MMH-Report 17

Projekt **Makrophyten Monitoring 2010-11**
Bewertung Helgoland 2010

Project **Water Framework Directive Monitoring**
Component Macrophytobenthos N5 Helgoland
EQR Evaluation 2010

Final report March 2011

Investigation period: July 2010 – February 2011

Client:
Landesamt für Landwirtschaft, Umwelt und ländliche Räume des Landes Schleswig-Holstein, Germany (LLUR-SH)

Reference number of the LLUR-SH: LLUR-AZ 0608.451013
GMSH Contract number: 4121.3-2010-272F

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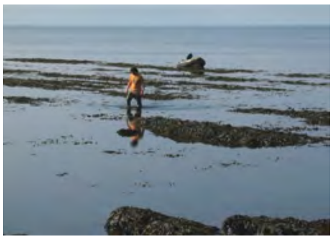

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Table of contents

1 Summary

Since 2005, a yearly monitoring of macroalgae according to national WFD-regulations (Water Framework Directive) has been performed. Quantitative abundance values were obtained by means of quadrat sampling within a fixed grid of stations in the northern intertidal (in the following text: N-Watt) of the northern coast of Helgoland (Bartsch *et al.* 2005, MMH-Report 2; Schubert *et al.* 2007, MMH-Report 5). Concomitantly, species richness was recorded based on the RSL-method (Wells et al. 2007), and diving transects provided sublittoral data on macroalgal abundance and depth limits since 2007. All data serve to fulfil the requirements for the component 'Macrophytes' within the biological package of the European WFD with respect to the coastal water body N5 at Helgoland (Kuhlenkamp *et al.* 2009a, MMH-Report 12). For this purpose, the specifically developed '**Helgoland Phytobenthic Index**' (HPI) provides comprehensive calculations in a modular format. This leads to the normalised ecological values necessary to establish the final Ecological Quality Ratio (EQR) used for reporting to the EU (Kuhlenkamp & Bartsch 2008, MMH-Report 9; Kuhlenkamp *et al.* 2009a, b, MMH-Reports 12 and 13).

During the present study, sampling of the fixed grid in the N-Watt was undertaken in July 2010 and February 2011 similarly to the years before. In parallel, quadrat measurements along an additional eulittoral transect implemented by LLUR (LANU-SH) were performed in summer 2010 and results were compiled according to previous reports (Schubert 2007, MMH-Report 6; Kuhlenkamp *et al.* 2009b, MMH-Report 12). If required, metric values were calculated for reporting to the national and international authorities in compliance with WFD regulations. In the following the results obtained are described and their seasonal variation depicted in detailed graphs. Descriptions of the methods have been given in Kuhlenkamp *et al.* (2009b, MMH-Report 13).

During recent months, first efforts have been undertaken to integrate the HPI which was especially developed for the unique Helgoland N5 water type, into the ongoing intercalibration process of the NEA-GIG (North East Atlantic Geographical Intercalibration Group) water types and demands. The state of the art will be reported here.

2 EQR-calculations within the Helgoland Phytobenthic Index (HPI)

2.1 Module 'Species richness' (SR-module, formerly RSL-module)

In July 2010, all macroalgae detected in the eulittoral of the N-Watt during one single visit at low tide were registered according to the RSL field method described in Kuhlenkamp & Bartsch (2008, MMH-Report 9). Specimens were identified to species level and a sample of each species was conserved as herbarium specimen for the Helgoland herbarium (Index herbariorum abbreviation: BRM).

Protocol:

- Date: 22.07.2010
- Area: N-Watt: eastern part from bunker remains to N-mole (see map in Bartsch & Tittley 2004)
- Operator: Ralph Kuhlenkamp

2.1.1 Results

All macroalgal species found are listed in Table 1 which constitutes the basis for further calculations according to the RSL-method. In total, 57 species were recorded, of which 15 were green algae (26%), 26 red algae (46%), 16 brown algae (28%), 27 opportunistic species (47%), 23 perennial, leathery species (Ecological State Group ESG1 species) and 34 fast growing species (ESG2 group). The ratio of the ESG1 : ESG2 species was 0.66. Overall, the list of species was very similar to that of July 2008 and 2009 and the proportions differed only slightly.

Tab. 1: Species richness: list of species collected during one observation in July 2010. ESG1 = perennial, leathery species, ESG2 = fast growing species, Opp1 = opportunistic species, Opp0= non-opportunists.

Class	Species	ESG	Opp
Chlorophyceae	*Acrosiphonia arcta*	2	1
	Blidingia minima	2	1
	Chaetomorpha linum	2	1
	Cladophora rupestris	2	0
	Cladophora sericea	2	0
	Prasiola stipitata	2	1
	Protomonostroma undulatum	2	1
	Chaetomorpha ligustica (Rhizoclonium tortuosum)	2	1
	Rhizoclonium riparium	2	1
	Ulothrix speciosa	2	1
	Ulva (Enteromorpha) compressa s. Kornmann	2	1
	Ulva (Enteromorpha) intestinalis	2	1
	Ulva (Enteromorpha) linza	2	1
	Ulva (Enteromorpha) prolifera	2	1
	Ulva lactuca	2	1
Phaeophyceae	*Cladostephus spongiosus*	1	0
	Dictyota dichotoma	2	1
	Elachista fucicola	2	0
	Fucus serratus	1	0
	Fucus spiralis	1	0
	Fucus vesiculosus	1	0
	Halidrys siliquosa	1	0
	Kützingiella holmesii	2	1
	Laminaria digitata	1	0
	Petalonia zosterifolia	2	1
	Pylaiella littoralis	2	1
	Petroderma maculiforme	1	0
	Ralfsia verrucosa	1	0
	Sargassum muticum	1	0
	Sphacelaria radicans	2	0
	Saccarina latissima	1	0
Rhodophyceae	*Aglaothamnion hookeri*	2	1
	Ahnfeltia plicata	1	0
	Audouinella sp.	2	1
	Ceramium virgatum	2	1
	Ceramium deslongchampsii	2	1
	Chondrus crispus	1	0
	Coccotylus truncatus	1	0
	Corallina officinalis	1	0
	Cystoclonium purpureum	1	0
	Dumontia contorta	2	1
	Erythrotrichia carnea	2	1
	Haemescharia hennedyi	1	0
	Hildenbrandia rubra	1	0
	Mastocarpus stellatus	1	0
	Membranoptera alata	1	0
	Neosiphonia harveyi	2	0
	Phymatolithon purpureum	1	0
	Phymatolithon laevigatum	1	0
	Phymatolithon lenormandii	1	0
	Plumaria plumosa	2	0
	Polyides rotundus	1	0
	Polysiphonia fucoides	2	1
	Polysiphonia stricta	2	1
	Porphyra umbilicalis	2	1
	Rhodomela confervoides	2	0
	Rhodothamniella floridula	2	1

In Table 2 the data of all internal metrics of the SR-module are listed based on field samples between July 2006 and July 2010. The coastal factor (last metric of the SR-module; for further description see Kuhlenkamp & Bartsch 2008, MMH-Report 9) stayed constant since the habitats in the sample area did not change. The SR-EQR for 2010 dropped very slightly in comparison to the previous years due to fewer overall species and a lower proportion of ESG 2 species but similar proportions of green algae and opportunistic species.

Tab. 2: Module 'Species Richness' EQR.

Quality classes	5	4	3	2	1	Jul 2006		Aug 2007		Jul 2008		Jul 2009		Jul 2010	
	Bad	Poor	Moderate	Good	High	Value	Metric EQR	Value	Metric EQR	Value	Metric EQR	Value	Metric EQR	Value	Metric EQR
EQR metric scale (WFD)	0 - 0.2	0.2 - 0.4	0.4 - 0.6	0.6 - 0.8	0.8 - 1.0										
Species richness	0 - 8	9 - 25	26 - 54	55 - 70	71 - 80	49	0.56	54	0.6	61	0.68	60	0.66	57	0.63
Proportion green algae [%]	100 - 90	91 - 70	71 - 30	31 - 10	9 - 0	27	0.64	25	0.66	25	0.66	27	0.64	26	0.65
Proportion red algae [%]	0 - 5	91 - 70	18 - 41	42 - 53	54 - 60	45	0.65	48	0.71	48	0.71	47	0.7	46	0.67
ESG1 : ESG2	0 - 0.09	0.1 - 0.29	0.3 - 0.69	0.7 - 0.89	0.9 - 1.0	0,58	0.54	0.61	0.56	0.61	0.56	0.62	0.56	0,68	0.59
Proportion opportunistic species [%]	100 - 90	91 - 70	71 - 30	31 - 10	9 - 0	47	0.52	46	0.52	44	0.53	47	0.52	47	0.52
Coastal factor	na	18 - 15	15 -11	11 - 8	1 - 7	14	0.45	14	0.45	14	0.45	14	0.45	14	0.45
SR-EQR (Median):							**0.55**		**0.58**		**0.61**		**0.6**		**0.58**

2.1.2 Discussion

Since 2007, the SR-EQR remained nearly unchanged between values of 0.58 and 0.61. The species number of certain groups like green algae and opportunistic species and the proportion of ESG-species did not show much variation over those years. This stability was present even though the winter conditions in 2006/2007 severely eradicated large amounts of algae and in 2009/2010 there was a long frost period – two events which were expected to have a negative impact on algal diversity. The winter in between was comparatively mild without causing a significant change in the SR-EQR value as well. As intertidal algae are used to changes in environmental conditions, it becomes obvious that they are able to cope with severe winter conditions without a change in species richness.

In 2008 and 2009, the EQR values of the SR-module (0.61 and 0.60 respectively) were at the border between the quality classes 'good' and 'moderate' while in the two years before and in 2010 the value of the SR-EQR was in the 'moderate' class. Between 2006 and 2009, a training factor indicating a higher ability of the operator to detect and determine species cannot be ruled out.

2.2 Module 'Fucetum'

In July 2010 large parts of the monitoring grid were covered by dense *Fucus serratus* (Fig. 1). Correspondingly, it was relatively easy to outline the area determined by the >90% cover of *Fucus serratus* (see protocol data in the appendix) since it was well developed and clearly visible. The measured polygon was clipped with the standard reference area with help of the software application ArcGis, resulting in a value of 11545 m^2 for July 2010 (Tab. 4). This value is similar to the previous maxima measured in 2005 and 2009 reflecting the fast and extensive recovery of *Fucus serratus* from the extremely reduced stock after winter 2006/2007. After application of the module, the final EQR of the 'Fucetum' for 2010 yielded a value of 0.56 (Tab. 4). This corresponds to the moderate class, but is very close to the boundary of the category 'good'. Considering all five sampling years, the final EQR results in a median value of 0.54, also corresponding to the moderate class and showing no change to former evaluations (Kuhlenkamp *et al.* 2009a, MMH-Report 12).

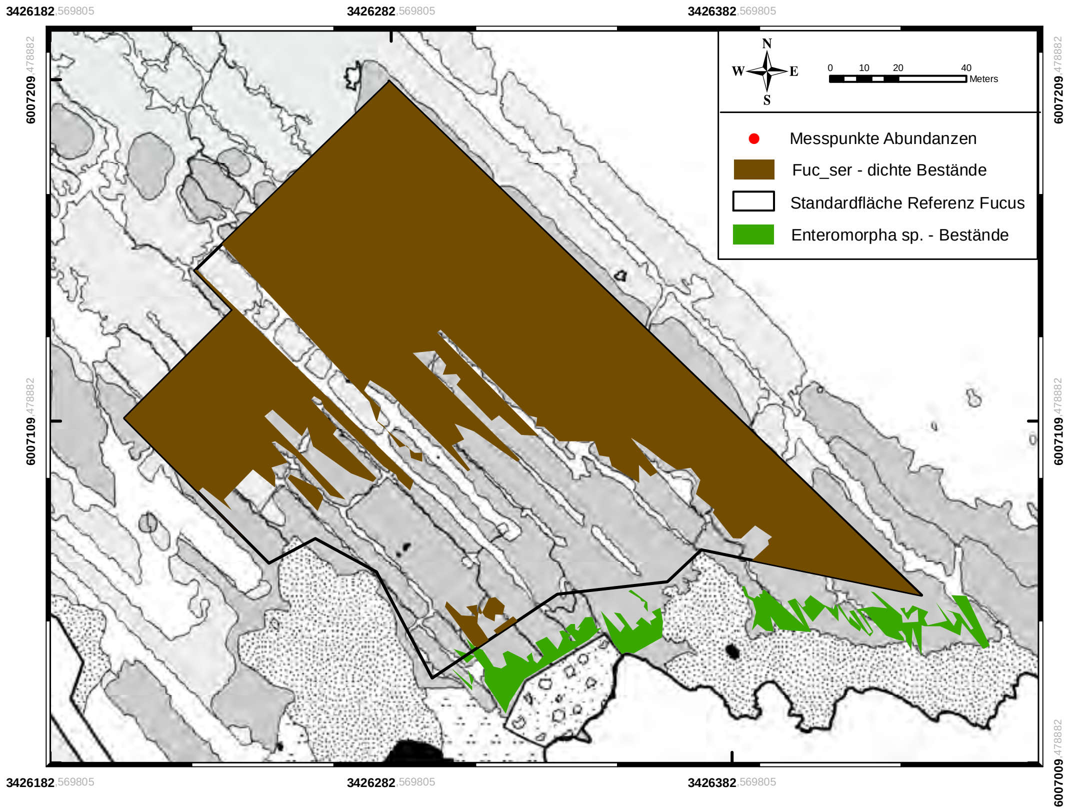

Fig. 1: July 2010; map of N-Watt Helgoland: standardised areas of dense *Fucus* cover (≥90%) and the *Enteromorpha*-Zone. The *Fucus*-polygon was clipped with the reference area.

Tab. 4: Module 'Fucetum' EQR: matrix based on new reference area (see Kuhlenkamp et al. 2009b, MMH-Report 13). Yearly polygon measurements and results from modelling (Jul 06, Aug 07).

Quality classes	**5**	**4**	**3**	**2**	**1**	**Metric EQR**
EQR metric scale (WFD)	**0 - 0.2**	**0.2 - 0.4**	**0.4 - 0.6**	**0.6 - 0.8**	**0.8 - 1.0**	
Fucetum boundaries area [m²]	0 - 2001	2002 - 5641	5642 - 12921	12922 - 16561	16562 - 18200	
2005			11869			**0.57**
Jul 06			10843			**0.54**
Feb 07	0					
Aug 07	1370					**0.14**
Feb 08		4530				
Aug 08			10918			**0.54**
Feb 09			9950			
Jul 09			12105			**0.58**
Jul 10			11545			**0.56**
Fucetum-EQR (Median of 6 years; only summer values):						**0.54**

2.3 Module 'Green algae: total abundance of *Ulva lactuca*'

2.3.1 Results of the monitoring grid

After the very low values of *Ulva* cover in February 2010, which may correspond to the unusually cold winter, the abundance of *Ulva lactuca* showed a strong increase in cover in those quadrats in which *U. lactuca* was present (Fig. 2). The number of quadrats where *U. lactuca* occurred increased as well and reached a similar level as in July 2008. Although the number of quadrats containing *U. lactuca* was much higher compared to July 2009, the mean cover per quadrat based on all quadrats of the whole grid was at its lowest summer value since 2005, but close to the value of 2008 (Fig. 3). This fact indicates a high patchiness of *Ulva* cover in the way that many small patches with *Ulva* existed instead of a few large areas like in July 2009. In February 2011, the patchiness of the *Ulva* abundance continued to increase, notable by the increased number of quadrats in which *Ulva* was found, while the average cover was much less than in July 2010 and comparable to other winter values.

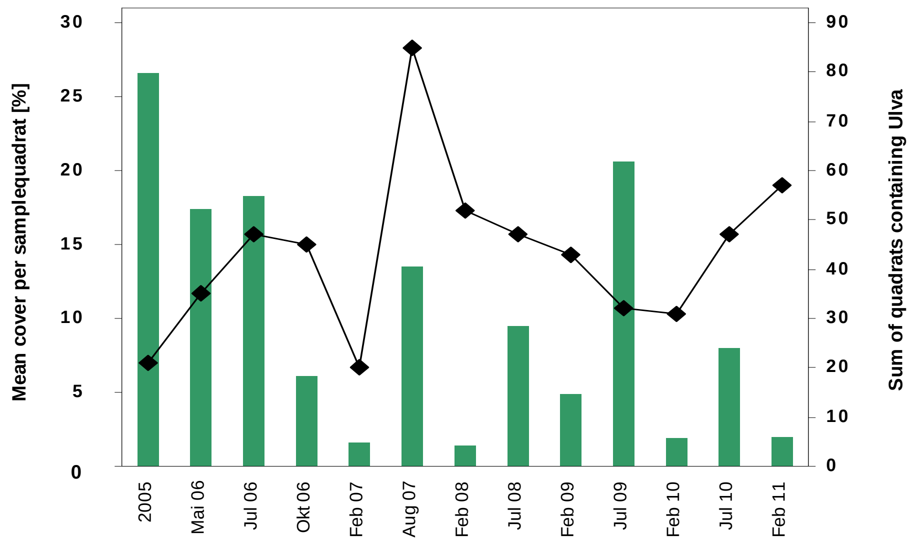

Fig. 2: Abundance of *Ulva lactuca* calculated from quadrats in which *U. lactuca* was present. Bars: Mean cover per quadrat; Points: number of quadrats containing *U. lactuca.*

The mean value of abundance expressed as percentage cover per sample quadrat based on all quadrats is rather a method of normalization of total abundance values than a basis for statistical comparison using standard deviation etc., since the number of quadrats measured was not the same in each monitoring campaign. Only in the cases where values are derived from quadrats which all contain the species to be evaluated (like *Ulva lactuca* in Figure 2), standard deviations are applicable.

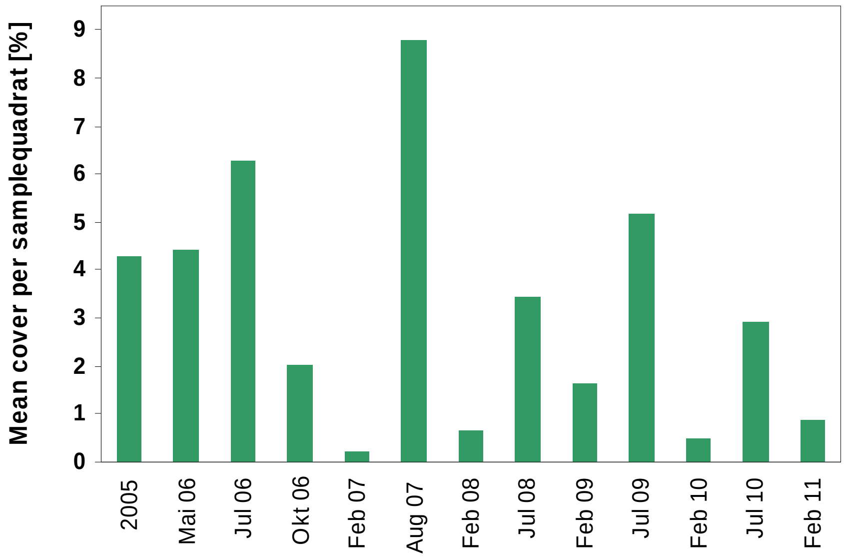

Fig. 3: Total abundance of *Ulva lactuca* as mean cover per quadrat of all quadrats measured.

2.3.2 Results and EQR

According to the guidelines of the HPI (Kuhlenkamp *et al.* 2009b, MMH-Report 13), the total abundance of *Ulva lactuca* in the whole sampling grid (sum of the area of all quadrats measured = number of quadrats x 0,25 m^2) has to be calculated in order to achieve the EQR value for the module 'Green algae'. Results of all sampling periods since 2005 are listed in Table 5.

Tab. 5: Mean cover of *Ulva lactuca* in all quadrats of the monitoring grid.

	Number of quadrats measured	**Mean cover per quadrat [%]**
2005	130	**4.3**
Mai 06	138	**4.4**
Jul 06	137	**6.3**
Okt 06	136	**2.0**
Feb 07	132	**0.2**
Aug 07	131	**8.8**
Feb 08	114	**0.6**
Jul 08	130	**3.4**
Feb 09	127	**1.7**
Jul 09	127	**5.2**
Feb 10	125	**0.5**
Jul 10	130	**2.9**
Feb 11	130	**0,9**

EQR

According to the HPI, only the summer values during the main growing season of macroalgae are used to calculate the EQR of the module 'Green algae' (Kuhlenkamp & Bartsch 2008, MMH-Report 9).

Compared to 2009, the yearly EQR for July 2010 increased and reached its highest value during the monitoring period since 2005 (Tab. 6). The final EQR over six years was calculated as 0.81 (mean). This is not very different from the 0.79 value of the year 2009, but nevertheless reached the best quality class since 2005. All abundance values since the beginning of the monitoring lie within the class 'good' or 'very good' and the six-year final EQR of 0.81 nearly represents the border between the quality classes 'good' and 'very good' (Tab. 6).

Tab. 6: Module 'Green algae' EQR for 2010. Matrix with class boundaries according to Wells *et al.* (2007b).

Quality classes	**5**	**4**	**3**	**2**	**1**	**Metric EQR**
EQR metric scale (WFD)	**0 - 0.2**	**0.2 - 0.4**	**0.4 - 0.6**	**0.6 - 0.8**	**0.8 - 1.0**	
Class boundaries [%]	100 - 75	74.9 - 25	24.9 - 15	14.9 - 5	4.9 - 0	
2005					4.29	**0.83**
Jul 06				6.28		**0.77**
Aug 07				8.78		**0.72**
Jul 08					3.44	**0.86**
Jul 09				5.23		**0.79**
Jul 10					2.9	**0.88**
Green algae EQR (median of 6 years):						**0.81**

2.4 Module 'depth limits'

The module ‘Depth limits of macroalgae’ described in MMH-Report 11 (Kuhlenkamp *et al.* 2008) is an important part of the HPI, since it represents a very reliable long-term indicator of water turbidity and therefore eutrophication. It was revised and improved after the first field experiences in 2008. The resulting methods were integrated in the updated monitoring guidelines (Kuhlenkamp *et al.* 2009b, MMH-Report 13) and employed in summer 2009. As sublittoral monitoring involves very high logistical and financial requirements it is sometimes only feasible every second two year. In 2010, therefore, no sublittoral monitoring was undertaken.

2.5 HPI-EQR

Since 2006, all eulittoral data essential for calculating the EQR of the Helgoland Phytobenthic Index HPI index are available, while data of the sublittoral transects were only obtained in 2007, 2008 and 2009. Modifications of the sublittoral module became necessary in 2009, involving the number and use of internal metrics and adjusting the reference values and boundaries. Since the median is used for calculating the module-EQRs after six years, variation between years does not seriously affect the final EQR. This is for instance demonstrated by the sublittoral EQR of 0.71 for 2007, which is very different from the other two years but not affecting the final EQR. For WFD purposes, an EQR has to be reported after six years and has to be robust against short term events unrelated to water or environmental quality. This is achieved by the HPI: the final value is composed of four single module-EQRs and calculated as a mean over six years. Each module-EQR obtained over the maximum period of six years is weighted before the sum of all EQRs results in the preliminary final WFD EQR of 0.601 (rounded to 0.60) according to the HPI matrix (Tab. 7). In this report we cannot give a new EQR value for the sublittoral depth limits as this module was not measured in 2010. Using the normative classification matrix, this value corresponds to the category 'good' (category 2), but as a rounded value of 0.60 it represents exactly the border between 'moderate' (category 3) and 'good' (category 2). This corresponds well to the former quality assessment of the water body N5 at Helgoland based on expert judgement (Bartsch & Kuhlenkamp 2004, MMH-Report 1; Kuhlenkamp *et al.* 2008, MMH-Report 11) and to the value of the year before.

Tab. 7: HPI-EQR calculated as the sum of all module-EQRs for the years 2006-2010.

EQR - Module	HPI metric	Metric EQR						Weighted EQR
		2006	2007	2008	2009	2010	Median over available years	
SR	Internal SR-metrics	0.55	0.58	0.61	0.60	0.58	**0.58**	**0.29**
Green algae	*Ulva lactuca* [% cover]	0.77	0.72	0.86	0.81	0.88	**0.81**	**0.081**
Fucetum	90% cover *Fucus serratus*	0.54	0.14	0.54	0.54	0.57	**0.54**	**0.108**
Sublittoral depth limit	Depth of 5 selected species	na	0.71	0.60	0.61	na	**0.61**	**0.122**
HPI – EQR 2006 till 2010 (sum of weighted EQR values):								**0.601**

3 Polygon measurements

3.1 *Enteromorpha*-zone

The 90-100% cover of *Enteromorpha* in the upper eulittoral of the N-Watt was used to define the area of dense *Enteromorpha*. This was achieved by delimiting the area with the help of polygon measurements with a D-GPS. During winter (measurements in February or March) the resulting area was very small and sometimes not discernable or too patchy like in February 2010 and 2011. During summer, the *Enteromorpha*-area was usually well developed and showed higher values (sampling periods June till August) than in the preceding winter period (Tab. 8). In summer 2006 and 2008 the area had its maximum extension since 2005, while in July 2010 it was substantially less and even lower than in 2009.

Tab. 8: Area values of *Enteromorpha*-polygons in the N-Watt Helgoland; calculated with ArcGis
(2005 and 2006 were corrected due to the loss of sampling area in 2007 because of a massive landslide of cliff material).

Sampling period	Area [m^2]
2005	1479
Mai 06	1325
Jul 06	1164
Feb 07	181
Aug 07	970
Feb 08	670
Jul 08	1301
Feb 09	1138
Jul 09	940
Feb 10	Too small and patchy to be measured
Jul 10	791
Feb 11	Too small and patchy to be measured

Figure 4 depicts the difference between summer 2009 and 2010. The main loss in summer 2010 compared to 2009 occurred in the easterly part of the monitoring area generally towards the edge of the boulder and gravel zone bordering the cliff in the uppermost eulittoral. This was obviously due to a massive accumulation of drift material including tough, slowly decomposing *Laminaria*-thalli.

There was again a clear borderline apparent between the dense *Fucus*-covered area and the *Enteromorpha*-zone (Fig. 4), which had previously been recognized as a constant line between both areas regardless of season and year (see also Kuhlenkamp *et al.* 2009a, MMH-Report 12). Some of the tongue-like extensions of *Enteromorpha* into the *Fucus*-area were again very stable independent of the spatial situation of the dense *Fucus*.

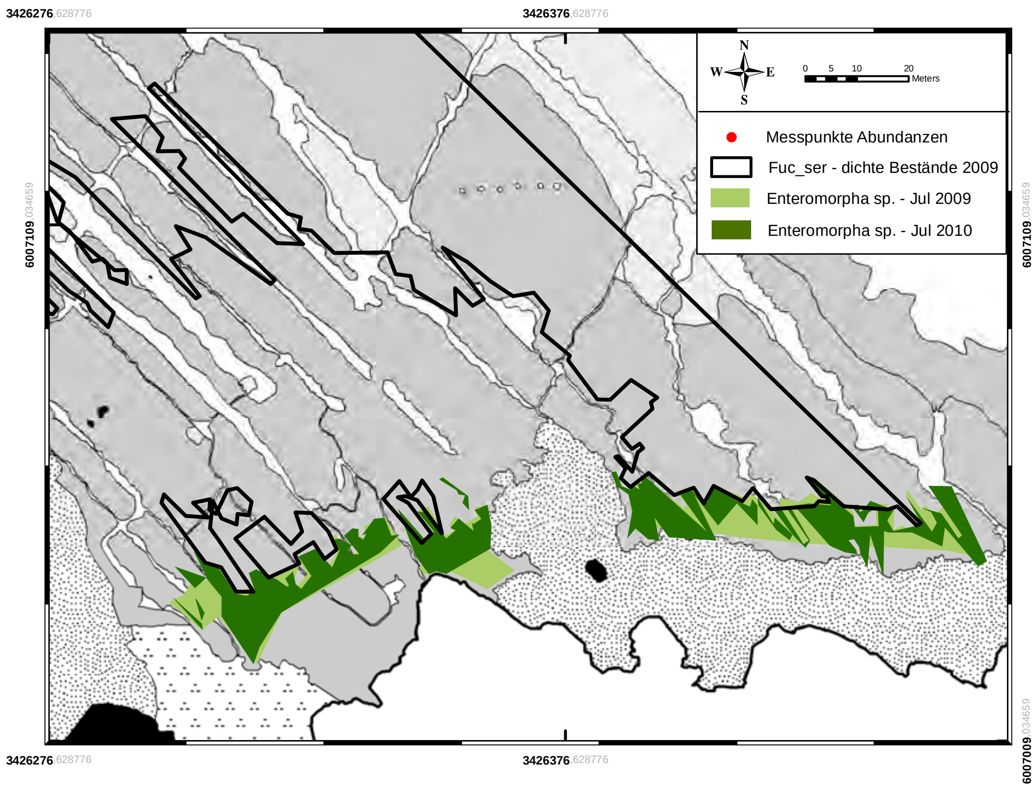

Fig. 4: Polygon of the *Enteromorpha*-zone in the N-Watt: July2009 und July 2010. The dense *Fucus*-area of July 2009 depicted by its outline is directly bordering the *Enteromorpha*-zone.

3.2 Polygon dense *Fucus*-cover

The area of the dense *Fucus* vegetation in July 2010 (Fig. 5) was comparable in size to the years 2005 and 2006. In the upper eulittoral, the measured *Fucus*-area extended beyond the reference area. Already in the field, it was clearly visible that the border between the dense *Fucus* and the *Enteromorpha*-zone was a clear-cut line with a characteristic pattern of tongue like extrusions either of *Fucus* or *Enteromorpha*. This seems to be a stable situation since the same pattern appeared every time the polygons were measured.

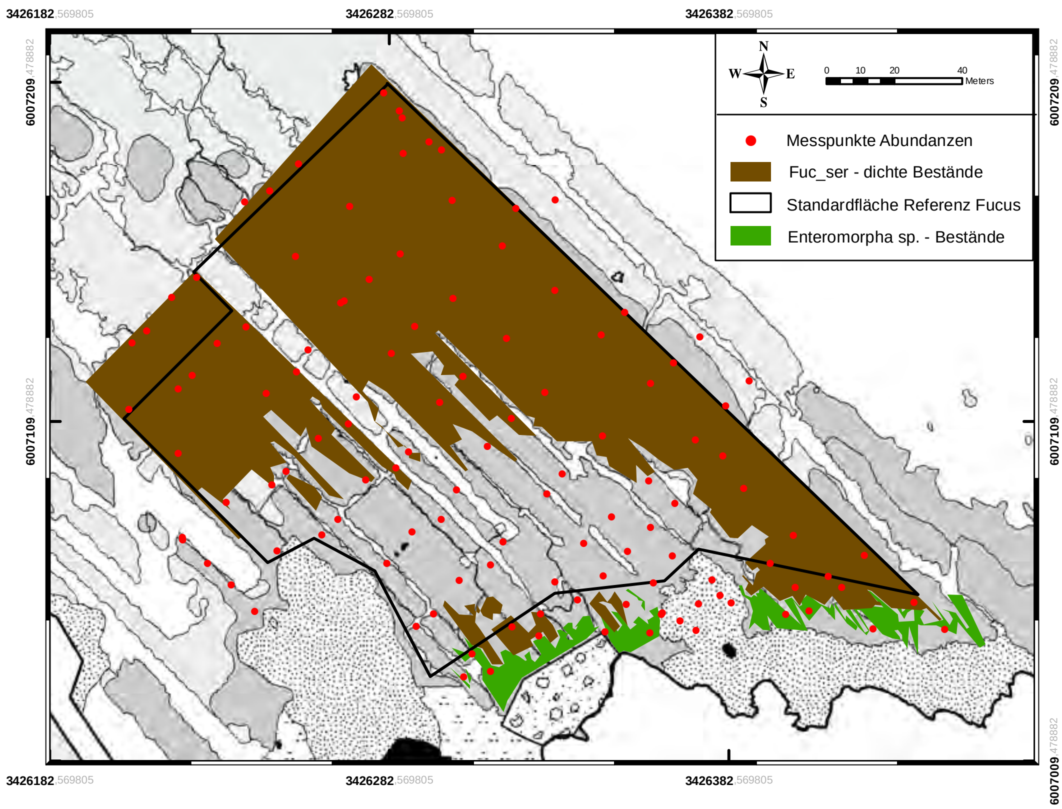

Fig. 5: July2010, N-Watt Helgoland with areas of dense *Fucus* with >90% cover and the *Enteromorpha*-zone in the upper eulittoral zone. The standardised *Fucus* reference area is outlined for comparison (black polyline).

4 Analysis of monitoring grid data

In addition to processing the grid data for the HPI, data of some selected species were analysed in order to show seasonal or interannual variation within the *Fucus*-dominated community. Some details are also listed in the descriptive protocols in the appendix.

4.1 Variation in *Fucus*-cover

Total abundance

Immediately after the severe decrease in total abundance of *Fucus serratus* in February 2007, a steady recovery of *Fucus* in terms of abundance measured as the simple top-layer percentage cover occurred (Fig. 6). Field measurements during the following years demonstrated the immense recovery ability of *F. serratus*, since total abundance reached former maximum values of the years 2005 and 2006 within 2-3 years (Fig. 6, Tab. 9). In each winter there was always a small (except in 2007 which showed a very strong decrease), but distinct and regular decrease in *Fucus* abundance compared to the preceding summer period. In February 2010 the drop in *F. serratus* cover compared to summer 2009 was more pronounced than in the previous winter periods, but the actual cover value was similar to February 2009. In July 2010 cover values reached the former maximum summer values of 2009 and of 2005 and 2006. Additionally in 2009 and 2010, the uppermost *Fucus* patches bordering the *Enteromorpha* zone became dense and more abundant.

In February 2011, the *Fucus* cover was again reduced to its usually low winter value and even a bit lower than in the two former winter periods (Fig. 6). None of the sample quadrats yielded 100% cover even in areas with high *Fucus*-density. The maximum was 98% and only 15 quadrats showed cover values above 90% cover.

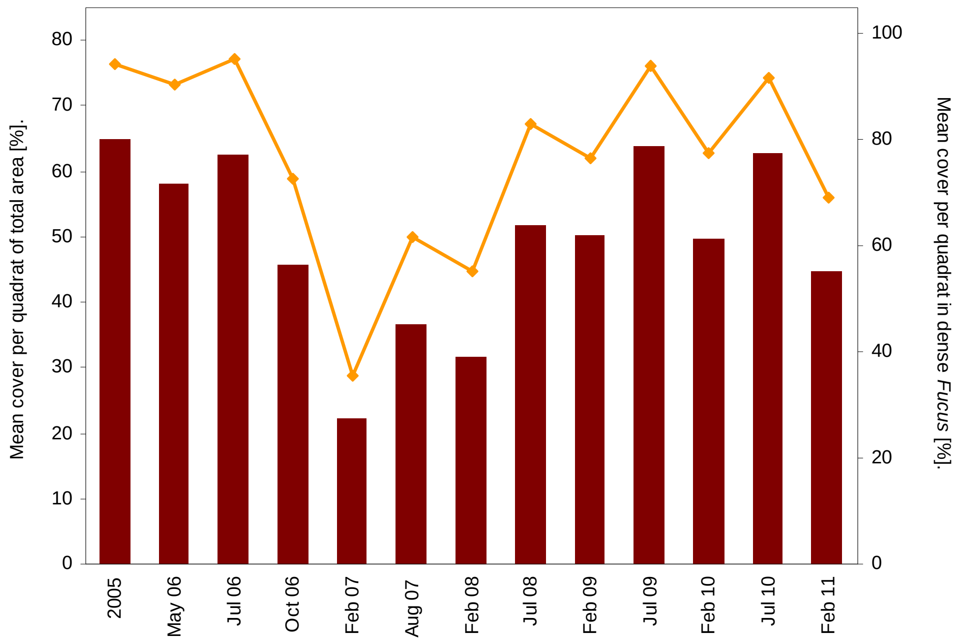

Fig. 6: *Fucus serratus*: mean cover per sampled quadrat during each sampling period
Bars: mean of all quadrats sampled within the whole grid
Points: mean of quadrats sampled only within the dense *F. serratus*-area (defined in 2005).

Tab. 9: *Fucus serratus* data and results of the grid sampling either based on all quadrats sampled within the observation area or only within the dense *Fucus*-area (polygon defined in 2005).

	Cumulative total abundance [%]	Cumulative total abundance [%] only dense *Fucus* area	Number of sampled quadrats	Number of quadrats with *Fucus*	Proportion of quadrats with *Fucus*[%]	Mean cover per sampled quadrat [%]	
						All quadrats	Quadrats of dense *Fucus* area
2005	8431	5386	130	106	82	65	94
May 06	8019	5251	138	122	88	58	91
Jul 06	8568	5440	137	114	83	63	95
Oct 06	6236	4069	136	104	76	46	73
Feb 07	2950	2026	132	100	76	22	36
Aug 07	4812	3456	131	98	75	37	62
Feb 08	3605	2712	114	91	80	32	55
Jul 08	6724	4574	130	114	88	52	83
Feb 09	6375	3978	127	119	94	50	77
Jul 09	8158	5178	128	116	91	64	94
Feb 10	6204	4028	125	117	94	50	77
Jul 10	8160	5143	130	117	90	63	92
Feb 11	5809	3867	130	113	87	45	69

Abundance data derived from all quadrats compared to those only within the dense *F. serratus* area (cover ≥ 90%, polygon defined in 2005) revealed an identical variation in *Fucus* cover with similar maxima and minima (Fig. 6). It is concluded that the different stands of *F. serratus* with cover values ranging from only a few percentages in the barren areas or in the *Enteromorpha*-area up to 100% in the dense *F. serratus* area responded similarly to seasonal effects or physical disturbances like storm events.

The continuation of the diagram by Schubert *et al.* (2007, MMH-Report 5) corroborates the recovery trend of *F. serratus* since 2007. The dense cover of 2005 was nearly reached on a broad spatial scale in July 2009 and July 2010 exhibiting numerous 100% cover values (Fig. 7).

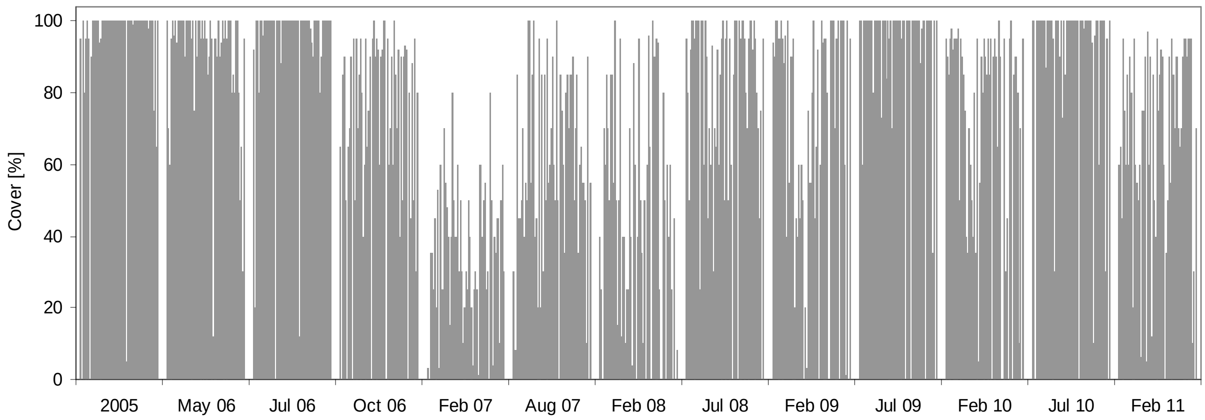

Fig. 7: *Fucus*-cover within the dense *F. serratus*-area (polygon defined in 2005 with >90% cover): shown is the percentage cover of each quadrat per sampling period.

4.2 Analysis of non-*Fucus*-species

4.2.1 *Enteromorpha*

Each year the quadrat sampling in the upper eulittoral of the N-Watt revealed a clearly defined zone in which tubular *Ulva*-species (*Enteromorpha*) were the dominant macroalgae nonetheless exhibiting seasonally highly fluctuating cover values (Fig. 8). This area was, therefore, designated as a special '*Enteromorpha*-zone'. Generally, values of the winter cover were much lower than the preceding summer values reflecting the general growth decrease of *Enteromorpha* species during periods of low light and temperatures. In summer 2010 the percentage cover per quadrat was higher than in summer 2009, but still much less than in summer 2005 and 2006. Since the *Enteromorpha*-species in this zone are fast-growing, easily reproducing and opportunistic species, high fluctuations are to be expected within short periods of time. Sampling at just one instant of time during summer is therefore not necessarily indicative for the whole period. During the last two winter periods, cover was very low compared to former winter situations, even to February 2007, when due to storm events a very strong overall reduction in biomass of all algae had occurred. In the last two winters temperatures had dropped below 0°C for prolonged periods. This suggests that temperatures might have a stronger negative influence than physical disturbance like abrasion.

We assume that cover values of *Enteromorpha* or other opportunistic species will remain low in the near future especially in the western area of the zone, since an extensive part of the *Enteromorpha*-zone was destroyed through a severe landslide in winter 2007, resulting in a large amount of moving debris which has a constant impact on the remaining community. The formerly dense *Enteromorpha* cover in this area was possibly supported by two factors. First, the area is close to the bird nesting places which likely supported the growth of *Enteromorpha* by additional input of nutrients. Secondly, the nearby cliff faces had been relatively stable the years before, producing very little debris with probably only minor physical impact compared to the situation now where large boulders and stones are continuously eroded and provide material which is washed into the algal community.

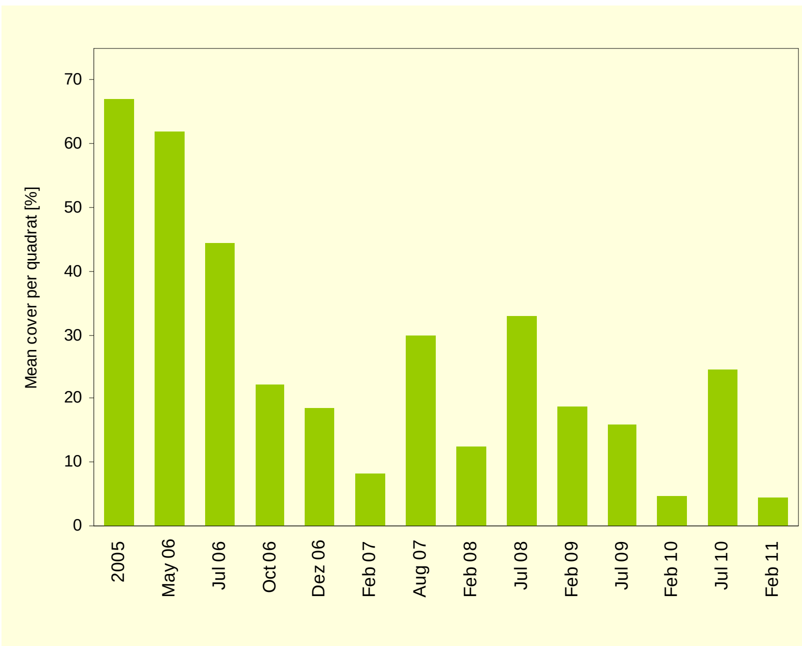

Fig. 8: *Enteromorpha* spp. in the *Enteromorpha*-zone: mean percentage cover per sampled quadrat.

4.2.2 *Cladophora rupestris*

Cladophora rupestris is a constant understorey-species in the N-Watt, although patches without *Fucus* cover are present in shaded areas. Abundance of *C. rupestris* was stable in February and July 2009 (Fig. 9), but was much less than in the years following the severe loss of *F. serratus* in 2007. This is especially obvious in the area of dense *F. serratus* where *C. rupestris* reached maximum cover values in summer 2007 following the severe winter loss of *F. serratus* and even in the winter thereafter (Fig. 10). Generally, abundance of *C. rupestris* reacted similarly in the dense *F. serratus* area as in the whole grid (Fig. 10). In both areas, the mean cover of *C. rupestris* dropped slightly in February 2010 and even further in July 2010 which marked the minimum measured so far since 2005. In February 2011 the value did not change compared to the summer before, indicating a stable situation. Seemingly this does not depend on the seasonal *Fucus* variation (compare with Fig. 7).

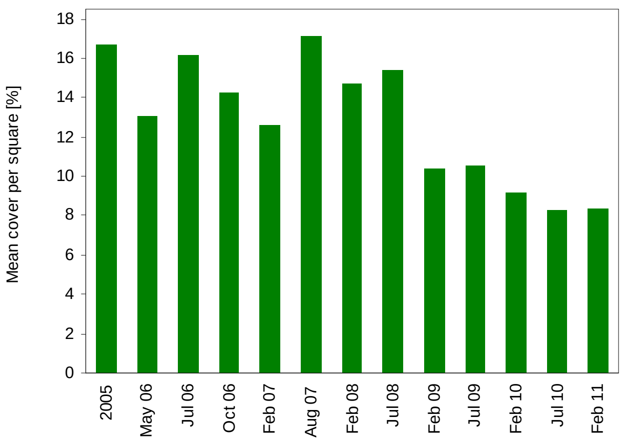

Fig. 9: Total abundance of *Cladophora rupestris*: mean cover per quadrat of all quadrats measured during each sampling period.

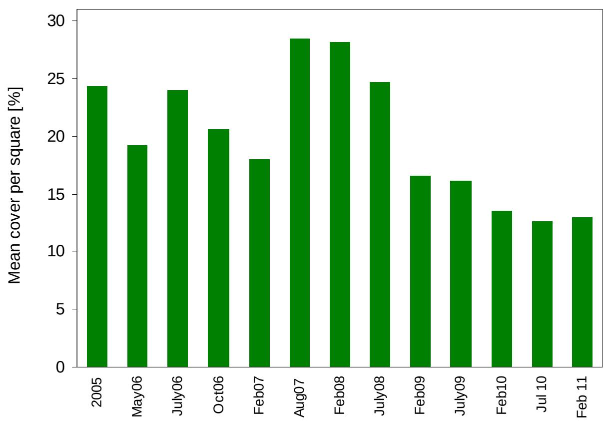

Fig. 10: Abundance of *Cladophora rupestris* only in the dense *Fucus*-area: mean cover per quadrat.

4.3 Zoobenthos

Benthic animals are not the focus of the present WFD macrophyte monitoring and are not part of the HPI-EQR. Some benthic invertebrates, however, are included in the quadrat sampling within the monitoring grid since they closely interact with macroalgae with a potential influence on their abundance. Either they constitute sessile filter-feeding species like *Mytilus edulis* and *Crassostrea gigas* which are known to act as dominant structuring components of intertidal communities antagonistic to *Fucus* (McCook & Chapman 1991) or they are semi-vagile species of the families Trochidae (*Gibbula*) or Littorinidae (*Littorina* spp.) which are characteristic species of the intertidal grazing on macroalgae like *Ulva* and *Fucus* amongst others (Watson & Norton 1985, Barker & Chapman 1990).
These invertebrate species were counted as individuals (cover values were calculated from these numbers) alongside with the measurement of algal cover, resulting in six years of data on the abundances of the main molluscs in the intertidal of the N-Watt of Helgoland. Some species were included in the data set of the monitoring grid as cover values after conversion of the numbers into equivalent values of percentage cover. In this chapter we only look at numbers of individuals per quadrat area based on the actual number of quadrats sampled. Actual cover values will therefore be different depending on the size of individuals and the space they covered. Especially *Mytilus edulis* appeared with a large range of sizes whereas in *Littorina* and the other snails the smaller size classes were not very abundant.

4.3.1 *Mytilus edulis*

The common blue mussel *Mytilus edulis* formed a small mussel bed from the 1980s to approximately 2000 in the presently 'barren area' of the monitoring grid. The mussel bed was still slightly discernable in 2005 but since then the bed has disintegrated and mussels are only found in very small aggregations or as single individuals interspersed in the upper eulittoral (Tab. 10). Since summer 2006 the number of individuals dropped continuously (Fig. 11). In summer 2010 a total abundance of only nine individuals in all investigated quadrats was recorded, indicating the minimum of the whole monitoring period in contrast to 354 individuals in 2006 (Tab. 10). In the following February 2011 the number of individuals increased again to 35 in total. Since July 2008, individual numbers stabilized at a very low level of about 19-42 individuals in all quadrats of the monitoring grid covering an area of about 140 x 250 m. The continuous drop in abundance might indicate that the species did not recruit successfully during recent years due to low larval settlement in relatively warm winter periods (Beukema *et al.* 2001).

Tab. 10: List of invertebrates sampled during the macroalgal monitoring in the N-Watt Helgoland as total number of individuals based on all quadrats sampled and numbers of individuals per sampling quadrat.

	Total number in all quadrats						Number per quadrat				
	Myt_edu_In	**Cra_gig_In**	**Gib_cin_In**	**Lit_lit_In**	**Lit_obt_In**	**Number of quadrats**	**Myt_edu_In**	**Cra_gig_In**	**Gib_cin_In**	**Lit_lit_In**	**Lit_obt_In**
2005	285	0	256	1274	285	130	2.19	0.00	1.97	9.80	2.19
May 06	317	0	52	875	293	138	2.30	0.00	0.38	6.34	2.12
Jul 06	354	1	102	1089	356	137	2.58	0.01	0.74	7.95	2.60
Oct 06	220	1	183	1630	577	136	1.62	0.01	1.35	11.99	4.24
Feb 07	185	0	221	1561	1032	132	1.40	0.00	1.67	11.83	7.82
Aug 07	77	5	104	1579	200	131	0.59	0.04	0.79	12.05	1.53
Feb 08	72	11	70	1407	423	114	0.63	0.10	0.61	12.34	3.71
Jul 08	34	3	104	1696	231	130	0.26	0.02	0.80	13.05	1.78
Feb 09	43	5	143	1084	638	127	0.34	0.04	1.13	8.54	5.02
Jul 09	19	14	71	1635	517	128	0.15	0.11	0.55	12.77	4.04
Feb 10	32	22	131	970	1695	125	0.26	0.18	1.05	7.76	13.56
Jul 10	9	15	90	896	570	130	0.07	0.12	0.69	6.89	4.38
Feb 11	35	21	181	778	1241	130	0.27	0.16	1.39	5.98	9.55

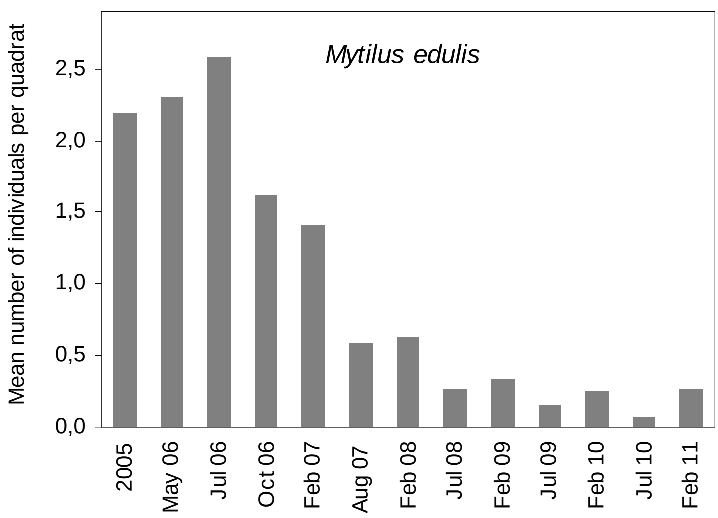

Fig. 11: Number of individuals of *Mytilus edulis* per sample quadrat.

4.3.2 *Crassostrea gigas* (Pacific Oyster)

The Pacific Oyster has successfully invaded the North Sea, escaping from oyster farms in Brittany, France. Especially artificial substrata like harbour walls and constructions for coastal protection along the coasts of the North Sea were colonized by these big oysters (Nehls & Büttger 2007).

During the macroalgal monitoring of the N-Watt of Helgoland, *C. gigas* was first found in summer 2006 with just one individual in the whole grid (Tab. 10). Since 2007 this number increased continuously. A maximum number of 22 individuals was measured during the very cold winter 2009/2010 (Fig. 12). This is especially noteworthy, because it indicates a high resistance at least to light frost and generally high survival capabilities of *C. gigas* in the Helgoland intertidal. In July 2010 the number dropped to a similar value as in summer 2009. In February 2011 numbers increased again reaching 21 individuals in all quadrats measured (Tab. 10), showing again its resistance to low winter temperatures.

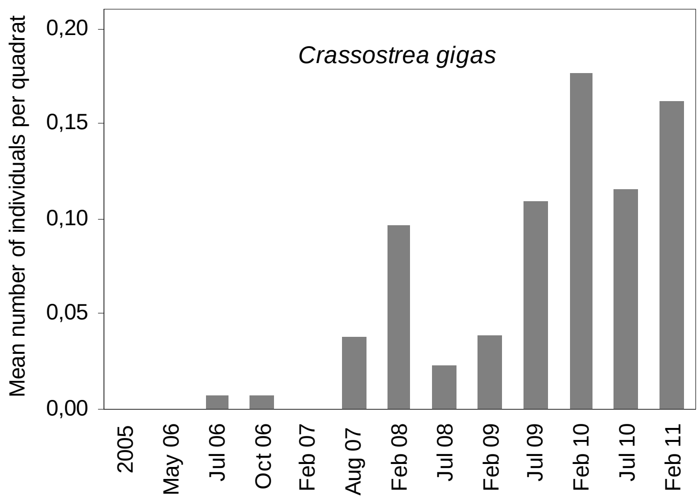

Fig. 12: Number of individuals of *Crassostrea gigas* per sample quadrat.

4.3.3 *Littorina littorea*

The common periwinkle *Littorina littorea* always showed a high density in the barren area of the mid to upper eulittoral and numbers never dropped below six individuals per quadrat based on all quadrats sampled within the sampling grid (Fig. 13). During the last seven years abundances varied between ~6-13 individuals per quadrat with a maximum number of nearly 1700 individuals in total in all quadrats during summer 2008 (Tab. 10). There is no clear pattern in the variation. Even after the heavy storms in winter 2006/2007 numbers stayed constant despite the heavily reduced *Fucus* cover in February 2007. In summer 2010 numbers reached a relatively low value, decreasing in February 2011 even more, but still lie within the range of previous measurements in 2006.

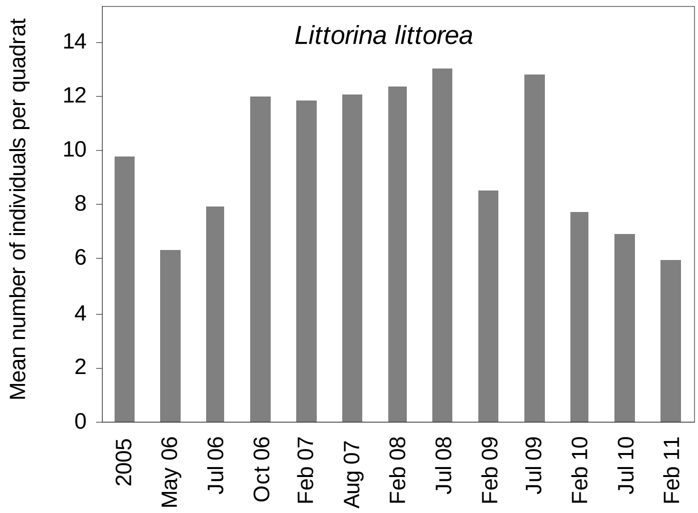

Fig. 13: Number of individuals of *Littorina littorea* per sample quadrat.

4.3.4 *Littorina obtusata*

The other periwinkle of the family Littorinidae found in the intertidal is *Littorina obtusata*. In contrast to *L. littorea* this species was nearly exclusively found among the dense *Fucus* vegetation, often grazing on the surface of *Fucus* fronds. There is no general trend in the variation recognisable, but the lowest numbers were measured in summer 2007 and 2008 when *Fucus* cover still was very low and had not yet recovered (Fig. 14). Generally, there is an increase during winter compared to the respective summer before. This might indicate a sampling error as individuals were counted after the *Fucus* top layer had been removed. If snails had attached firmly to *Fucus* fronds, they were likely not considered during measurements. Low cover of *Fucus* might interfere with the measured occurrence of *L. obtusata* in two ways: either the snails are more visible or snails also move towards other substrata. The maximum numbers found during winter 2009/2010, however, are not explainable by low *Fucus* cover as the Fucetum was well developed with cover values similar to July 2008 and February 2009. In July 2010 the total number of *L. obtusata* reached only values of summer 2009.

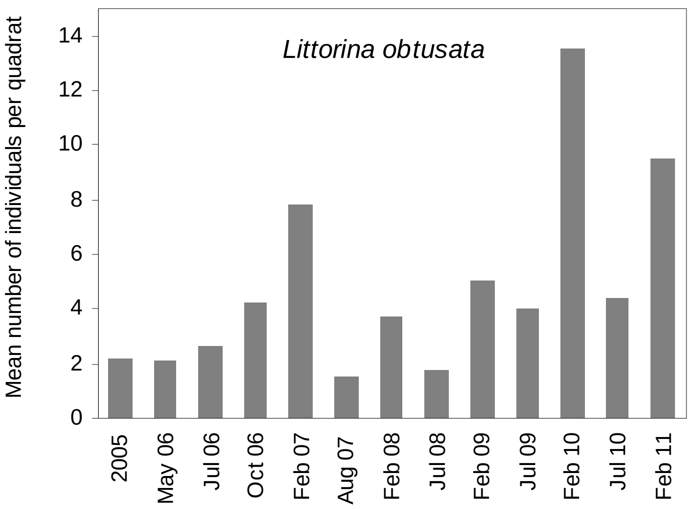

Fig. 14: Number of individuals of *Littorina obtusata* per sample quadrat.

4.3.5 *Gibbula cineraria*

Gibbula cineraria was generally found in low numbers in the areas covered with *Fucus*. Over the last three years an intra-annual abundance pattern seemed to have emerged with low abundances in summer and numbers increasing during winter (Fig. 15). A sampling error has to be considered, since the reduced *Fucus* cover might have facilitated detection of the snails. The clear differences in abundance between sampling periods, however, indicate a real change between seasons.

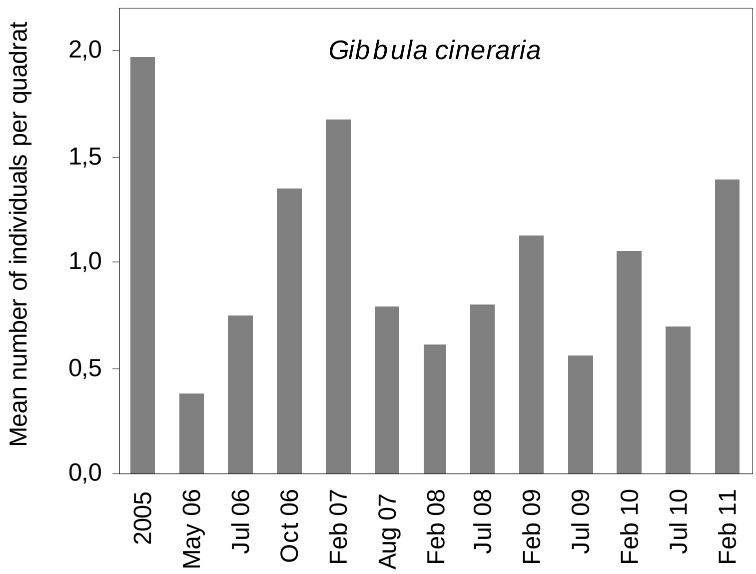

Fig. 15: Number of individuals of *Gibbula cineraria* per sample quadrat.

5 Eulittoral monitoring of the LLUR

The ongoing LLUR-monitoring programme is not part of the WFD-monitoring and not incorporated into the HPI. Results from that study are, however, described in this report because the LLUR-transect is situated in the WFD monitoring grid and thereby provides additional data on the intertidal macroalgal community.

Starting in 2003, the State Agency for Agriculture, Environment and rural areas in Schleswig-Holstein (LLUR, formerly LANU) commenced an annual monitoring of macroalgae along a line transect and with fixed sampling stations in the intertidal of the N-Watt Helgoland. In the first two years the monitoring methods were designed and tested. Following a workshop on the topic in April 2005 the details of the method and a yearly summer sampling was agreed upon. Details of the method were described in previous LLUR reports (Schubert 2006, MMH-Report 3; Schubert 2007, and MMH-Report 6).

Observations 2010 and comparison to previous years

After the great impact of the storms in winter 2006/07 (Kuhlenkamp *et al.* 2009a, MMH-Report 12), the recovery of the vegetation cover was completed in summer 2009 / 2010. In 2010, in both, the transect and fixed quadrats, the *Fucus*-cover reached the highest values ever since the start of the monitoring campaign five years ago.

In summer 2010, mean cover of *Fucus serratus* along the LLUR-transect was 68.0% (Tab. 11), which clearly exceeded the mean values of 2005/06 (62.8% and 62.9% respectively). Number of quadrats containing *Fucus* along the transect had further increased since 2009 to 90 quadrats (2005: 91 quadrats).

Mean cover of *Fucus* in the pre-defined *Fucus*-zone (between transect meter 56 and 156) was reduced after winter 2006/2007, from 96% in 2005 down to 82% in 2007 and reached a maximum of 99% in summer 2010.

Tab. 11: Mean cover of selected species along the LLUR transect in all quadrats and number of quadrats where species were present.

		Fuc_ser	Cla_rup	Cho_cri	Mas_ste	Ulv_lac	Ent_sp	Rhi_tor	Cla_ser
2005	**mean cover**	62.82	11.41	6.06	1.35	2.21	6.23	3.99	6.37
	number of quadrats	91	58	85	28	22	12	28	31
2006	**mean cover**	62.87	9.55	3.51	1.53	1.74	4.28	2.32	1.93
	number of quadrats	94	64	83	30	28	11	29	28
2007	**mean cover**	50.94	14.11	10.18	1.02	5.38	4.55	0.53	2.66
	number of quadrats	73	66	90	25	65	10	26	34
2008	**mean cover**	53.56	9.40	7.83	1.52	1.36	4.68	0.08	0.29
	number of quadrats	79	77	89	42	30	12	16	32
2009	**mean cover**	65.07	6.54	6.79	0.84	1.60	3.68	3.65	2.84
	number of quadrats	87	66	86	29	26	8	26	31
2010	**mean cover**	68.03	5.66	6.00	1.03	1.69	3.84	3.19	7.01
	number of quadrats	90	62	92	39	36	13	21	36

In the group of fixed quadrats (FQs), the number of quadrats with attached *Fucus serratus* was clearly reduced in 2007 (10) and only recovered slightly in 2008 (11; Tab. 12). In 2010, *Fucus* populated 14 of 21 FQs, which was comparable to 2005/06 (17/15 respectively). The mean length of *Fucus* in the FQs showed a clear decline in 2008 due to resettlement in barren areas with young, small individuals up to 31.1 cm in length. In 2010 the mean length was 54.8 cm (Tab. 12, Fig. 16), more than 10 cm longer than in the reference year 2005 (44.4 cm).

Obviously resettlement had accelerated between 2008 and 2009 as the number of attached *Fucus* had risen to 263 individuals, which even exceeded the year 2005 (177 individuals) and was about four times higher than after the storms (Fig. 17). In 2010 the numbers of attached *Fucus* were back to level of 2005/06 with 163 counted individuals.

Tab. 12: Mean lengths of *Fucus serratus* in the fixed quadrats (FQs).

quadrat	species	mean length 2005	mean length 2006	mean length 2007	mean length 2008	mean length 2009	mean length 2010
O 15	Fuc_ser	23.75	28.50	-	-	16.00	16.00
M 15	Fuc_ser	24.33	22.83	-	-	-	-
U 15	Fuc_ser	17.00	18.00	-	16.50	31.00	-
O 30	Fuc_ser	16.00	25.67	-	-	-	21.00
M 30	Fuc_ser	22.00	-	-	-	-	-
U 30	Fuc_ser	-	-	-	-	-	-
O 54	Fuc_ser	19.00	19.00	-	19.50	27.38	23.67
M 54	Fuc_ser	27.00	-	-	-	19.50	22.67
U 54	Fuc_ser	-	-	-	-	21.00	-
O 69	Fuc_ser	51.44	46.69	71.40	29.82	40.70	37.46
M 69	Fuc_ser	38.33	53.40	19.75	23.00	41.46	53.23
U 69	Fuc_ser	-	-	-	21.00	-	-
O 91	Fuc_ser	47.71	64.00	36.82	34.30	43.24	54.73
M 91	Fuc_ser	35.25	73.80	53.00	-	55.33	73.33
U 91	Fuc_ser	22.00	-	27.00	-	-	18.00
O 122	Fuc_ser	49.25	51.22	39.67	46.92	63.33	78.89
M 122	Fuc_ser	39.96	42.25	50.94	46.95	43.73	52.71
U 122	Fuc_ser	-	-	-	-	57.00	-
O 149	Fuc_ser	48.00	58.13	68.86	25.59	43.52	48.84
M 149	Fuc_ser	49.76	64.69	68.75	28.90	47.02	63.52
U 149	Fuc_ser	63.53	69.75	65.50	23.45	44.15	70.58
	mean	44.40	50.39	49.71	31.11	43.63	54.83
	st dev	22.07	24.66	23.47	15.53	18.75	25.89
	number of quadrats	17	14	10	11	15	14

The length distribution of *F. serratus* on Helgoland is only recorded by the LLUR-monitoring programme and showed specific changes in mean length and number of individuals after the disturbance in winter 2006/2007. In summer 2007 following the physical impact, mean length was unchanged (apparently because all length classes were affected similarly), whereas the number of individuals had decreased significantly. In the second year (2008), mean length decreased considerably due to recruitment with young plants while the number of individuals was about three times higher than in summer 2007. This trend stopped in 2010 with lower numbers of attached algae and a high mean length.
The mean length showed a high standard deviation, because of a generally high variability of length in *Fucus* plants and too few replicates.

The exceptionally cold winter of 2009/10 had no negative effect on the *Fucus* cover. *Fucus* showed a stable abundance with large plants and a dense cover, which was also confirmed by the grid monitoring (Chapter 4.1).

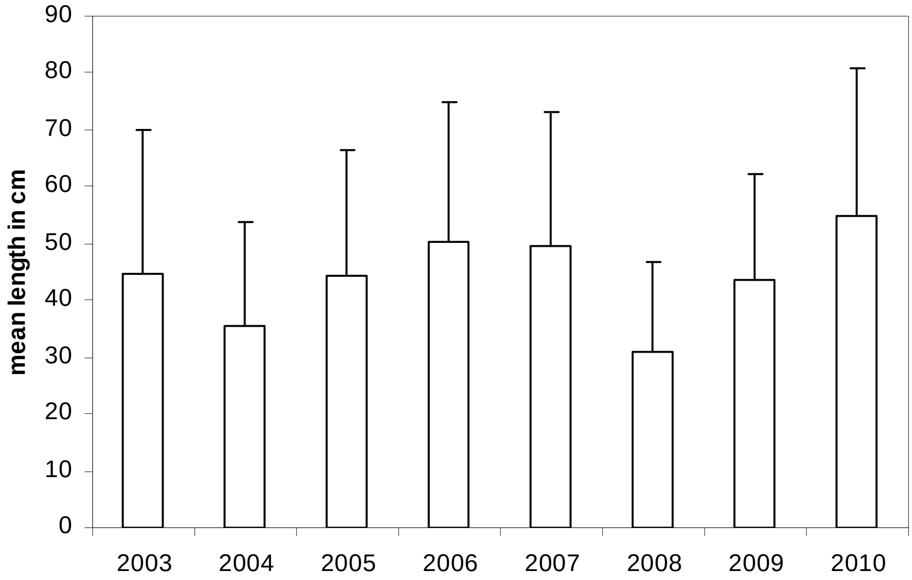

Fig. 16: Mean length of *Fucus serratus* in the fixed quadrats.

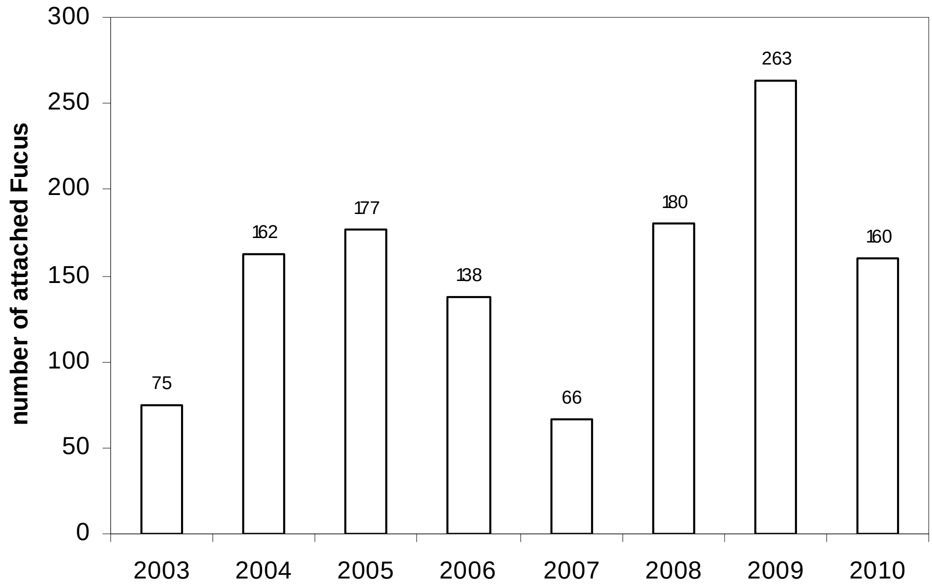

Fig. 17: Total number of attached individuals of *Fucus serratus* in the fixed quadrats.

Considering the non-*Fucus* understorey species, a consistently lower coverage was detected in 2009 than in the years following the storm winter (Fig. 18). This trend even intensified in 2010, with a mean cover of *Cladophora rupestris* along the transect of only 5.7%, representing the lowest value since the start of the monitoring programme and indicating a possible negative effect of high *Fucus* cover on *Cladophora*. Mean cover of *Chondrus crispus*, a species that benefited greatly from the loss of *Fucus*, showed values comparable to pre-disturbance. Quite similar in habitus, the species *Mastocarpus stellatus* did not show any significant changes in mean cover over years.

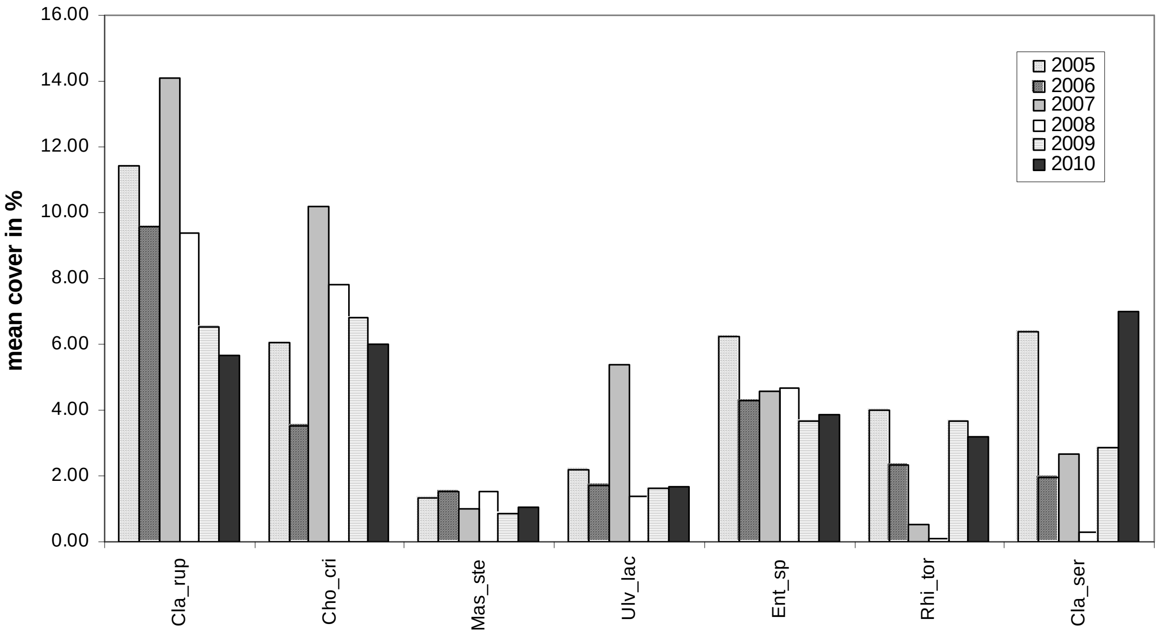

Fig. 18: Cover of selected seaweed species averaged over all quadrats of the transect.

In 2007, the green alga *Ulva lactuca* doubled its mean cover (Fig. 20) and the number of quadrats in which *U. lactuca* was found along the transect was more than twice as high as before (Fig. 19). In 2008, *Ulva* cover was back to pre-disturbance values and only slightly increased in 2010.

Enteromorpha spp. showed a slight downward tendency since 2005 and was generally present with only low abundances in the *Enteromorpha*-Zone of the transect until 2009. In 2010 however, *Enteromorpha* slightly increased as most of the ephemeral green algae.

Mean cover of other green algae like *Chaetomorpha ligustica* (*Rhizoclonium tortuosum*) and *Cladophora sericea* was very high in 2010, especially compared to 2008, when very low abundances of these species had been recorded

(Kuhlenkamp *et al.* 2009a, MMH-Report 12). The high variability of this group between consecutive years complicates the interpretation of results especially in terms of evaluation for the water quality as no general trend can be identified.

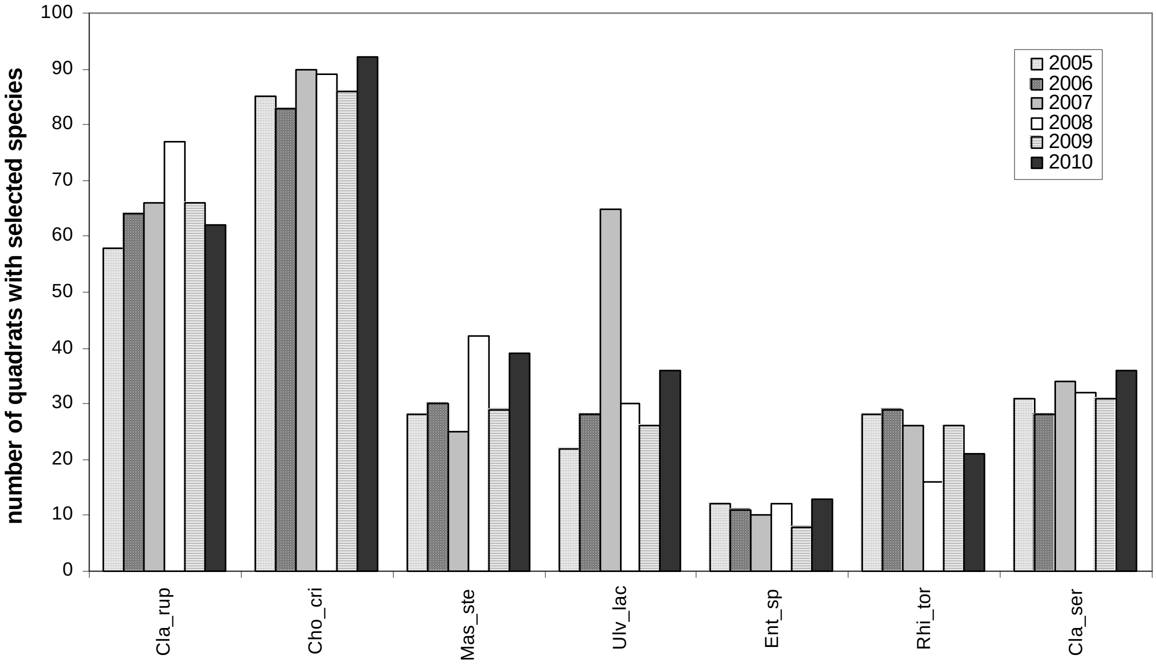

Fig. 19: Number of quadrats along the transect which showed presence of the selected seaweed species.

Blue mussels (*Mytilus edulis*) in the rocky intertidal of Helgoland decreased gradually in numbers since the start of the monitoring programme. In 2010 this trend reached its hitherto minimum. Along the whole transect 14 mussels were found, roughly 4% of the abundance recorded in 2005, but for the first time more than in the previous year. In the FQs, number of mussels also decreased greatly since 2005, in some quadrats by up to 39 individuals. But in 2010 the number of fixed quadrats with attached *Mytilus* increased for the first time since 2005 compared to the preceding year.

In 2007, the first three individuals of the pacific oysters (*Crassostrea gigas*) were found in the course of the LLUR monitoring programme. In 2010, seven oysters were found, the same number like in 2008. Compared to other substrata in the German Bight and even on Helgoland (like harbour walls and concrete), the rocky intertidal of Helgoland seems to be less suitable for an invasion of the Pacific Oysters, as numbers stayed low until now.

6 Intercalibration

In order to develop a WFD assessment tool for the macrophytobenthos at Helgoland, the Helgoland Phytobenthic Index (HPI) applied a new integrative concept adapted to the special situation at Helgoland which prevented the sole usage of one of the hitherto established indices only.

In contrast to many other regions, calibration of its indicator systems is impossible at Helgoland due to missing environmental gradients within the small water body, preventing the application of a reference-based evaluation for eutrophication and other stressors (Bartsch & Kuhlenkamp 2004). Furthermore, only few historical abundance data for macroalgae at Helgoland are available. In order to overcome these limitations, the main concept meant to integrate several metrics. The HPI combines indicators with fast (green algae) and slow response (*Fucus* cover, depth limit) to environmental changes thereby including several components which could reflect adverse changes in biological quality (Tab. 13). The HPI evolved stepwise, beginning with the analysis of historical data in order to extract a baseline for the undisturbed reference situation as required by the WFD (Bartsch & Kuhlenkamp 2004).

Tab. 13: HPI-metrics and their indicator properties

IP	Environmental factor	Time-scale	Metric	Properties	Effects on
Stress-sensitive taxa, abundance	Nutrients	Month	**Green algae *Ulva lactuca***	Opportunistic; early successional	Production; covering other species
Stress-resistant taxa, abundance	System stability	Year	**Fucetum: dense *Fucus***	Perennial; dominant structuring species	Top-down control; diversity
Depth limits	Water-turbidity	Several years	**Sublittoral depth limits**	Light dependence	Zonation; production
Taxonomic composition	General change	Several years	**RSL**	Biodiversity	Diversity, structure

Structurally based on the RSL-method (Wells et al. 2007), several modules were integrated into the HPI using species richness, abundance, occurrence of specified algae, extent and cover of dominant structuring macroalgae and the depth limit of selected sublittoral algae. One major change compared to the British RSL was the definition of new class boundaries and species lists. As the general structure of the RSL index and the matrix used for conversion of measured values including the calculation procedures for the EQR seemed practicable and useful it was used as a basis for the HPI. Class boundaries and the RSL species lists applicable for European countries, however, were modified according to the situation at Helgoland. Besides qualitative measurements, the WFD requires quantitative data which facilitate evaluation of marine macroalgal communities in relation to natural changes of ecosystems and to anthropogenic influences (European communities, 2009). The HPI therefore integrates several qualitative and quantitative modules (metrics). The number of metrics included exceeds those of other European systems developed within the North Atlantic Intercalibration Group (NEA-GIG) (Tab. 14).

The new HPI evaluated the ecological water quality at Helgoland with results similar to those achieved by expert judgement and hindcasting done in previous studies (e.g. Bartsch & Kuhlenkamp 2004). The HPI is highly compatible to WFD systems in that it fulfils requirements regarding the different ecological quality parameters like abundance data, species richness, indicators for eutrophication, long-term indicators and structuring elements of marine ecosystems. Its shortcoming however is the missing possibility to apply a proper calibration along environmental gradients. Although the water type N5 for Helgoland was considered unique, the habitat and flora is adequately related to other North European coastlines such as southern Norway, Denmark (Kattegat), and Scotland (Kraberg and Bartsch, unpublished) and thereby would allow an intercalibration with UK, DK, NO and S on floristic reasons and could be incorporated into the international intercalibration process of the NEA-GIG.

Tab. 14: Details of national methods used in the NEA-GIG. Each method is listed with its specific metrics. The HPI is not yet internationally implemented, but listed for comparison. (Based on European Communities, 2009; Carletti and Heiskanen, 2008)

Index	Full name	State	Metrics
RSL	Reduced Species List	Great Britain Ireland Norway	Species Richness Proportion red algae Proportion green algae Proportion opportunists ESG-ratio Coastal correction
CFR	Quality of rocky bottom	Spain	%-cover characteristic algae Richness of characteristic algae % cover opportunists
P-MarMAT	Portuguese Marine Macroalgae Assessment Tool	Portugal	Richness Proportion red algae Proportion green algae Proportion opportunists ESG-ratio Coastal correction Abundance opportunists
MAB	Macroalgae Blooming	Germany (WaddenSea) Great Britain Ireland	%-cover green algae Area Biomass
Sublittoral algae		Norway Sweden	Depth extension of selected algae Cover of sublittoral community
HPI	Helgoland Phythobenthic Index	Germany: Helgoland (water type N5)	Species richness Proportion red algae Proportion green algae Proportion opportunists ESG-ratio Green algae blooming abundance Fucetum (*Fucus*-cover) Depth extension selected algae

During recent months, contact was established to the head of the NEA-GIG sub-group 'Coastal macrophytobenthos', José A. Juanes from Spain, initiated by the German representative of this NEA-GIG, W. Heiber. Under the auspice of J. Juanes' working group an initiative has been started to newly define the European water bodies with the help of an objective and scientific approach. Although re-consideration of WFD water types might be dangerous from the administrative point of view (re-evaluation of water types leading to new groupings etc.), it seems to be fruitful with respect to an international calibration process. In short, European data were collected on coastal habitat structure, irradiance, sea-surface temperatures, salinities etc. to establish a convincing European coastal classification system based on physical habitat features. All data were integrated in a Geographical Information system (Ramos et al. 2011, submitted). In a second step, floristic data shall be applied to this system in order to show related areas. Intercalibration could then be performed between nations and water types (habitats) with a close relationship. The process is ongoing and several documents have been distributed within the NEA-GIG community. We were invited via W. Heiber to comment on these developments and also to hand in data for Helgoland. We delivered a species list for Helgoland according to the required master list and also developed a list of structuring species being present with more than 5% cover at Helgoland. These were sent to the NEA-GIG.

It becomes evident that the HPI has developed a similar approach as some other countries, e.g. Spain, by integrating diversity information with quantitative data and partially also depth limits. An overview about existing approaches is given in Table 14. Whether Helgoland will become part of the intercalibration process is not foreseeable yet. As the Helgoland water body is unique it was not considered in the first NEA-GIG Intercalibration phase. Meanwhile UK, IRE and NO intercalibrated the RSL index, S and NO intercalibrated the sublittoral depth limit and IRE and UK intercalibrated the 'Opportunistic macroalgae tool'. All three metrics are part of the Helgolandic HPI and could theoretically be intercalibrated with the respective countries. Whether a second Intercalibration, as required by WFD, will take place in 2011 is still uncertain, but we strongly recommend participating if possible. Otherwise the Helgoland HPI will always stay alone and thereby will have less impact and less chance to be published.

The HPI fulfils all preconditions as required by the Guidance 14 document of the Common Implementary Strategy (CIS) for the WFD. Within the complex of status classification, the HPI conforms to the five required ecological classes corresponding to the normative definitions of the WFD. Numerical evaluation is based on relevant parameters indicative of the biological quality elements and works within the typological ranges given by the WFD. Based on a reference situation, the final numerical result is expressed as an EQR. Data acquisition provides representative spatial and seasonal data through a yearly to biannual monitoring procedure. The relevant biological parameters are accessed by data on abundance, sensitive taxa, depth limits etc. In all metrics of the HPI, highest taxonomic standards are assured in order to provide adequate precision in the classification of species. As required, the metrics of the HPI, describe the pressures indicative of the impacts working in the system by using the adequately selected parameters.

In order to intercalibrate, the method needs to fulfil certain acceptance criteria. Since typology is one of the restricting factors, the HPI cannot strictly comply here, because it is at moment only applicable to the very small and specific water body N5 within the NEA-GIG and represents only one measurement point. In order to overcome the shortcomings of a restricted water body, the HPI should intercalibrate with areas in other member states of the NEA-GIG providing similar typology and floristic composition, like certain coastlines of Great Britain, Norway and Denmark. Since the modules of the HPI correspond to indices of other countries in the composition of the metrics used to assess the required indicators of biological quality (see Tab. 14), the HPI complies with the key principle 6 of the CIS guidance No.14 in that methods can intercalibrate partially. In our case, several metrics of other countries are applicable due to similar methods and parameters (Tab. 15). It needs to be further investigated if also data and typology provide an adequate basis for an intercalibration process.

Tab. 15: HPI modules and their possible calibration partner modules in assessment indices of other NEA-GIG countries

HPI module	Equivalent module	NEA-GIG member state
Module SR (species richness)	RSL	UK, NO, IRE
Sublittoral depth limits	Sublittoral indices	NO, S
Opportunistic green algae	Opportunistic algae tool, CFR, P-MarMat	UK, IRE, (ES, PT)

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8 Appendix

8.1 General descriptive protocol - monitoring July 2010

Sampling period: 9.7. – 24.7.2010

Photographs: R. Kuhlenkamp

General descriptions and details of the sampling area:

Mild winter seasons, especially the unusually mild winter in 2008/2009 were responsible for many algae to have started with new outgrowth already by February like *Cladophora sericea*. In February 2010, however, a severe frost period led to the idea that intertidal species might be affected by the cold and would appear in the following summer with fewer numbers and lower abundance than during the previous summer periods. Instead, the quadrat sampling of the monitoring grid in summer 2010 showed abundances comparable to summer 2009 while the species list for the SR-module of the HPI recorded only three species less than the year before, indicating that most species were well adapted to cold winter seasons even after many years with mild winters.

Bleached algae due to strong insolation at low tide

Another sign of calm weather conditions and strong insolation during low tide in combination with warm temperatures during summer was the bleaching of thalli of some intertidal and upper subtidal species. *Laminaria digitata* developed light damage in parts of the blades exposed directly to sunlight during low tide (Fig. 20 left). This was observed within the short sampling period of two weeks in summer 2010. And even some *Chondrus crispus* stands, growing in the upper and mid-eulittoral and used to exposure during low-tide, became badly damaged during prolonged and strong sunlight exposure (Fig. 20 right).

Fig. 20: 19.7.2010: Bleached *Laminaria digitata* (left) and *Chondrus crispus* (right) due to strong insolation.

8.1.1 Description of the polygon areas and specific biotopes

Enteromorpha*-zone*:

The area was nearly completely covered by *Enteromorpha* recognisable by the high abundance during summer 2010 (Fig. 21, left), but this year not all patches showed a 100% cover. *Enteromorpha* plants were well developed and *Ulva lactuca* and *U. linza* were present. The border between the dense *Fucus* cover and the *Enteromorpha*-Zone was mostly well developed and showed signs of whiplash by *Fucus* plants (Fig. 21, right).

Fig. 21: *Enteromorpha*-zone with patches of dense *Fucus* (left). Border area between dense *Fucus* cover and *Enteromorpha* (right).

In July 2010, the sloping area with sand and pebbles in the upper eulittoral close to the western edge of the monitoring grid (near Lange Anna) was covered with a dense layer of decaying drift algae indicating a long period of calm weather conditions for the N-Watt (Fig. 22).

Fig. 22:
Details of the western *Enteromorpha*-zone: decaying layer of algae within elevated ridges of sandstone covered partly by *Fucus*.

Area of dense *Fucus*-cover

The area with dense *Fucus* cover was well developed in July 2010 (Fig. 23) and its >90% cover border easily recognisable. D-GPS measurement of the *F. serratus* polygon for the HPI module Fucetum was therefore facilitated and could be performed with high accuracy. Most of the area exhibited 100% *F. serratus* cover as in 2005/2006.

Fig. 23: Area of dense *Fucus serratus* viewed from the upper eulittoral.

Generally, the *Fucus* cover was similar in density and extension as in 2009, often showing thick, well-developed thalli (Fig. 24).

Fig. 24: Quadrat sampling at the station 101 in the lower eulittoral of the dense *Fucus serratus* area: typically thick and complete cover by *F. serratus*.

Barren areas with degraded *Fucus*-cover

The barren area was still characterised by only sparse or no *Fucus* cover. Additionally, a high abundance of *Chondrus* and several ephemeral green algae and high numbers of *Littorina littorea* were typical (Figs. 25 and 26). Like in previous summers, *Chaetomorpha ligustica* had appeared in thick and extensive mats in the mid-eulittoral and was loosely attached to small durable and perennial algae like *Chondrus crispus*. But this time it was also intermingled with *Cladophora sericea,* which was present on exposed bedrock during low tide in contrast to *Chaetomorpha ligustica* which appeared to grow more often in or close to tide pools.

Fig. 25: Area of degraded *Fucus* with small patches of *Fucus vesiculosus* (left).
Large cluster of *Chondrus crispus* were often covered with dense mats of *Chaetomorpha ligustica* (right).

Fig. 26:
Detail of a barren area with degraded *Fucus* cover (Station 50).

Rhodothamniella area

In the lower eulittoral, close to the *Laminaria*-girdle, elevated parts of the abrasion platform are covered by a specific turf community. The species composition is relatively constant with additional species depending on the season. During July 2010 this turf area was partly covered by *Ulva lactuca* and a thick sediment layer was found to be always present in this special area (Fig. 27). *Rhodothamniella floridula* is the main turf-species always growing in the sediment layer, but this summer only little of that community was visible. Much of the *Rhodothamniella* mat was covered by sand and sediment.

Fig. 27: *Rhodothamniella* area. View from the southern tip towards the lower eulittoral of the monitoring grid (left). Cover of *Ulva lactuca* on the turf community and patches of the sediment layer with only little *Rhodothamniella* visible (right).

Laminaria belt

After the severe decrease of *Laminaria digitata* during the very warm summer in 2006, which had coincided with low tides, and after the storm winter 2006/2007, high densities were again observed in July 2010. Much of the community had already recovered in 2009 (Fig. 28).

Fig. 28: View of the transition zone between the area of dense *Fucus* cover and the *Laminaria*-girdle with well developed *Laminaria digitata*.

8.1.2 Specific remarks

Green algae

- *Chaetomorpha ligustica* showed very high densities in summer 2010 in the barren area either on the elevated parts populated by *Chondrus* or in the channels and tide pools (Fig. 29).

Fig. 29: *Chaetomorpha ligustica* in the barren grounds loosely attached and floating in tide pools.

- *Cladophora sericea* was often found in combination with *Chaetomorpha ligustica* (Fig.30).

Fig. 30: *Cladophora sericea* intermingles with *Chaetomorpha ligustica* in the barren area (above) or in small tide pools (below).

Turf algae:

The small, but distinct area at the high eulittoral sample station 31 is always exhibiting a dense cover of mostly turf-like species growing firmly attached to the sandstone bedrock (Fig. 31). Some *Fucus serratus* or *F. vesiculosus* specimens are occurring within, but they never establish a continuous cover.

Fig. 31: Turf-community at station 31 with interspersed specimens of *Fucus*.

Molluscs:

Next to old specimens of *Crassostrea gigas*, quite a few young ones were found within the grid stations (Fig. 32). As pointed out before, this species had survived the severe winter quite well.

Fig. 32:
Young specimen of C*rassostrea gigas* in a sample quadrat in the mid-eulittoral of the dense *Fucus* zone.

The first time since the start of the monitoring programme, one specimen of *Modiolus barbatus* was found within a sample quadrat (Fig. 33). This species has been recorded by Harms (1993) for Helgoland but has not before been recorded during the intertidal monitoring programme since 2005.

Fig. 33:
Modiolus barbatus in the mid-eulittoral attached to stones.

8.2 General descriptive protocol - monitoring February 2011

Sampling period: 31.1. – 17.2.2011
Photographs: R. Kuhlenkamp

General descriptions:

During winter 2010/2011, low temperatures with prolonged frost periods already occurred in November 2010, giving winter conditions an early start. The floristic aspect in February 2011, however, showed an intermediate position between that of last winter, when January and February exhibited strong winter conditions, and that of February 2009 with very mild temperatures not below zero. Several species indicative of warm spring temperatures like *Cladophora sericea* were found to have started outgrowth in February 2011, albeit in very small quantities. Remnants of *Chaetomorpha ligustica*, which had been developed the summer before, were found as well as the sporophytic phase of *Bonnemaisonia hamifera*.

Renewed and continuous physical stress through abrasion by rocks, sediment and shell debris seemed to have occurred during these winter months. In the western part of the monitoring area, the rocks on the shore platform in front of the cliff derived from the collapse of a large rock face in Winter 2006/2007 had become dislodged (compared to the situation in July 2010) and were eroded by wave action producing many smaller rock and debris (Fig. 34) which were carried away into the lower areas of the intertidal. A similar situation occurred in the eastern part, where rocks and pebbles in front of the cliff had been moved further down into the *Enteromorpha*-zone (Fig. 35) compared to former situations in summer or winter, when the borderline of rocks and pebbles was further up the shore.

Generally, many patches within the monitoring grid were found to be influenced by loosely lying shell debris or pebbles (Fig. 36).

Fig. 34: Western area of monitoring grid: upper border with large rocks from cliff collapse in 2006/2007 now eroded and dispersed.

Fig. 35: Eastern area of monitoring grid: upper border with rocks and pebbles being moved further down into the Enteromorpha-zone.

Fig. 36: Cover of shell debris and pebbles in area with *Fucus serratus*, *Chondrus crispus* and *Cladophora rupestris* in the mid-eulittoral.

8.2.1 Description of specific biotopes

Enteromorpha*-zone*:

The border between the dense *Fucus* cover and the *Enteromorpha*-zone was still well developed whereas the *Enteromorpha* cover was strongly reduced and only present on high ridges obviously not affected by abrasion (Fig. 37).

Fig. 37: Denuded *Enteromorpha*-zone at border to dense *Fucus*-patches.

In areas close to the upper limit of the monitoring grid which are directly influenced by debris and rocks form the cliff, much of the area was completely barren (Fig. 38).

Fig. 38: Details of *Enteromorpha*-zone grid position 45: completely barren sandstone substratum.

In the eastern part of the *Enteromorpha*-zone a distinct elevation was always found to be covered with *Fucus* (Fig. 39) while *Enteromorpha* showed clear differences in cover depending on season, the severity of abrasion and temperature conditions during winter (winter 2008/2009 was a very mild winter without prolonged frost period) (Fig. 39, 40).

Fig. 39: February 2011. Details of *Enteromorpha*-zone with characteristic elevation covered with *Fucus*: highly denuded *Enteromorpha*-cover.

Fig. 40: Same elevation covered by dense *Fucus serratus* within the *Enteromorpha*-zone as in figure 39 with well developed cover in February 2009 (left) and July 2009 (right).

Area of dense *Fucus*-cover

In February 2011, the dense *Fucus* cover was far less developed than in the summer before. The usually uniform and dense cover exhibited many open patches (Fig. 41, 42).

Fig. 41: Area of dense *Fucus serratus* viewed from the mid eulittoral towards the *Rhodothamniella* patch.

Fig. 42: Area of dense *Fucus serratus* viewed from the mid eulittoral towards the cliff.

Ridges which had been populated by a dense cover of *Fucus* during summer were often denuded and showed understorey algae or bare substrata (Fig. 43). The same was true for most sample quadrats. Even those samples in prospected areas of dense *Fucus* cover did not exhibit a 100 % coverage. A coverage of 98% was the highest value and only 15 quadrates exhibited a coverage > 90% (Fig. 44).

Fig. 43: Ridges covered by *F. serratus* in summer showed many open patches in winter 2010/2011.

Fig. 44: Grid position 111: Sample quadrat with high density (95%) of *F. serratus* in February 2011.

Barren areas with degraded *Fucus*-cover

The barren area was still characterised by sparse or no *Fucus* cover (Fig. 45). Additionally, a high abundance of *Chondrus crispus* and several ephemeral green algae and a relatively high numbers of *Littorina littorea* were fairly typical even in February. Remnants of *Chaetomorpha ligustica* were present: Next to perennial algae like *Chondrus crispus* many young plants of *Monostroma grevillei* were found.

Fig. 45: Area of degraded *Fucus*. Left: view towards cliff. Right: view along tidal channels towards low water tide level.

Transition area between *Enteromorpha*-zone and *Fucus*-areas

In some places the lower border of the *Enteromorpha*-Zone was very distinct and showed an extremely clear-cut borderline to patches of dense *Fucus*-cover (Fig. 46). Even after erosion and reduction of plant-cover during winter, the distinct areas were clearly discernable and borders did not change position. During winter, the *Enteromorpha*-cover within the *Enteromorpha*-Zone was nearly completely eradicated except for small areas in top-level positions (Fig. 46, right image, left side) and the dense *Fucus*-cover had become very patchy. Obviously erosion by gravel and other debris from the cliff explains the difference in cover between low-lying and top-level positions of *Enteromorpha*. Once established, *Fucus* seems to resist a certain abrasion (Fig. 47) even in low-lying areas where debris was most effective.

Fig. 46: View of abrupt transition from the *Enteromorpha*-zone to patches of dense *Fucus*-cover and barren area. Left: summer aspect in July 2010. Right: winter aspect in February 2011.

Fig. 47: *Enteromorpha*-zone in February 2011: patches of dense *Fucus*-cover withstood erosion by sandstone debris while the understorey-cover was completely eradicated and *Enteromorpha* in higher positions was not affected.

Laminaria belt

Laminaria digitata was well developed in February 2011 and covered the usual areas within the monitoring grid near the low water tide level (Fig. 48). Even though *Fucus* showed reduction in cover, *Laminaria digitata* appeared healthy and not affected (Fig. 49).

Fig. 48: View of the transition zone between the area of dense *Fucus* cover and the *Laminaria*-girdle with well developed *Laminaria digitata*.

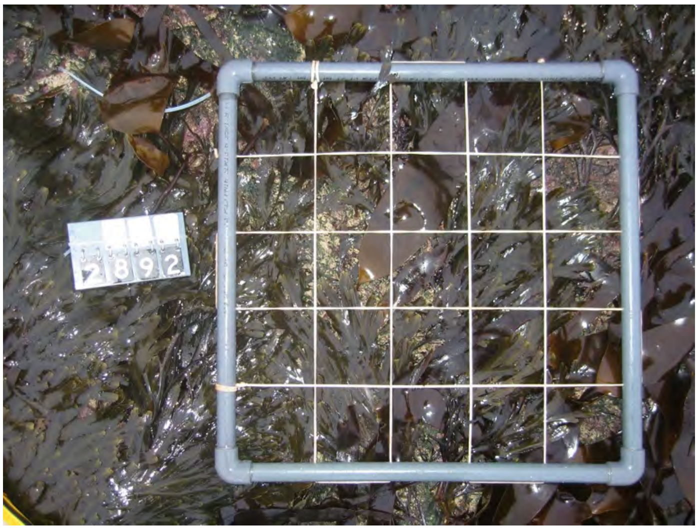

Fig. 49: Grid position 104. View of the transition zone between the area of dense *Fucus* cover and the *Laminaria*-girdle with well developed young *Laminaria digitata*.

8.2.2 Specific remarks

Despite the severe winter conditions in November and December 2010, *Ulva lactuca* was present in small patches with relatively large plants up to 15 cm in length (Fig. 50).

Fig. 50: *Ulva lactuca*: small patches of well developed plants interspersed in the dense *Fucus*-zone.