REMOTE SENSING AND GIS-TECHNIQUES FOR THE EVALUATION OF MACROPHYTES IN THE GREIFSWALDER BODDEN

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ABSTRACT

There are great demands for information about the distribution of macrophytes in coastal and brackish water areas. Continuous data of distribution of macrophytes as well as detailed information about the structure of the population is required. Defects in the marine ecosystem could be detected only with periodical mapping of the macrophytobenthos. Remote sensing data offer the possibility to observe a large area at the same time and substitute most dives. The aim of the investigations is to test the suitability of digitized aerial photographs and other multispectral sensor data for the evaluation and differentiation of the vegetation under water. Beyond that changes of the macrophyte populations within a short and a long time period will be investigated by multitemporal analysis.

KURZFASSUNG

Es besteht großer Bedarf an Informationen zur Verbreitung von Makrophyten in Küsten- und Brackwassergebieten. Dabei werden einerseits flächendeckende Angaben zur Verbreitung der Makrophyten, andererseits aber auch detaillierte Angaben zur Bestandszusammensetzung benötigt. Periodische Bestandsaufnahmen des Makrophytobenthos sind Voraussetzung für das zeitige Erkennen von Schäden im marinen Ökosystem. Fernerkundungsmaterialien ermöglichen eine flächendeckende Abbildung der Gewässer zu einem bestimmten Zeitpunkt und ersetzen einen großen Teil der Taucharbeiten. Ziel der Forschungen ist es, die Eignung von digitalisierten Luftbildern und anderen multispektralen Sensordaten für die Erfassung und Differenzierung der Unterwasser-Vegetation zu testen. Außerdem sollen die kurz- und langfristigen Veränderungen des Pflanzenbestandes mittels multitemporaler Analysen untersucht werden.

1. INTRODUCTION

The Greifswalder Bodden is an important brackish water area in the southern Baltic Sea. It is the buffer zone between the salty Baltic Sea and the influx of fresh water from the inland, where intensive exchanging, mixing and distribution processes take place. The Greifswalder Bodden is an important economical factor in the region because of the herring-fishery. The macrophytes are the basis for spawning of the fishes and the refuge of young water animals. The macrophytes are an important element in the ecosystem. They take part in the sedimentation, decrease the power of streams, influence the chemical properties of the waterbody and indicate the quality of water. In the last years the demand for information about the distribution of macrophytes in the Bodden area increased. Continuous and quantitative data are required about the distribution of macrophytes, the local structure of population and about the quantitative and qualitative changes of macrophyte communities over time to detect trends inside the marine ecosystem.

Remote sensing data offer the possibility to observe a large area at the same time. The most used method to map or monitor submersed vegetation is the photointerpretation (e.g. Lang, 1969; Remillard, 1992; Ferguson, 1993). Another method is the combination of photointerpretation with measurements of photo-density (Tanaka,1988). Siegels investigations (Siegel, 1992) about the spectral reflectance of sediments and phytobenthos admit the conclusion that benthic organisms can be mapped by digital remote sensing data. Digital procedures of remote sensing are more effective and flexible than analogous methods and they are more suitable for continuous and semi-automated processes and for integration within an information system.

2. STUDY AREA

The Greifswalder Bodden is a 51000 ha large, eutrophic shallow water area in the north east of Germany and in the south of the island Rügen. The average depth is 5.60 m and the maximum depth is 13.30 m. Tidal effect is scarcely noticed. Geomorphology of the bay and the physical and chemical properties of the water are very heterogeneously. Salinity, flow chart, nutrient and sediment transportation change extremely with the wind conditions. All these factors influence plant growth and macrophyte communities. Few species of macrophytes (*Zostera marina*) build up unmixed populations in the bay, the most species form mixed communities (*Cladophora glomerata, Enteromorpha* spec., *Polysiphonia nigrescens, Furcellaria fastigiata, Potamogeton pectinatus, Fucus vesiculosus* and other). The portions of the species in the community and their frequencies depend strongly on the sediment, slope, aspect, light and temperature (Geisel, 1986). Dependent on the season epiphytes (*Ectocarpus*

spec., *Pilayella litoralis, Ceramium* spec.) cover more or less closed the submersed vegetation.
For the studies some special test sites were selected at the south-eastern bight reach coast of the island Rügen. They include different shore types. The main sediment is sand, in front of active cliffs the ground is litter with boulders and rubbles or marl plates. This conditions allow the growth of the most macrophyte communities of the bay.

3. DATABASE

In the last years a lot of different data, images and maps were collected about the test area to find the best combination of information for the evaluation of macrophytes with remote sensing and GIS.
The basis for interpretation and classification was scanned color aerial photographs in transparency format, taken by an photogrammetric camera in 1992 and 1994. In addition color negative photographs were made with the amateur camera Rollei Metric 6006 at a Cessna in 1994 and 1995 in the scale of 1:5000.
Investigations were made to evaluate the best time period for taking the photos representing sufficiently the underwater vegetation. It is important to make a compromise on visible growth of vegetation and the water transparency. At the Greifswalder Bodden the best period to take photos of macrophytes is between the end of April and early in May with low amount of chlorophyll and suspended particles in the waterbody.
Besides the aerial photographs satellite images were used. It was found that there were no Landsat scenes at the right time, without clouds or ice. So only a Landsat TM scene from July 1989, a SPOT (P) scene from July 89 and March 1995 could be used. This scenes fit best to the discussed requirements.
The extensive map material was digitized: topographical maps in the scale 1 :10000 and hydrographic maps with bathymetric information in the scale 1 :10000.
Further information about distribution of macrophytes, mussels, sediment, geomorphology and others were taken from the literature (Geisel, 1986; Scabell & Jönsson, 1984).
Shots with an underwater video camera were made at the same time of the photo flights.
The geometric link of all data is guaranteed through Gauss-Krueger-Coordinates. Through this uniform geographical reference the image data can be tied independently of their scale and the collected data can be proved integrately in a GIS.

4. METHODS

4.1 Ground Truth Processing

At the same time of the photo flights aquatic studies were realized. From a rubber dinghy the vegetation was recorded with a SVHS underwater video camera and additional parameters were measured, like water depth, position, transparency of the water column. Plant and sediment samples were taken, determined and related to the videos and the imagery. The details of macrophytes obtained by the samples are not usually recognizable on the videos. The turbider the water is or the quicker the camera skims over the ground, the more difficult the evaluation of the macrophytobenthos is. However the underwater videos document continuously the vegetation borders and the horizontal and vertical structure of populations that is not possible with a simple sampling.
The recordings were repeated every 3 weeks in one year to monitor the structural and phenological changes of the macrophytobenthos within a vegetation period.
Based on the videographic recording the vegetation was grouped into typical macrophytic societies according to their appearance (Fig. 1). This grouping corresponds well with the sociological units of the macrophytes evaluated by Geisel in 1986 (Geisel, 1986).

Nb.	Macrophyte communities	Depth
1	Enteromorpha, Cladophora, (Pilayella)	0.0-1.0 m
2	Potamogeton, (Ceramium, Laomedia)	1.0-3.0 m
3	Zostera	2.0-4.0 m
4	Furcellaria, Polysiphonia	2.0-5.0 m
5	Fucus, (Polysiphonia, Furcellaria)	0.5-2.5 m
6	Chorda, (Potamogeton)	0.5-1.5 m

Fig. 1: Typical plant societies in the study area

Based on the results of the under water videos the training areas for the supervised classification were chosen.
For geocoding of all data of the ground truth processing and for a later rectification of imagery control points were signalized and measured by differential GPS. Classical measurements of some points by electronical tachymeters supported the surveying by GPS. A high number of potential control points is present on the land surface. In the water 'natural' control points are very rarely to find. Therefore the stakes of the permanent weir-baskets were used as control points.

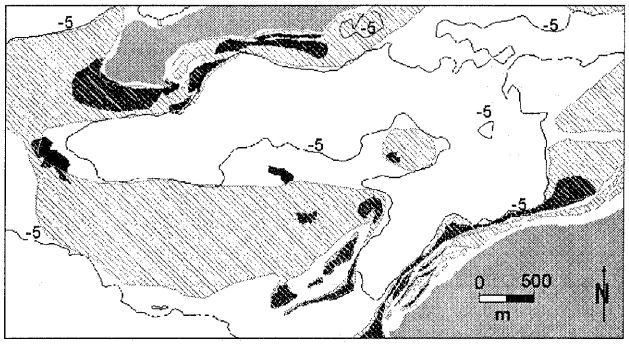
4.2 Digital Image Analysis

The aerial photographs were digitized and rectified. The geocoding was difficulty because of large water areas in the images and the relative small number of control points in the water area.
After the geocoding the 1:5000 scaled images were mosaiced. In that way bad edge regions of the images like sunglitter or distortions could be eliminated, the radiometric appearance will be more homogeneously and the expense of the following processes decrease. The images taken by the photogrammetric camera were not mosaiced because of the high amount of working space needed at the computer.
Imagery was spectral classified with the Maximum-Likelihood method according to the founded macrophytic societies. The satellite images also were spectrally analyzed. Only the first 3 bands of the Landsat scene were used for the classification. A merge of Landsat and Spot increased the geometrical resolution. The Spot scene from 1995 was used to produce a binary mask with the regions of the macrophytes.

4.3 GIS-Analysis

Based on the existing sociological studies of macrophytes and the own experiences conditions for the incidence and growth of macrophytes were defined. They depends mainly on sediment, water depth and related conditions like aspect and slope. This ancillary data were used together with the images for the classification.

Another GIS application is to overlay the data sets for change detection. For this macrophyte coverages obtained by the classification of the aerial photographs from 1992 and 1995 were overlayed (Fig. 2).



Macrophytes, May 1992

Macrophytes, May 1995

Land

Fig. 2.: The change of distribution of the macrophytes between 1992 and 1995

5. RESULTS

The processing of the data of different sensors illustrates that the acquisition time of the images is very important for the quality of image interpretation and classification. A high amount of chlorophyll and suspended material in the water falsifies the spectral reflectance of the macrophytes. In addition they decrease the visibility of the ground. In the Landsat TM scene from July the macrophytes differ from the background maximally up to 3.5 m water depth. The visible macrophytes could be separated only in 2 classes. The low resolution of the scene does not permit a sharp demarcation of macrophytes in the Greifswalder Bodden. The population areas especially near the coast are too small for the rough resolution. That means a lot of mixed pixels.

The Spot images represent the boundary of macrophytes better, that's why Spot scenes can be used as a filter mask for macrophytes. A classification and separation of the vegetation under water was not possible with the Spot scenes.

Photo flights offer great possibilities to get high quality photographs in accordance to the requirements of the application; scale of the photos, film material, filter and others can be considered. A further advantage of photo flights is the flexibility in flight planning. Thus, the optimal time can be chosen.

The spectral classification of the aerial photographs did not bring satisfying results in spite of carefully selected training areas. Up to 2 m water depth the classes are be very good separable. If the water depth increases the classification accuracy decreases. Deeper than 4.5 m the variance of the spectral class values of the macrophytes and the background are higher then the distance of their class centers. Therefore a definite delimitation of macrophytes is impossible in this depth only by spectral classification. The combination of ancillary data together with remote sensing data within a GIS supports the classification process. The use of ancillary data improved the classification results on an average of 9 percent.

The evaluation of the vegetation changes (Fig. 2) indicate seemingly a high decreasing of macrophytes from 1992 to 1995. A check of some test sites in summer of 1995 did not supported this result. In the time of the photo flights the vegetation was not enough developed because of cold and stormy weather conditions before.

6. CONCLUSION

All tested sensors can be used in the digital mapping of macrophytes. The use of a special sensor depends on the application. The best results come from aerial photographs taken by a photogrammetric camera in the scale of 1:10000. This photos represent an acceptable area of ground. That facilitate the view over the area, the rectification and the georeferencing. The processing of images is more effective than the processing of the 'Low-Cost'-Images taken by an amateur camera in the scale of 1:5000. The Low-Cost-Images should be used only for small areas close to the shore because the rectification and geocoding is very difficult. A lot of images could not be georeferenced without a high number of put out control points in the water area. On the other side the classification results are finer than from the aerial photographs. The self-made photoflights with an amateur camera are very flexible and their costs do not exceed one fourth of the photoflight with a photogrammetric camera.

The use of satellite imagery in the Greifswalder Bodden for mapping macrophytes is limited because of the low resolution (Landsat TM) and/ or the absence of multispectral bands (Spot).

The integration of remote sensing data within a GIS is necessary to combine the advantages of several sensors and to compensate their disadvantages, which are increased by special properties of under water research. Moreover the integration improves the quality of the classification results and approves the comparability of data at different times.

7. ACKNOWLEDGMENT

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