Holistic marine monitoring in the Environment Agency - Backscatter Magazine, August 1999

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Accurate physical, chemical and biological data sets from the upper ocean are essential if we are to have an understanding of those structures and processes that affect climate and help us to harvest living resources rationally. Traditional profiling of oceanographic instruments is inefficient (Burt 1997). It has in many cases been replaced by the use of towed undulating vehicles combined with remote sensing techniques. The resulting rapid spatial coverage and high data density provides a unique tool for the study of pollution effects in coastal regions.

The Environment Agency (EA) of England and Wales has a responsibility to form an opinion on the state of pollution of the environment under the Environment Act 1995. In the marine environment, this responsibility extends to 5 kilometres offshore from defined baselines. The EA has developed a holistic approach to marine monitoring utilising remote sensing techniques in association with *in-situ* sensors.

Traditional marine water quality monitoring involving the collection of water samples from fixed sampling points does not provide the required spatial frequency for describing processes in the highly dynamic coastal zone. The EA has developed a shipborne system which allows the collection of oceanographic data between sampling stations and when calibrated may be used to place the *in-situ* samples in spatial context and to provide some temporal information. This provides high quality data along the track of the sampling vessel which when combined with remote sensing techniques enables a comprehensive survey of the 20,000 square kilometres of coastal water for which the Agency is responsible.

The National Coastal Baseline Survey (1993 to 1998) developed a holistic approach to this survey consisting of three major elements. A total of 186 sampling sites were established around the coastline of England and Wales at approximately 15 km intervals. The sites were sampled between 2 and 4 times each year for a wide range of substances including nutrients, dissolved metals, chlorophyll-*a* and suspended sediments. Each of four survey vessels regularly tow Chelsea Instruments Aquashuttle systems recording temperature, salinity, transmission, fluorescence, pH and dissolved oxygen monitoring at 10 second intervals between the survey sites. At selected sites this equipment was also used to profile the water column to provide additional depth information. In later surveys the vessels monitored nutrient concentrations between the sample sites at 1-minute intervals using a Skalar auto-analyser.

AQUQ*shuttle* Towed Oceanographic Vehicle

To enable monitoring of the extensive coastal zone the Environment Agency used an airborne mounted combined optical and thermal system. The Compact Airborne Spectrographic Imager (CASI) is an imaging spectrometer that records the upwelling signal from the surface in a number of wavelengths from 420 to 920 nm. The CASI may be operated in a number of modes.

- Spatial mode: up to 19 spectral channels over 512 spatial pixels
- Spectral mode: 288 spectral channels over 39 spatial pixels
- Enhanced spectral mode: 72 spectral channels over 300 spatial pixels

The system was used in spatial mode for the coastal baseline survey, with wavelengths selected to allow interpretation of patterns in suspended solids and chlorophyll-*a*. The thermal sensor operates in the 10-12 mm range measuring the radiation emitted from the very top of the land or sea surface. Variations in the thermal data reflect boundaries between different water bodies and allow the investigation of discharge mixing zones and estuarine plumes.

The data collected from the Survey provided an invaluable indication of those areas of the coastal zone consistently high in parameters such as chlorophyll-*a* or orthophosphate. It also provided important information on those areas where there was no pollution.

In order to identify areas for improvement in the coastal baseline survey, the National Centre for Environmental Data and Surveillance carried out a review of the data gathered and a number of case studies in specific areas of interest.

The review concluded that whilst providing adequate spatial coverage the baseline survey did not provide the required temporal resolution to fully characterise processes within the coastal environment. Biological processes, particularly those associated with phytoplankton, occur at temporal scales that are inappropriate to sampling four times annually.

The case studies considered the ability of remotely sensed imagery to accurately measure the concentrations of chlorophyll-*a* and suspended solids in the coastal environment. Estimates of chlorophyll-*a* concentration are necessary in response to requirements of the EC Urban Waste Water Treatment Directive (EEC/271/91) and commitments to the Oslo and Paris Conventions. The presence of persistently high concentrations of chlorophyll-*a* has been identified as one of the key indictors of eutrophication. This may be defined as the enrichment of water by inorganic plant nutrients, which results in the stimulation of an array of symptomatic changes. Chlorophyll-*a* concentrations are particularly variable over short spatial dimensions and as such are not accurately represented by spot sampling. Monitoring with remote sensors offers the potential for collecting the wide area estimates required.

Commonly available algorithms for converting remotely sensed imagery to chlorophyll-*a* concentration have been developed mainly for satellite imagery and for open ocean waters. Application of these to the coastal zone results in errors due to presence of suspended sediment within the water column.

In order to improve the prediction of chlorophyll-*a* and the discrimination of suspended sediment the National Centre for Environmental Data and Surveillance conducted algorithm development and validation campaigns (Matthews *et al*). These campaigns utilised the approach developed in the National Coastal Baseline Survey, but for a defined geographical area. CASI imagery was collected in enhanced spectral mode, with *in-situ* water samples analysed for chlorophyll-a and suspended sediment, and fluorescence and transmission sampling using the Aquashuttle. The fluorescence and transmission data sets were calibrated using the *in-situ* water samples to provide a spatially dense data set.

Results showed that the currently available algorithms could be used in the coastal zone, with limited *in-situ* data collection. It did not, however, prove possible to develop a single algorithm for application to all geographical areas without *in-situ* data. The National Centre for Environmental Data and Surveillance is therefore continuing to review the available algorithms and is currently undertaking trials using neural network technology and multiple regression techniques.

The results of the review of the baseline survey and the case studies led to the development of an enhanced marine monitoring strategy which more fully addresses the temporal and spatial variability of the coastal zone, using advanced technologies. To allow more representative temporal sampling, the use of continuous monitoring equipment mounted on marine buoys is being investigated with the development of the Proteus system. The Proteus buoy was originally developed for estuarine use to determine episodic pollution events. The system currently includes at Chelsea Instruments Aquapack (CTD-Chlorophyll), Aquatrace (pH, dissolved oxygen, redox) and Alphatracka transmissometer sensors and nitrate. The telemetry system allows for both automatic and responsive sampling and various water sampling systems are being investigated. This system is currently being transferred to a marine platform to provide high temporal resolution data of, in particular nitrate and chlorophyll-*a* in the coastal environment.

The marine monitoring strategy also utilises earth observation satellite data to provide a representative spatial picture of the entire coastal zone. Specifically, the National Centre is investigating the use of satellite imagery from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS). A pilot study has been completed using the satellite imagery to identify the presence of algal blooms in coastal waters and to direct aircraft and ship-borne sampling to these areas. Figure 4 shows a SeaWiFS image of an algal bloom on 24 July 1999 off the Cornwall coast. A CASI overflight tracked this into the Falmouth estuary three days later.

This powerful combination of the AquaShuttle towed vehicle and advanced remote sensing techniques provides a comprehensive picture of the temporal and spatial variability in water quality in the highly dynamic coastal environment. This enables the Environment Agency to conduct cost-effective sampling of coastal water quality in order to form an opinion on the state of pollution of the marine environment.

References

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