Biotope Mapping of the Intertidal Zone of Heligoland (North Sea) Using Hyperspectral Remote Sensing Images

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Introduction

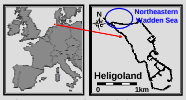


Fig. 1: Location of the test area

The island of Heligoland is located in the North Sea at about 54°11'N and 7°53'E (Fig. 1). It extends about 0.9 km² and was formed by an uplift of Mesozoic red sandstone (redsand) above a salt dome during the Tertiary period. The upper island rises about 50 m above sea level showing a typical cliff coast.

Fig. 2: Overview from the upland

The rocky shore is an abrasion platform also built of red sandstone, partly covered by man made hard substrate boulders (granite, basalt, concrete), especially near the sea- and harbour walls. The intertidal platform is geomorphologically structured by distinct creeks (Fig. 2). The test area in focus comprises approximately 350 m x 500 m.

Fig. 3: The visual appearance of the main communities *(photos: I. Bartsch)*

Most of the intertidal platform is characterised by algal dominated communities. Besides these sites there are other visually distinct areas present that are either characterised by the substrate type or by the water body. All relevant expected classes are listed in the Table on the right hand side; examples of communities are given in Fig. 3.

The communities create a small-scaled mosaic within the horizontally orientated areas of the intertidal. They are mostly visually discernable by the naked eye.

Code	Community or substrate	Zone
Fser dense	Dense fucoids mainly composed of the dark brown alga *Fucus serratus*	Lower intertidal
Fser degraded	Cover of fucoids reduced, thereby showing a variety of crustose, red and green algal species	Lower intertidal
Mas	dense cover of the visually dark red algae *Mastocarpus stellatus* and/or *Chondrus crispus*	Middle to lower intertidal
Ent/Por	Band of dense tubular or bladelike light-green algae	Middle intertidal near cliffs
Rho	*Rhodothamniella* biotope; small patches within the dense fucoids covered by light-green algae (*Ulva* sp.)	Lower intertidal
Cor	mixed flora characterised by calcareous red algae often overgrown with seasonal green and brown algae; covered with water during low tide	Intertidal channels
Myt	sparsely vegetated areas dominated by the blue mussel *Mytilus edulis* and limpets; crustose algae and few red and brown algae present	Middle intertidal
SemLitX	sparsely vegetated areas dominated by barnacles and limpets; crustose algae and few fucoids and red algae present	Middle intertidal
Ldig	Dense belt of laminarian kelps (*Laminaria digitata*) with a light-brown colour; mostly water covered during low tide, in part floating on water surface	Sublittoral fringe
Sar	Dense cover of the light-brown invasive species *Sargassum muticum*, floating in part on water surface and invading channels	Sublittoral fringe and intertidal channels
redsand	Non-vegetated red sandstone areas	land
rock	Non-vegetated areas other than red sandstone	land
sandy bottom	Water covered inlets covered by sand or defractured shells	sublittoral
Sub-littoral	Vegetated sub-littoral areas	sublittoral
water	Supposed non-vegetated pure water	sublittoral

Tab. 1: Description of communities and substrate types

Data & Methods

The Reflective Optics System Imaging Spectroradiometer (ROSIS) is an airborne push broom scanner with 512 spatial and 115 spectral pixels recording in the wavelength range between 430 nm and 860 nm. Technical details are given in the Table on the right.

On July 16th, 2002 and September 5th, 2003, ROSIS data were acquired during low tide over the test area in Heligoland.

- Radiometric correction: laboratory measurements to convert counts into radiance values
- Atmospheric correction: parametric program ATCOR-A for airborne data after Richter (1996) resulting in surface reflectance
- Geometric correction: parametric calculation of the flight angles roll, pitch, and heading (yaw) registered by the airplane's inertial system after Müller et al. (2002) plus adjustment via GCPs

Spectral range	430 - 860 nm
Sampling interval	4.0 nm
Number of spectral bands	115
Pixel per scan line	512
Radiometric quantisation	14 bit
Field of view	± 8,7°
Instantaneous field of view	0.59 mrad
Pixel size at 1600 m altitude	1 m x 1 m
Possible mirror tilt in flight direction	± 20°

Tab. 2: ROSiS technical data

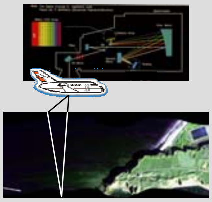


Fig. 4: ROSIS scanning system

Compared to the existing in situ biotope map and other field informations, the results by standard classification methods remained unsatisfactory. Therefore, a stepwise (here called: hierarchical) classification scheme was developed based on ROSIS spectra from the spectral library after extended spectral inspections of all present characteristic biotopes or substrates (see Figure 6 on the right). The most representative spectrum for each class (Fig. 6) was determined heuristically and used as endmember for the further classification (Fig. 5).

The result of each step was masked out from the rest of the scene. The scheme developed for this is shown on the right (Fig. 5).

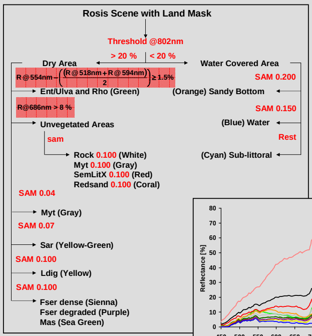


Fig. 5: Hierarchical classification scheme

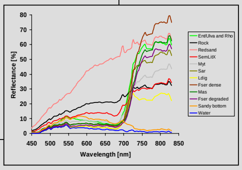


Fig. 6: Endmember spectra

Results

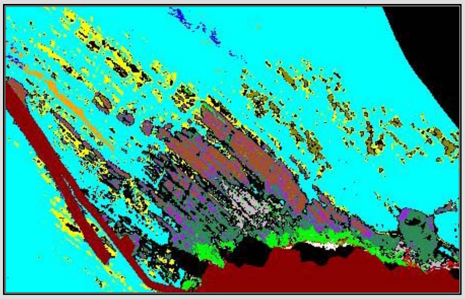
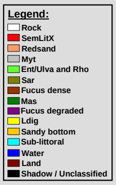


Fig. 7: Resulting biotope map generated from the 2002 ROSIS data

Rock, Myt, Ent/Por and Rho, Fucus dense: extent could be well detected in comparison with in situ biotope map
Fucus degraded, Mas: reduced and mixed Fucus are difficult to discriminate - more in situ spectral information is needed
Sar: its spread is doubtful due to lacking field information
Ldig, Sub-littoral: the sublittoral continuity of Ldig covers was not verified in detail by diving observation, but the general occurrence is known
SemLitX: its spread is doubtful here, but fits much better in other regions within the scene
Sandy bottom: is according to in situ observed location in a deep channel



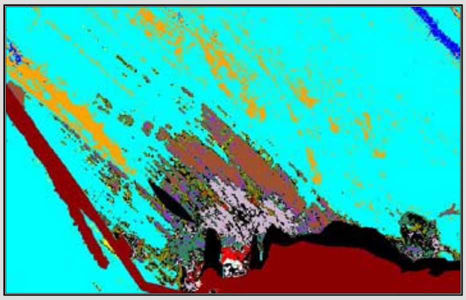


Fig. 8: Resulting biotope map generated from the 2003 ROSIS data

SemLitX: occurrence does not conform to biological situation; re-interpretation of class needed as well as better spectral field informations

Rock, Myt, Ent/Por and Rho: extent differs due to especially dry preceding summer and different shadow situation; ‚Myt' biologically includes part of ‚Fucus degraded'
Fucus dense: extent is congruent with biotope map and 2002 ROSIS data
Fucus degraded, Mas: the same problem as in 2002 data
Sar: is reduced to channel regions and very doubtful
Ldig, Sub-littoral: extent changed due to different water cover compared to 2002
Sandy bottom: differs due to assumed greater spread caused by strong winds and heavy sea; delimitation problematic from sun glint and partially ‚Ldig' class

Discussion and Conclusion

- Hyperspectral airborne data support mapping of major small-scaled intertidal communities and/or status of the vegetation.
- Remote sensing data provide a synoptic view, a major prerequisite for the generation of time series
- The remote sensing classes do not coincide with those mapped in situ.
  This can be explained by the different approach of separability - spectral differentiability versus biological knowledge of species composition and their abundances.
- Green algal dominated sites generally had to be aggregated in one class although they comprise several biotopes.
- Some biotopes like *Corallina* tidal inlets could not be spectrally detected at all.
  This is probably explained by their variable species content and water cover.

→ More knowledge of the spectral characteristics of the different visually dominating species within biotopes is needed.
→ Field work with a portable spectrometer will be necessary in the future.
→ The validation by in situ campaigns in future has to concentrate on areas with overlapping communities or edge situation of communities.

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