantitative investigations of the Baltic Fucus belt Macrofauna. 3. Quantitative seasonal variations in biomass, reproduction and population dynamics of the dominant taxa. Contributions from the Askö Laboratory (University of Stockholm, Sweden) 10, 1-84.

Hagermann, L. 1966. The macro- and microfauna associated with *Fucus serratus* with some ecological remarks. Ophelia 3, 1-42.

Jansson, A.-M. 1966. Diatoms and microfauna producers and consumers in the *Cladophora*-belt. Veröffentlichungen des Instituts für Meeresforschung Bremerhaven, Sonderband 2,, 281-288.

Jansson A.-M. 1967. The food web of the *Cladophora*-belt fauna. Helgoländer wissenschaftliche Meeresuntersuchungen 15, 575-588.

Jansson, A.-M. 1974. Community structure, modelling and simulation of the *Cladophora* ecosystem in the Baltic Sea. Contribution from the Askö Laboratory 5 1-130. University of Stockholm, Sweden.

Jansson, B.O., & Kautsky, N. 1977. Quantitative survey of hard bottom communities in a Baltic archipelago, p.p. 359-366. In: Biology of benthic organisms (Keegan, B.F., Ceidigh, P.O., & Bowden, P.J.S., eds). Pergamon Press, London.

Jansson, B.O. 1972. Ecosystem approach to the Baltic problem. Bulletins from the Ecological Research Committee/NFR 16, 1-82.

Jansson, B.O., & Wulff, F. 1977. Ecosystem analysis of a shallow sound in the northern Baltic – a joint study by the Askö group. Contribution of the Askö Laboratory University Stockholm 18, 1-160.

Kautsky, N. 1974: Quantitative investigations of the red algal belt in the Askö area, northern Baltic proper. Contribution of the Askö Laboratory University Stockholm 3, 1-29

Kautsky, N. 1981. On the trophic role of the blue mussel (*Mytilus edulis*) in a Baltic coastal ecosystem and the fate of the organic matter produced of the mussels. Kieler Meeresforschungen 5, 454-461.

Kirkegaard, J.B. 1978. Production by polychaetes on the Dogger Bank in the North Sea. Meddelser Danmark Fiskeri- og Havundersøking 7, 447-496.

Leidenberger, S., Harding, K., & Jonsson, P.R. 2012. Ecology and distribution of the isopod genus *Idotea* in the Baltic Sea: Key species in a changing environment. Journal of Crustacean Biology 32, 359-381.

Lindemann, R.L. 1942. The trophic-dynamic aspect of ecology. Ecology 23, 399-418.

Lüthje, H. 1978. The macrobenthos in the red algal zone of Kiel Bay (western Baltic). Kieler Meeresforschungen 4, 108-114.

Mohr, T. 2015. Riffe in der Ostsee. Zwischenbericht 2014. Landesforschungsanstalt für Landwirtschaft und Fischerei Mecklenburg Vorpommern.

Odum, E.P. 1968. Energy flow in ecosystems: A historical review. American Zoologist 8, 11-18.

Remane, A. 1940. Einführung in die zoologische Ökologie der Nord- und Ostsee, pp. 1-328. In: Die Tierwelt der Nord- und Ostsee, Band 1a (Grimpe, G., & Wagler, E., eds). Akademische Verlagsgesellschaft, Leipzig.

Remane, A. 1958. Ökologie des Brackwassers, pp. 1-126. In: Die Biologie des Brackwassers (Remane, A., & Schlieper, K., eds). Die Binnengewässer 12.

Remmert, H. 1968. Über die Besiedlung des Brackwasserbeckens der Ostsee durch Meerestiere unterschiedlicher ökologischer Herkunft. Oecologia 1, 296-303.

Saleema, H. 1979. Ecology of *Idotea* spp. (Isopoda) in the northern Baltic. Ophelia 18, 133-150.

Schramm, W. 1996. Veränderungen von Makroalgen- und Seegrasbeständen, pp.150-157. In: Warnsignale aus der Ostsee (Lozan, J.L., Lampe, R., Mathäus, W., Rachor, E., Rumohr, H., & von Westernhagen, H., eds). Parey Buchverlag, Berlin.

Schwenke, H. 1996. 6.3.1 Phytobenthos, pp. 163-172. In: Meereskunde der Ostsee (Rheinheimer, G., ed.). Springer, Heidelberg, Berlin.

Voce, J., & Zander, C.D. 2013. Analysis of the biocenosis of a small artificial reef on a sand bottom and of an autochthonous rocky field in the shallow SW Baltic. Verhandlungen des Naturwissenschaftlichen Vereins Hamburg Neue Folge 47, 149-172.

Vogt, H. & Schramm, W. 1991. Conspicuous decline of *Fucus* in Kiel Bay (western Baltic): what are the causes? Marine Ecology Progress Series 69, 189-194.

von Weber, M., & Gosselck, F. 1997. Pflanzen und Tiere des Meeresbodens der Wismar-Bucht und des Salzhaffs. Meer und Museum (Stralsund) 13, 41-52.

Zander, C.D. 1990. Prey selection of the shallow water fish Pomatoschistus minutus (Gobiidae, Teleostei) in the SW Baltic. Helgoländer Meeresuntersuchungen 44, 147-157.

Zander, C.D. 1991. Die biologische Bedeutung der Lebensgemeinschaft „Miesmuschelgürtel in der Ostsee. Seevögel, Sonderheft 1, 127-131.

Zander, C.D. 2002. The influence of eutrophication on parasite communities in the Baltic Sea. Proceedings of the 10th International Congress of Parasitology – ICOPA X Vancouver (Canada), 247-253.

Zander, C.D. 2008. Veränderungen der Fischdichte in der flachen SW-Ostsee im Laufe von 20 Jahren. Bulletin of Fish Biology 10, 11-23.

Zander, C.D. 2009. Parasitengemeinschaften von 'Wirbellosen' und Kleinfischen an sechs Standorten der SW Ostsee – ein Vergleich. Bulletin of Fish Biology 11, 61-72.

Zander, C.D., & Hagemann, T. 1986. Fluctuation of prey, abundance and biomass of gobies (Gobiidae, Pisces) in a shallow habitat of the western Baltic Sea. Zoologischer Anzeiger 216, 289-304.

Zander, C.D., & Hagemann, T. 1987. Predation impact and ecological efficiency of *Pomatoschistus* spp. (Gobiidae, Pisces) from a clay/sand ecotone of the western Baltic Sea. Zoologischer Anzeiger 218, 33-48.

Zander, C.D., & Blessin, H. 1996. 3.4.7 Abgestorbene Algenmatten – Leichentuch im Flachwasser. pp. 287-290. In: Warnsignale aus der Ostsee (Lozan, J.L., Lampe, R., Mathäus, W., Rachor, E., Rumohr, H., & von Westernhagen, H., eds). Parey Buchverlag, Berlin.

Zander, C.D., Koçoglu, Ö., Skroblies, M., & Strohbach, U. 2002. Parasite populations and communities from the shallow littoral of the Orther Bight (Fehmarn, SW Baltic Sea). Parasitology Research 88, 734-744.

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