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FerryBox

From On-line Oceanographic Observations to Environmental Information

Report and Draft of Scientific Papers on Eutrophication

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Document Reference Sheet

This document has been elaborated and issued by the European FerryBox Consortium.

P 1	**GKSS**	**GKSS Research Centre** **Institute for Coastal Research**	**Coordinator**
P 2	**NERC.NOC**	**NERC.NOC – National Oceanography Centre** **Southampton University and National Environment Res. Council** formerly NERC.SOC – Southampton Oceanography Centre	
P 3	**NIOZ**	**Royal Netherlands Institute of Sea Research**	
P 4	**FIMR**	**Finnish Institute of Marine Research**	
P 5	**HCMR** (formerly NCMR)	**Hellenic Centre for Marine Research** (formerly National Centre for Marine Research)	
P 6	**NERC.POL**	**Proudman Oceanographic Laboratory**	
P 7	**NIVA**	**Norwegian Institute for Water Research**	
P 8	**HYDROMOD**	**HYDROMOD Scientific Consulting**	
P 9	**CTG** **(formerly CIL)**	**Chelsea Technology Group** **(formerly Chelsea Instruments Ltd.)**	
P 10	**IEO**	**Spanish Institute of Oceanography**	
P 11	**EMI**	**Estonian Marine Institute** (in cooperation with the Estonian Maritime Academy)	

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1 Objectives

Overview

The key project objectives in WP-4 were to provide a scientific support for the principle that FerryBoxes can deliver information of immediate scientific value, based on a coordinated approach which can quantify environmental variability on a European scale. It concentrated on 3 scientific areas relevant to issues of water quality, eco-system stability and climate variability and change. (1) Eutrophication including plankton productivity and variability in productivity in relation to physical and biogeochemical constraints. (2) Transport of sediments (and associated contaminants) over long and short spatial and temporal scales. (3) Determination of the stability and transport of water masses. It implemented and tested the procedures and software developed in WP-2 and WP-3. The work was structured to provide a basis for the calibration and validation of the associated models developed in WP-5.

1.1 Task 4-3 – Eutrophication

The hypotheses to be tested in this task were that FerryBoxes could accurately and precisely determine the variations in timing and intensity of blooms, and that this could related to the range of conditions encounter in different European seas. In addition the aim was identify :- (i) if plankton abundance and patchiness could be related to specific physical features (ii) enhanced freshwater flows due to summer storms produce blooms (iii) if new measurement systems can improve the predication and identification of blooms (e.g. use of FRR Flourimetry, and comparison with other data sources such as buoys and satellite)

2 Results and Achievements

2.1 Indexing of Blooms

A method for establishing a numerical index (indicator) to summarise annual variations in plankton bloom intensity and duration in different sea areas was tested. Such an index has the potential to be used by organisations such as the European Environment Agency as a management tool. The procedure tested is based on work by FIMR (Fleming and Kaitala In Press). A simple numerical index is calculated to describe the magnitude of the spring bloom. This is an integration of the variation in concentration of chlorophyll over the spring bloom period in different regions. The key to its use as management tool is understanding the degree to which the index can be taken as a measure of eutrophication because it is proportional to the amounts of nutrient present at the end of winter (Hydes et al., paper 2).

A general relationship between a high index and higher concentrations of nutrients does exist. (see Figure 2-1 below from the paper presented by Hydes at the EuroGOOS Conference in Brest in June 2005). However, further work needs to be done to refine the idea. It is clear that in the Baltic there is a wide variation in the index and its relationship to concentrations of nutrients from year to year.

In the North Sea the GKSS data show no relationship across the different areas studied. This provides a challenge, to extend the analysis to see if the reasons for these variations can be found in the available data sets. In the North Sea the poor relationship may stem from the availability of light and advection controlling biomass rather than simply nutrients.

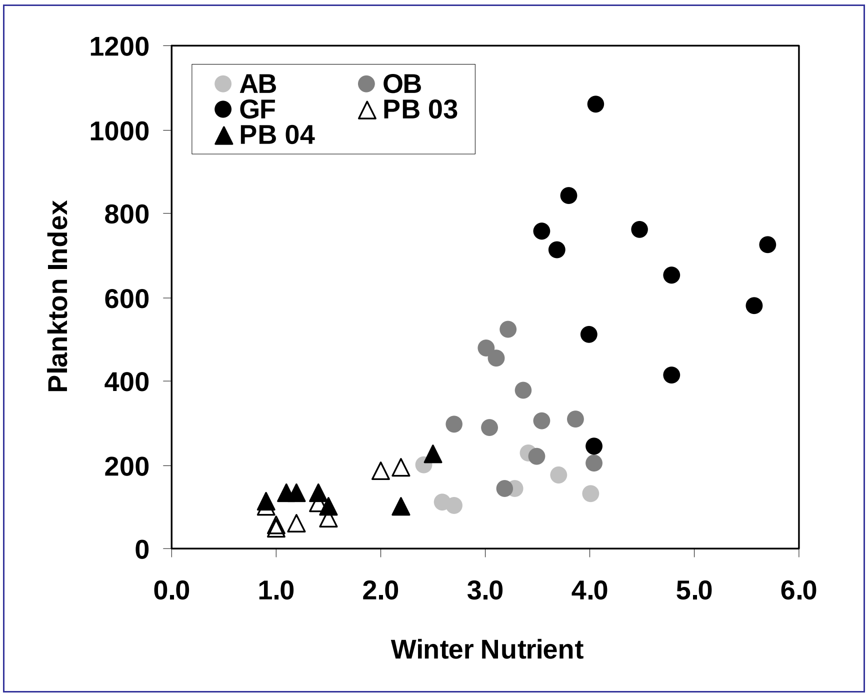

Figure 2-1: Plot of the spring phytoplankton bloom index against the geometric mean of the maximum winter nutrient concentrations – for results from the Baltic (Gulf of Finland - GF, Open Baltic -OB and Arkona Basin -AB) in 1992-2004 and Portsmouth to Bilbao in 2003 (PB 03) and 2004 (PB 04).

2.2 Relationship to Physical Features

A key aspect of the work in the project has been the development of ideas for the succinct presentation of the data from the different FerryBox lines. Figure 2-2 to Figure 2-9 below present a description of the FerryBox line Helsinki – Travemünde (Route 1A), FIMR, based on the principals developed at the FerryBox meeting at NIOZ Texel February 2004.

This Ship of opportunity (SOOP) monitoring system is the backbone for the Baltic monitoring. The ferry sails every week from Helsinki to Travemünde (Figure 2-2) and back, so the route is monitored twice a week.

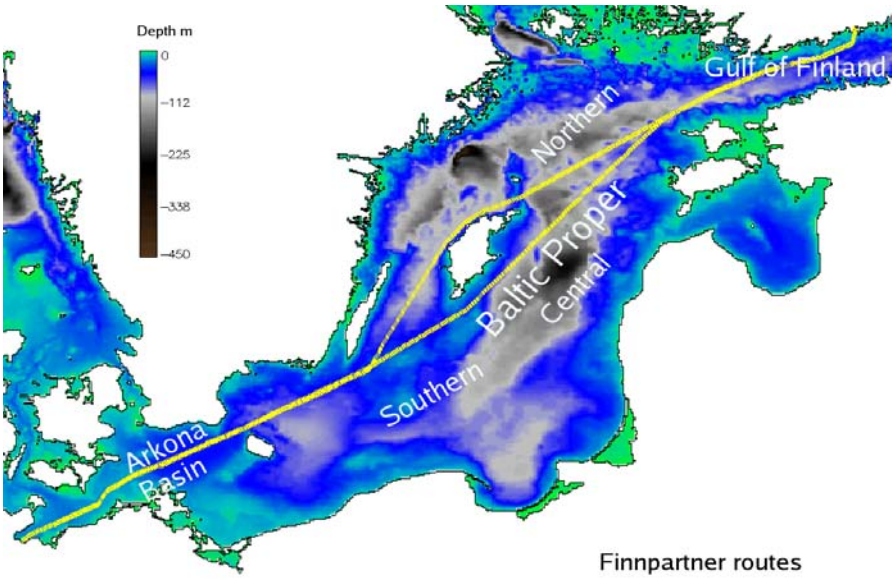

Figure 2-2: The route of the ferry "FINNPARTNER" from Helsinki to Travemünde and the bathymetry of the Baltic Sea.

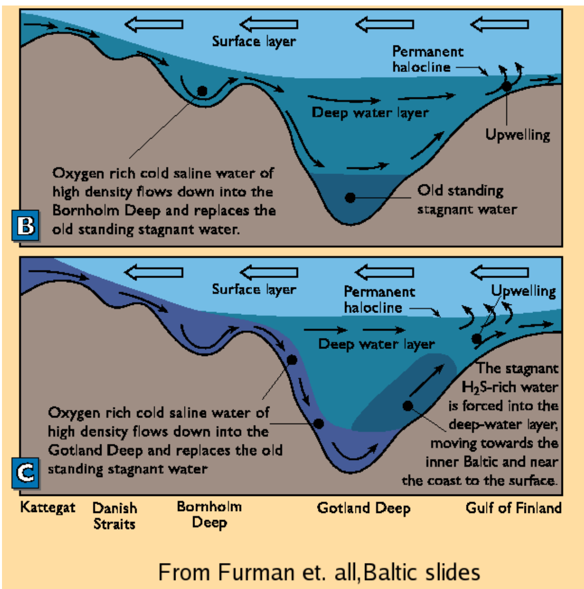

Figure 2-3: Vertical section of the circulation along the Baltic Sea.

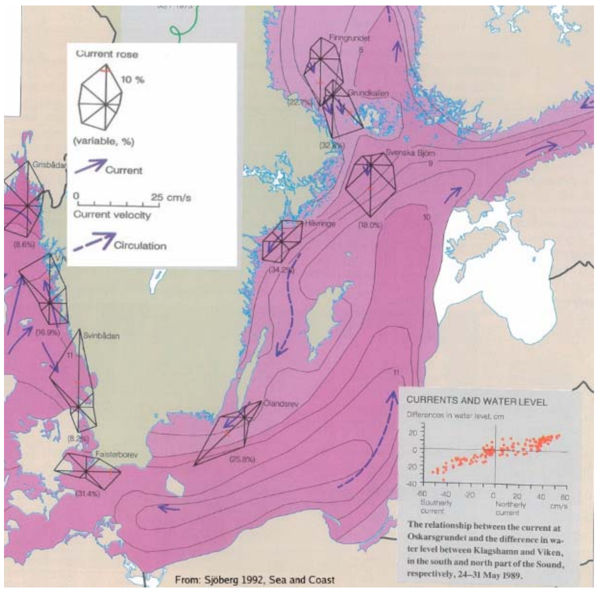

Figure 2-4: Circulation and water levels in the Baltic Sea.

The vertical water circulation dominates the hydrological regime in the Baltic Sea (Figure 2-3 and Figure 2-4). Tides in the Northern Baltic Sea are small (max 5 cm), but the water level varies due basin oscillations (seiches) caused by wind and air pressure. In Helsinki the highest water level record is +151 cm (9.1.2005) and the lowest 92 cm (22.3.1916, FIMR water level records since 1904).

There is salinity gradient into the North Sea (Figure 2-5). The stratification in the Baltic Sea is thus regulated by salinity, temperature and fresh water contributions. Ice cover forms regularly during the winters (Figure 2-6) in the northern parts of the Baltic Sea and leads to strong stratification in spring giving good conditions for the phytoplankton spring blooms (Figure 2-7). So the highest chlorophyll-a levels are reached in the Gulf of Finland during the spring blooms, but the most intensive cyanobacteria blooms occur in the the Baltic Proper. The highest fluctuations of inorganic nutrients occur in the Arkona basin due to salt water intrusion through from the North Sea (Figure 2-8 and Figure 2-9).

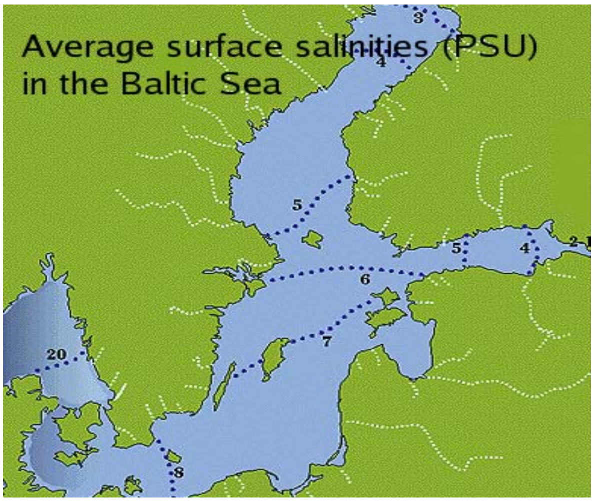

Figure 2-5: Typical surface salinity contours in the Baltic Sea.

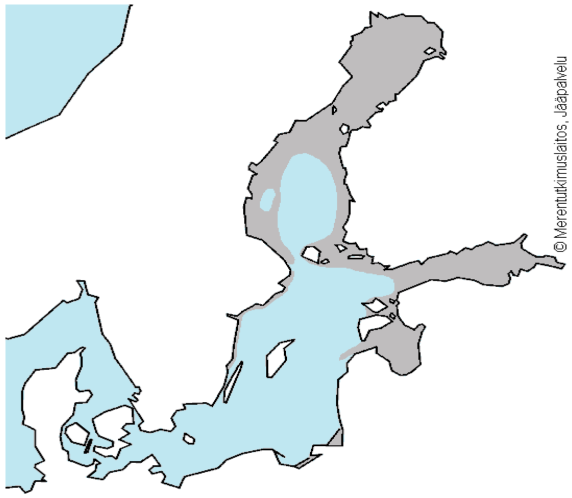

Figure 2-6: Baltic Sea ice extent in February 2004.

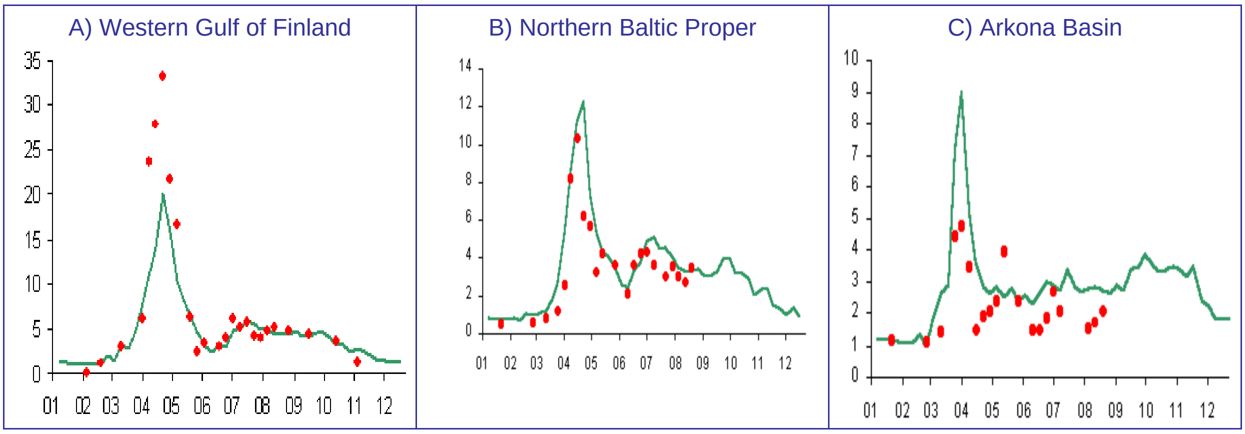

Figure 2-7: Annual variation of phytoplankton (chlorophyll a mg m^{-3}) in the Baltic Sea. The green curves are weekly averages for the years 1992-2004, red dots are for 2005 (www.balticseaportal.fi).

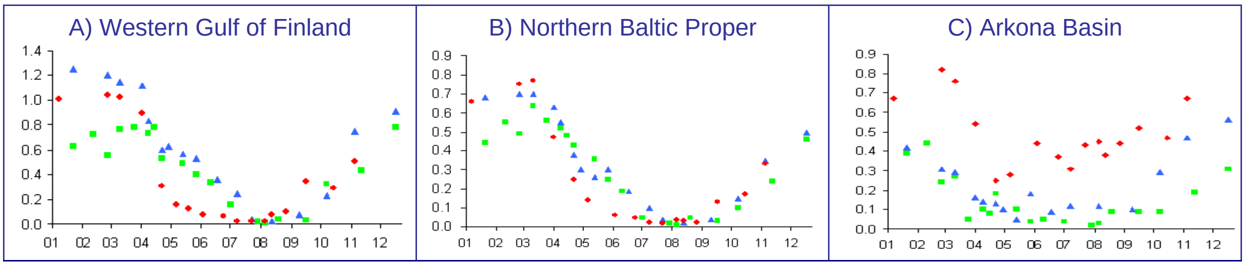

Figure 2-8: Annual variation in the concentration of phosphate (mmol m^{-3}) in the surface water of the Baltic Sea. The green squares represent measurements made in 2003 and the blue triangles measurements made in 2004. The red dots represent measurements made this year (www.balticseaportal.fi).

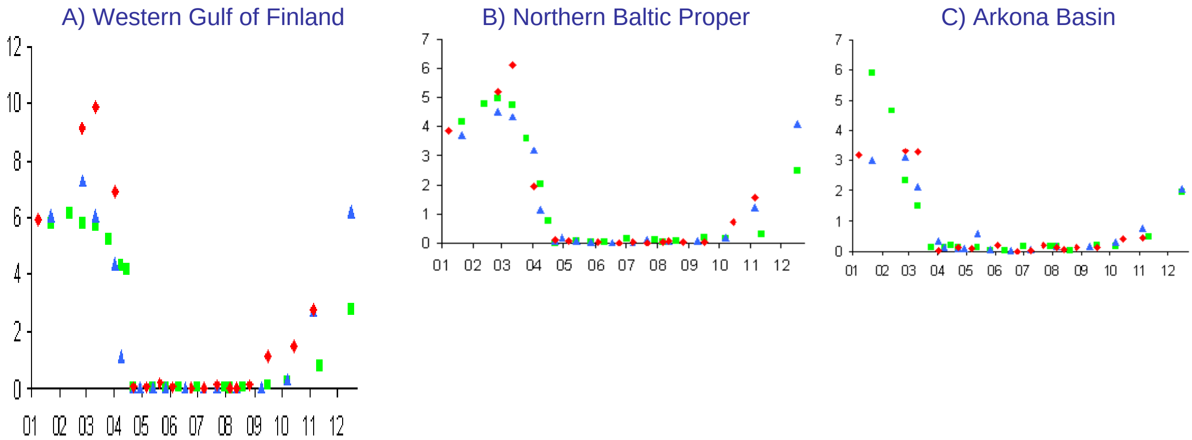

Figure 2-9: Annual variation in the concentration of nitrate (mmol m^{-3}) in the surface water of the Baltic Sea. The green squares represent measurements made in 2003 and the blue triangles measurements made in 2004. The red dots represent measurements made this year (www.balticseaportal.fi).

2.3 Enhancement due to Fresh Water Flows

In several areas FerryBox data has provided evidence of the enhanced of blooms that could be related to specific physical processes such a fresh water flows. In the Bay of Biscay and English Channel it has been possible to link bloom activity to specific hydrographic features (Kelly-Gerreyn et al., paper 9). Figure 2-10 below shows observations made by NERC.NOC with their Ferrybox on the route from Portsmouth to Bilbao of an intense monospecific bloom (~100 mg Chl *a* m^{-3}) of the Dinoflagellate *Karenia Mikimotoi* in the western English Channel in summer 2003. The onset of the bloom in 2003 occurred within 2 days of the arrival of low salinity (<35) waters (Figure 2-10) originating from French Atlantic rivers (Loire and Gironde). The hypothesis is that the low salinity intrusions enhance blooms of *Karenia Mikimotoi* through increased buoyancy of the upper water column and thereby influence the observed inter-annual variability in the abundance of this phytoplankton in the western English Channel.

Specific relationships have been identified in the Baltic. In the Baltic cyanobacterial blooms are problem of specific interest. EMI have analysed FerryBox data collected in years 1997 – 2004 to determine the main factors controlling the intensity and species composition of cyanobacterial blooms in the Gulf of Finland (Lips & Lips, paper 11).

This has demonstrated that the difference between bloom and non-bloom years can explained predominantly by differences in amounts of photosynthetic active radiation and upwelling intensity. The changes in these two parameters can explain 46% of the variation in cyanobacterial bloom intensities.

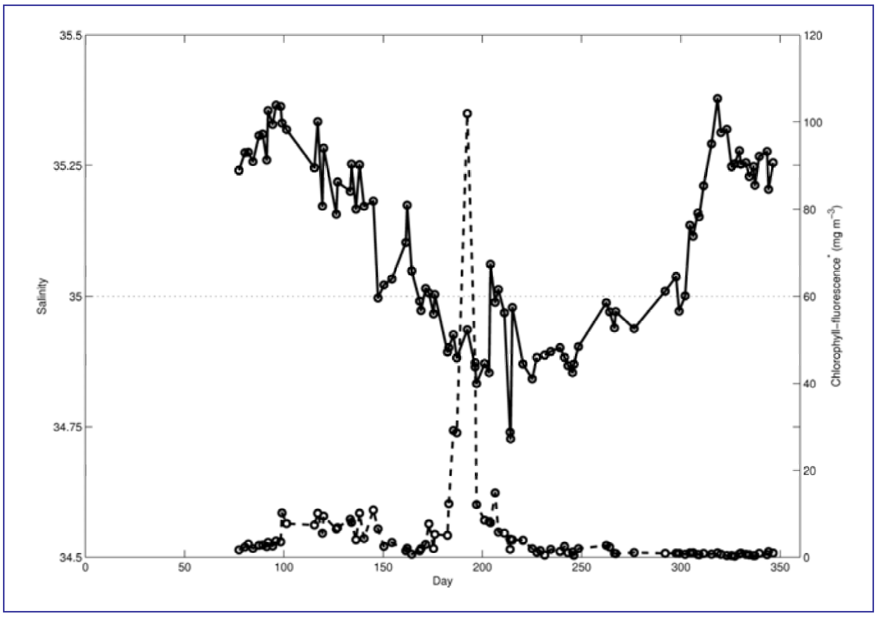

Figure 2-10: Time series data of chlorophyll-fluorescence and salinity showing the coincidence in the timing of the bloom in *Karenia Mikimotoi* and the arrival of low salinity water in the western English Channel (49.1°N, 4.1°W).

FIMR has evaluated the occurrence of cyanobacteria in relation to nutrients and salinity and temperature in the Baltic Sea using Alg@line data along the route Helsinki –Travemünde for the years 1997 – 2002 (Kaitala et al., paper 10). This has allowed specific organism relationships to be determined. For example *Aphanizomenon* tends to dominate at lower temperatures and so is more abundant in spring than *Nodularia*. High abundances tends be found in spring with a maximum density in the Gulf of Finland in June/July. While in summer higher temperatures over 15ºC and minimum concentrations of phosphate and nitrate are associated with the maximum abundance of *Nodularia*.

2.4 Use of New Instrumentation and Comparison to other Systems

Evaluation of new instruments has been covered in detail in the reports of WorkPackage 2. A particular success has been the use of measurements of oxygen to to determine productivity on both the NOC and GKSS routes. Planned use of FRRF was less successful due both to problems with the availability of the instrumentation and the scientific interpretation of the data.

Examination of the wider potential of the use of FerryBox data in combination other data sources was successful area of the project. The combination of the FerryBox data with those from remote sensing and from research vessels allows in observations of the duration, and composition of blooms, to be extended to generate estimates for wider areas.

Data extracted along the FerryBox tracks has been compared to data from the SeaWiFS, MERIS and MODIS satellites.

This work has been carried out by GKSS, FIMR, NIVA, NERC.NOC, IEO and EMI). For example limitations of the currently used algorithms for deriving chlorophyll-a from remote sensing images for coastal and shelf seas (Case-2 water) have been examined, as well as the problem of how representative sampling at a fixed depth or making surface observations are of the whole water column (e.g. Petersen et al., Paper 15, Carlos-Soto, paper 8 and Sørensen et al., paper13).

In the Irish Sea and North Sea work has been carried out by NERC.POL and GKSS comparing FerryBox data generated by buoys and model observations. In the Irish Sea the ferry measurements are complemented by buoy measurements near the Mersey Bar and in Belfast Lough and by nested 3-D hydrodynamic and ecosystem models run daily, covering the ocean / shelf of northwest Europe (at 12 km resolution), northwest European shelf (at 7 km) and the Irish Sea (at 1.8 km). The ferry measurements have tested the temperature and salinity hindcasts of the Irish Sea model for 2004 and 2005 showing the importance of correct estimation of river discharge for the models.

In the North Sea a detailed examination was made (Wehde et al., paper 5) using a hydrodynamic model and an ecosystem model to compare the comparability of the FerryBox data and an adjacent data buoy (CEFAS Gabbard Buoy – Mills et al., 2003). This work has been valuable in demonstrating that the buoy and FerryBox data cannot be compared directly. The model demonstrates that the two sites are more distant from one another than might have been expected. However, use of the model demonstrates that the two observational data sets are consistent with one another (Wehde, paper 5).

Please find the drafts of the scientific papers as Annex to the Final Report.