

## Background and Rationale

A fundamental requirement of any effective environmental monitoring programme is that the sampling strategy should be able to resolve all the relevant scales of variability. In the marine environment, as on land, relevant temporal and spatial variability may occur a wide range of scales (Figure 1). Typically marine monitoring programmes reliance on ship based surveys alone results in good spatial coverage at the expense of temporal resolution.

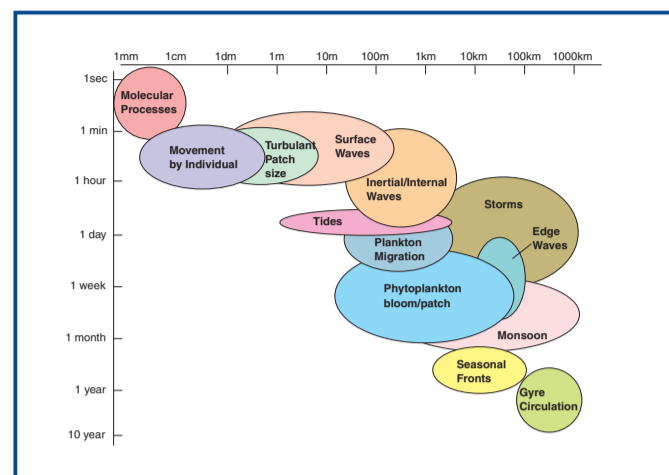


Figure 1: An overview of the temporal and spatial scales of a range of physical and biological phenomena.

Table 1: SmartBuoy instrumentation.

Instrument/sensor	Measurement	Derived Variable
CTD*	Conductivity, Temperature, Pressure	salinity (psu) density ( $\text{kg m}^{-3}$ ) depth (m)
Fluorometer (blue LED type)	Chlorophyll fluorescence	Phytoplankton biomass ( $\text{mg chl m}^{-3}$ )
Optical back-scatter sensor	Turbidity	suspended particle load ( $\text{mg l}^{-1}$ )
Quantum irradiance sensor (at 1 and 2 m depth)	Downwelling Photosynthetically Active Radiation (400 - 700 nm)	Ed (light available for phytoplankton growth at depth d) k, vertical extinction coefficient ( $\text{m}^{-1}$ )
Dissolved Oxygen sensor	Oxygen concentration ( $\text{mg l}^{-1}$ )	Oxygen concentration ( $\text{mg l}^{-1}$ )
In situ Nutrient Analyser (NAS2-E)	Nitrate concentration ( $\mu\text{M}$ )	Nutrient uptake rates
Aqua Monitor (Automated water sampler collecting up to 50 x 200 cc samples)	Samples collected, preserved and stored for subsequent lab analyses	Phytoplankton numbers and species composition, Nutrient concentration, (nitrate and silicate)
Eco-System Monitor (ESM-2)	Multi-channel programmable logger incorporating CTD*, controls satellite (ORBCOMM) telemetry	

To meet the future needs of the UK National Marine Monitoring Programme (NMMP) CEFAS has developed SmartBuoy; a platform carrying a suite of automated *in situ* instrumentation that measure a range of physical, chemical and biological variables (Table 1). SmartBuoy collects high frequency (minutes to daily) data on the phytoplankton and the environmental control variables that allows an assessment of nutrient status and ecosystem response. Two buoys have been deployed at NMMP monitoring sites in the southern North Sea and a further buoy at a location in Dutch coastal waters as part of a joint UK Netherlands programme funded by the UK DETR and the Netherlands government (Figure 2).

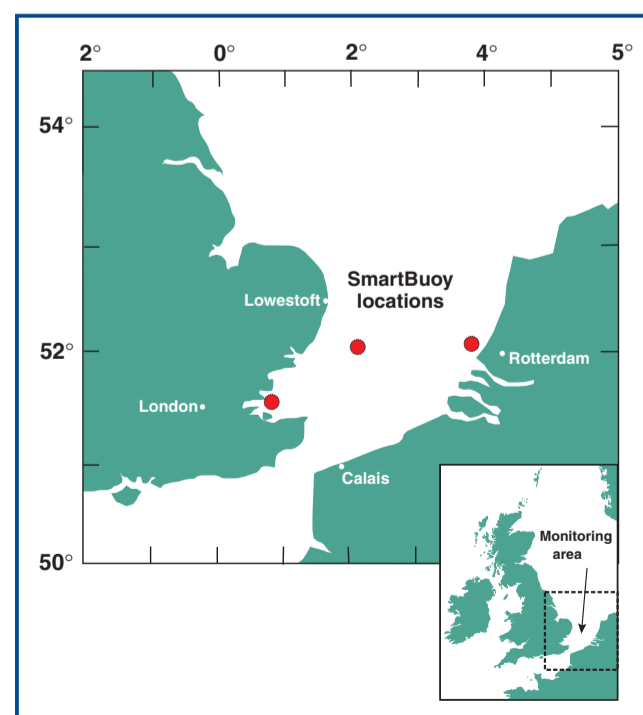


Figure 2: Map showing the location of 3 SmartBuoys. The 2 westerly sites are located at UK NMMP monitoring sites with an additional site in Netherlands coastal waters.

## New Observational Technologies - SmartBuoy

The SmartBuoys currently in use are designed to make near surface (1–2 m depth) observations for periods of 1–2 months before servicing. Details of the buoy are shown in Figure 3. The main elements of the SmartBuoy are a toroidal buoy and instrumentation. Measurements are made using a combination of sensors and an *in situ* nutrient analyser. Water samples are also collected and stored on board for subsequent analysis in the laboratory.

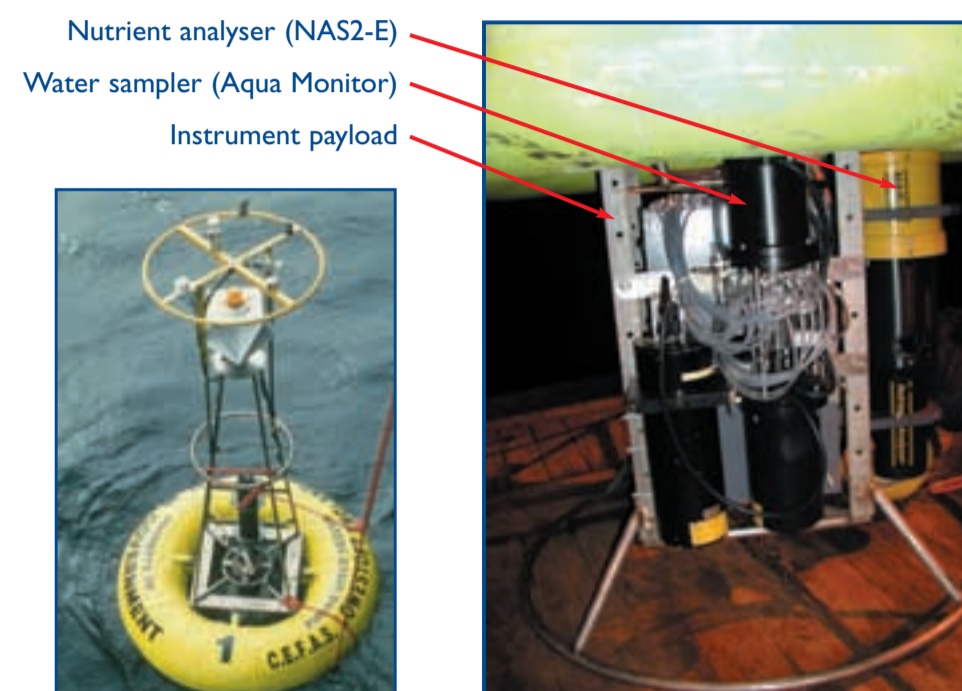


Figure 3: SmartBuoy alongside after deployment showing the surface met sensor package and a view of the sub-surface instrument payload.

## Results

Time series obtained in spring 2000 from the central southern North Sea site (Outer Gabbard) show the effectiveness of the approach. In Figure 4 the spring bloom of phytoplankton is shown in relation to the ambient nitrate concentration. High frequency measurements (hourly or less) enable the full range of variability in these critical environmental conditions to be described. The spring bloom is regarded as one of the most significant events in seasonal cycle of phytoplankton with its timing, amplitude and duration of importance within overall ecosystem function.

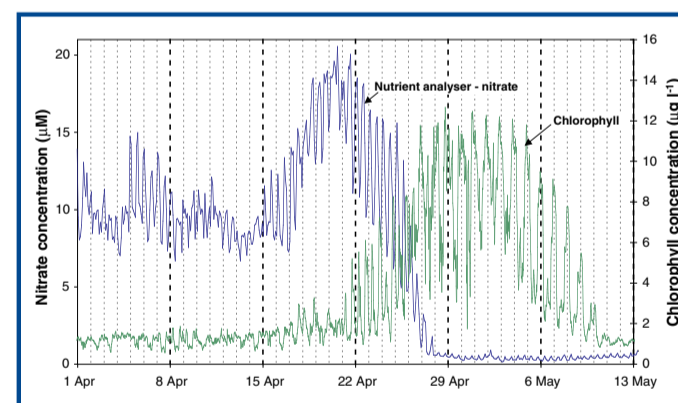


Figure 4: Time series of hourly nitrate concentration and chlorophyll concentration at southern North Sea central site in 2000. Nitrate is the major limiting nutrient for phytoplankton growth in the marine environment.

The over winter nitrate concentration is a required measurement within the NMMP with Figure 4 demonstrating the range of variability over short (hourly) and longer (> weekly) time scales. Figure 5 demonstrates the inverse relationship with salinity and also shows the measurements of nitrate and silicate concentration from discrete water samples collected on the buoy.

In addition, the chlorophyll biomass yield from nitrate and phytoplankton growth rates can also be derived from the measurements made during the spring bloom. These direct and derived measurements have the potential to form the basis of diagnostic criteria against which to assess ecosystem function.

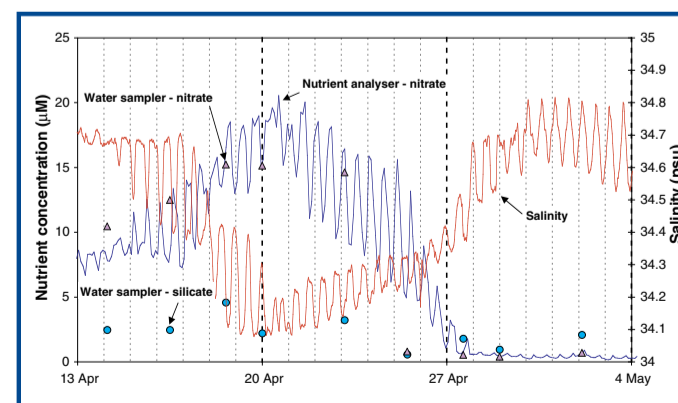


Figure 5: An expanded time series of plant nutrient concentration (nitrate and silicate) and salinity. Discrete water samples collected by an automated water sampler (Aqua Monitor) are shown and provide additional information on silicate (a requirement for diatoms) and also nitrate. The latter data can be compared with nitrate concentration determined by the *in situ* nutrient analyser. Here the data show a good relationship.

## Data processing and dissemination

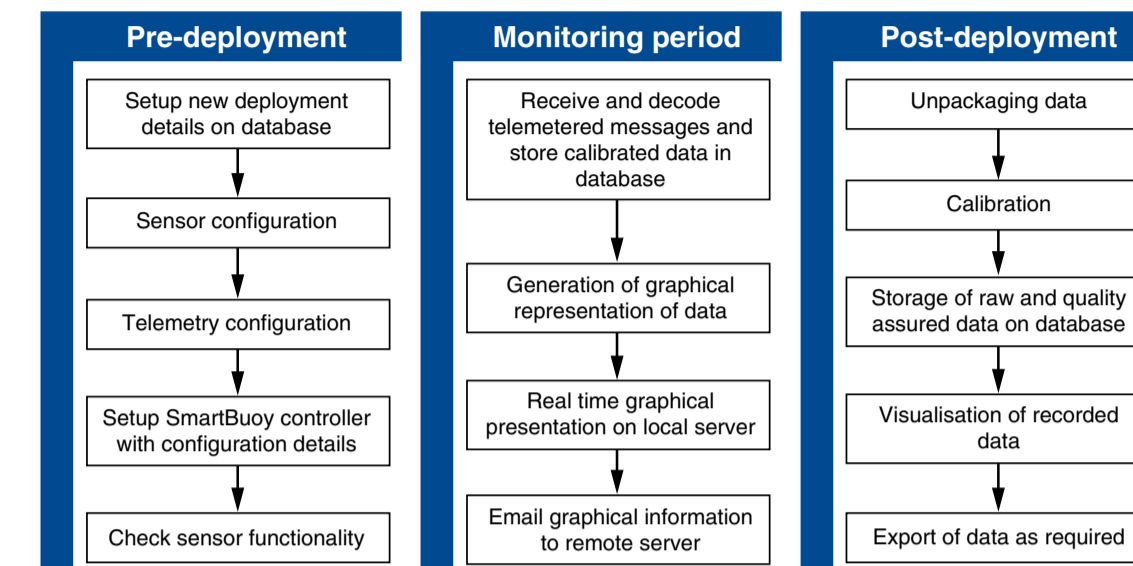


Figure 6: A schematic showing the major elements of the software environment for SmartBuoy data handling.

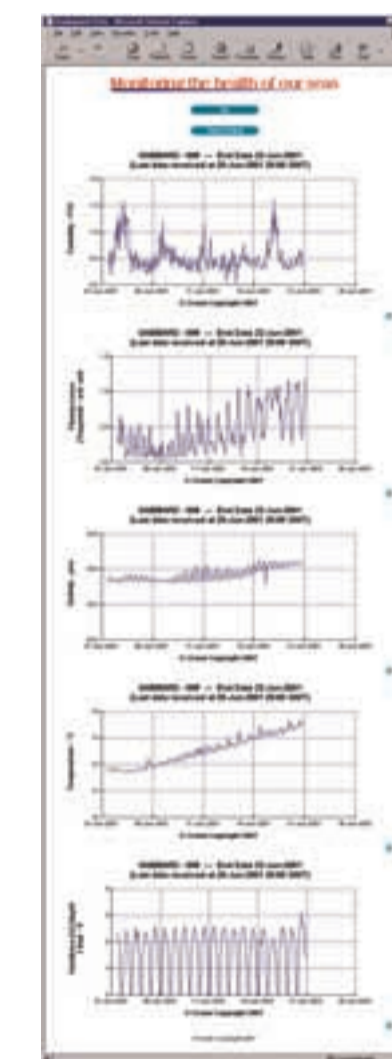


Figure 7: Example of SmartBuoy satellite telemetered data output from the central North Sea site (Outer Gabbard).

## The Vision

Future expansion of the network is under consideration but depends on a number of factors including funding. As automated *in situ* sensors and sampler development proceeds and reaches fruition a range of additional and new determinands will become available including bio-sensors for toxic phytoplankton, bio-optical sensors for microplankton rate determinations and samplers for chemical pollutants. As robust anti-biofouling strategies are developed and introduced increased service intervals will drive down operational costs. Plans for a multi-buoy network are currently being considered and this could underpin the development of a marine environmental change network forming basis of an integrated and co-ordinated programme to monitor future marine environmental change in UK and European shelf-seas and oceans.

## Acknowledgements

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