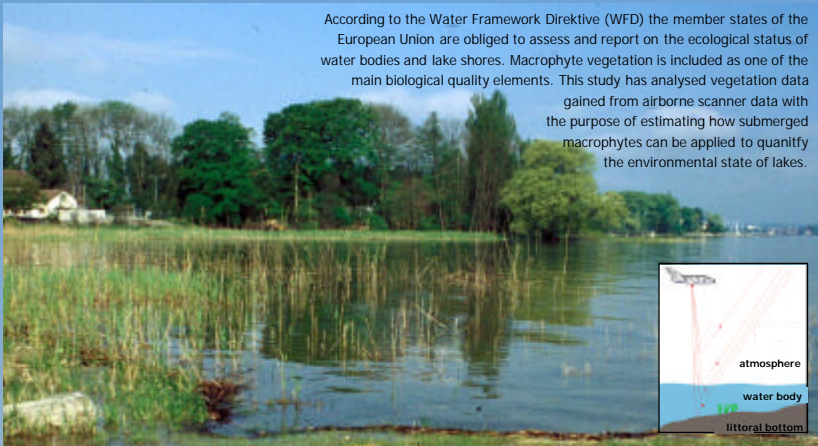




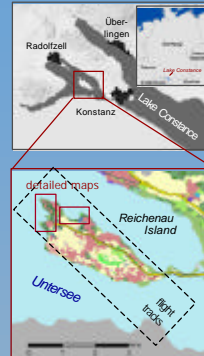
Remote Sensing Techniques and GIS Modeling Approaches for Monitoring the Spatial Distribution of Submerged Vegetation at Lake Constance, Germany

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According to the Water Framework Directive (WFD) the member states of the European Union are obliged to assess and report on the ecological status of water bodies and lake shores. Macrophyte vegetation is included as one of the main biological quality elements. This study has analysed vegetation data gained from airborne scanner data with the purpose of estimating how submerged macrophytes can be applied to quantify the environmental state of lakes.



Study area

The study area is located at **Lake Constance**, which is situated between the countries of Austria, Switzerland and Germany. With a surface area of approximately 530 km², Lake Constance ranks among the largest lakes in Europe. **Settlements, recreational use and intensive agriculture** exert a high pressure on the shore and littoral area. The flight tracks and the field campaigns for the physical measurements and ground truth validation were carried out around **Reichenau Island**.

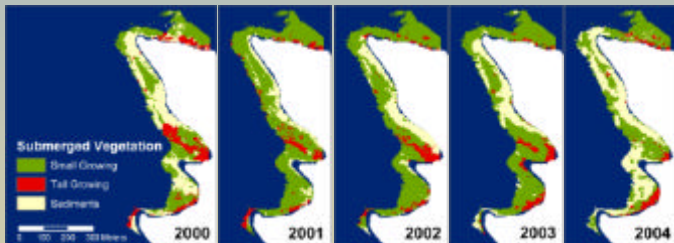
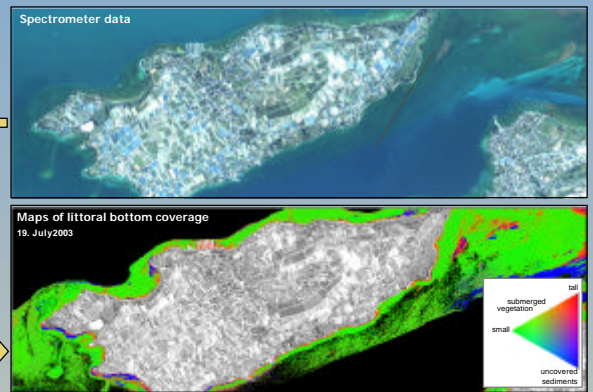
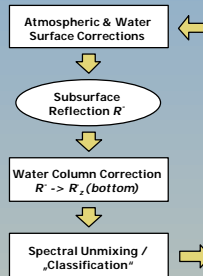
Material and Methods

The Modular Inversion Program (MIP) is a processing and development tool designed for the recovery of hydrobiological parameters from **multi- and hyperspectral remote sensing data**. The architecture of the program consists of general and transferable algorithms based on physical inversion schemes that derive biophysical parameters from the measured radiance signal at the sensor.

The **spectral reflectance of macrophytes** collected from several habitats at different lakes in South Germany were measured in the field with hyperspectral radiometer Spectral

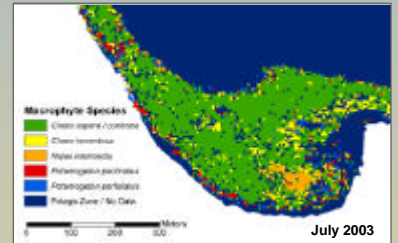
variations of sunangle effects and seasonal changes were also investigated to determine the intraspecific variability.

To assess the ecological status of the littoral areas, a monitoring system was designed based on these remote sensing data using GIS. With spatial analysis techniques the decline and recovery of macrophyte vegetation can be illustrated. Different **indices for reporting the structural and trophic quality** of the littoral area can be calculated.



Results

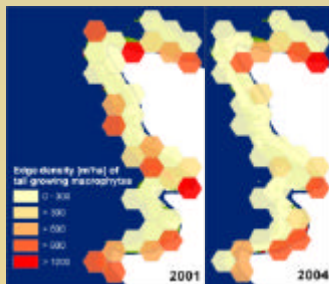
The **multitemporal results** contain classes of small growing macrophytes, tall growing macrophytes and bottom sediments for the years 2000 to 2004. Macrophyte taxa were classified to bottom cover classes by linear spectral unmixing combined with spectral derivative analysis in 2003 and 2004. **Spectral discrimination to species level** is possible depending on the amount of epiphytic growths, water depths and clarity.



Structural Diversity

The architecture and spatial arrangement of submerged plant species has a significant impact on fish communities. Many studies could demonstrate, that aquatic macrophytes are **important nursery and feeding habitats** (PETER, 2000).

For instance, ecological and behavioural studies carried out at University of Konstanz have shown that Eurasian perch (*Perca fluviatilis*) prefers littoral zones with **high structural complexity** of tall growing macrophytes at Lake Constance. Especially the border areas of the vegetation patches are attractive for this species.



Spatial habitat differences indicated by spatial pattern analysis

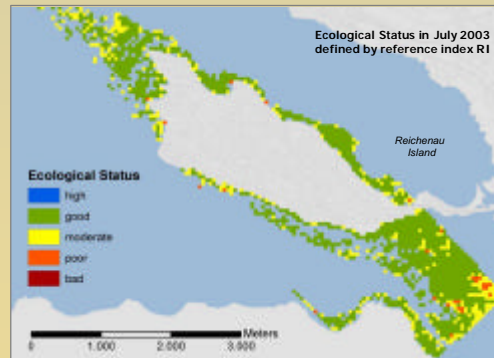
To quantify this habitat factor, we used the landscape metric 'Edge Density' ED (MCGARIGAL et al. 2002). The result table show a continuous decline of mean edge density in the spatial analysis units.

Year	Mean ED [m/ha]
2001	473
2002	450
2003	406
2004	329

PETER, T. (2000): Interactions between fish and aquatic macrophytes in inland waters. A review. Rome: FAO Fisheries Technical Paper.
MCGARIGAL, K., CUSHMANN, S. A., NEEL, M., ENE, E. (2002): Fragstats. Spatial pattern analysis program for categorical maps. Massachusetts.

Ecological Classification for WFD

STELZER et al. (2005) developed an **assessment system based on macrophyte species** according to the WFD. Three groups of species with typical ecological qualities were identified for specific types of lakes in Germany: taxa dominating under reference conditions, species with wide ecological amplitude and taxa dominant at highly disturbed sites. The assessment of the lake sites results from the calculation of the reference index RI, which quantifies the deviation of the vegetation at the sample sites from those at reference conditions.



Using the data from the large scale inventory by remote sensing, the reference index can be calculated not only for lake sites, but also for the entire lake. To apply the assessment system to hyperspectral data, the reference index RI was calculated from the probability values of the different macrophyte spectra.

STELZER, D., SCHNEIDER, S., MELZER, A. (2005): Macrophyte based assessment of lakes – a contribution to the implementation of the European Water Framework Directive in Germany. Int. Rev. Hydrobiol. 90/2



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Further information: www.uni-hohenheim.de/efplus

