RV Pelagia Shipboard Report:

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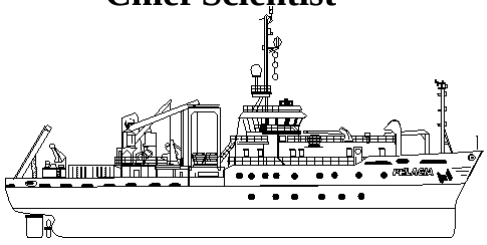
64PE184, 64PE187, 64PE190, 64PE195

Project:
The continental shelf pump hypothesis:
A pilot study in the North Sea

(CANOBA)

Helmuth Thomas
Chief Scientist



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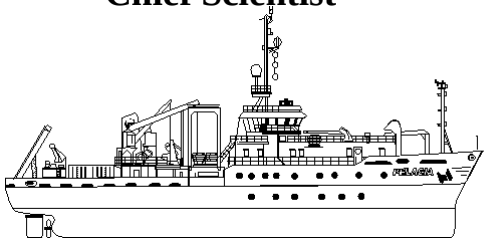

Author‘s address:
Dr. Helmuth Thomas
Royal Netherlands Institute for Sea Research (NIOZ)
Department of Marine Chemistry and Geology
P.O. Box 59, NL-1790 AB Den Burg, Texel
The Netherlands
phone: +31-222-369-438
fax: +31-222-319674
email: hthomas@nioz.nl

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1: Introduction - The CANOBA program

1.1. Scientific background

The combustion of fossil fuels as well as deforestation have led to emission of carbon dioxide (CO_2) into the atmosphere. About half of this CO_2 remains airborne, where it is expected to cause global warming. The other half is partly taken up by the oceans, and partly by the land biosphere. Understanding of the global carbon cycle both in pre-industrial times (before ~1780 A.D.) and with the current perturbation by mankind, is essential for quantifying the fate of fossil fuel CO_2 in the next decades. This in turn is needed to support policy decisions about curtailing emissions (e.g. Kyoto convention).

Thus far global carbon budgets have largely been constructed in terms of oceanic and terrestrial compartments linked by their exchanges with the atmosphere. Coastal seas, here treated as separate compartments, provide a second link between terrestrial and oceanic compartments. The relevance of coastal seas to the global carbon budget is reflected by their high biological activity. Although coastal seas cover less than 10% of the global sea surface, the primary productivity in coastal seas is estimated to be up to 30% of the overall marine productivity. A large part of this primary production is recycled within the euphotic zone by the bacteria and grazers of the planktonic foodweb. Yet some part (10-50%) of the fixed carbon will settle out to the bottom sediments, but then it is mostly (>90%) decomposed at the sediment/water interface, yielding an increase of DIC in bottom waters. The subsequent outflow of such DIC-enriched subsurface waters into the oceans would then provide a net export of DIC from the coastal seas.

The direct impacts of natural terrestrial ecosystems as well as of mankind, of which 37% is living within 100 km of the coast, are buffered or at least smoothed by the coastal seas before they reach the oceanic systems. Largely due to the supply of nutrients (nitrogen (N), phosphorus (P), silicium (Si)) both from river inputs and from shallow marine sediments, there is high primary productivity in coastal surface waters. Additional nutrient input from fertilisers (N, P) used in agriculture, via streams and rivers into the sea, has led to enhancement of this primary productivity (eutrophication) sometimes also leading to severe depletion of oxygen in coastal waters. High loading of rivers with particulate and dissolved organic carbon (POC,

DOC) from municipal waste waters may further enhance this oxygen depletion of the coastal zone.

Until now there has been much speculation but limited facts about the role of coastal seas in the global carbon cycle. Available information , for example about the East China Sea or the Baltic Sea has recently been summarised in an excellent review article by Liu et al. (2000). The North Sea itself has been subject of very intense investigations for many decades by several institutes, making it one of the best understood coastal seas of the world. Most notably hydrography and nutrient inventories are well understood and quite accurately quantified, relative to any other coastal seas in the world. However, in spite of the well publicised relevance of coastal seas for the global carbon cycle, there is only limited information available dealing with namely the inorganic carbon cycle in any coastal sea, this including the otherwise well-studied North Sea. Previous attempts mainly focussed on only certain aspects related to the organic carbon cycle, e.g. primary production of particulate organic matter both suspended as well as within sediments and transport of such organic matter within the North Sea. However, for a carbon budget approach the dominant pools of dissolved inorganic and organic carbon (DIC and DOC) in the water column have been largely unknown until recently due to lack of reliable measurement techniques or due to regionally restricted studies. The currently available carbon data sets have been very sparse hitherto not allowing unequivocal conclusions about the carbon cycle of the North Sea. It thus remains an open question, whether and to what extent the North Sea act as sink or source for atmospheric CO_2, and – related to that - what role the biological fixation and respiration of the North Sea plays in exporting CO_2 to the Atlantic Ocean: the continental shelf pump.

1.2. The North Sea: a brief overview

Location and hydrography

The North Sea is a continental sea with a total surface area of 575000km^2 located on the north-western European continental margin. In the east and south it is bordered by the European continent (Norway in the north to France in the south) while its western boundary is formed by the British Isles. In the south it is connected to the Atlantic Ocean through the English Channel, and in the north it has an open connection to the

Norwegian Sea. In the north the shelf break is located at approximately 200m water depth. The maximum water depth in the southern North Sea is 40-50m. Smaller depressions in the central and northern North Sea are in the order of 40-300m deep. In the central North Sea a large shoal with a minimum water depth of less than 20m is present. The Norwegian Channel, a large depression running in parallel to the Norwegian coast, shows depths of more than 400m and is separated in the south from the Skagerrak by a sill of approximately 280m. The Skagerrak itself is the deepest part of the North Sea (deeper than 780m) and represented the connection to the Baltic Sea.
The dominant hydrographic feature in the North Sea is the tidal motion. It is responsible for the vertical and horizontal mixing of water masses and causes in combination with the long term effect of mainly westerly winds and the baroclinic effect an overall anticlockwise circulation. Atlantic Ocean water enters the North Sea from the south through the English Channel. Baltic Sea water flows through the Kattegatt into the Skagerrak. In the north Norwegian Sea waters enters the North Sea between the Scottish mainland and the Orkney and Shetland Islands and at depths along the western margin of the Norwegian Channel. The main outflow of the North Sea water occurs along the eastern margin of the Norwegian Channel and as the surface current more to the west. During summer only the northern North Sea is stratified allowing the development of several fronts playing an important role in controlling biological processes.

Primary production and nutrients

Since the exchange time for the entire water volume of the North Sea is 6 months to one year, nutrient inputs from the Atlantic Ocean play the major role in the North Sea's nutrients budgets. Other sources such as rivers and the atmosphere are less dominant finally enabling high levels of primary production. The level of net primary production is 250g$Cm^{-2}a^{-1}$ the central North Sea decreasing to 200g$Cm^{-2}a^{-1}$ and 150-200 g$Cm^{-2}a^{-1}$ in the southern and northern parts, respectively. Locally, up to tenfold higher levels can be observed along the coastal lines. Despite of the high production values almost no significant sedimentation of organic matter can be observed in the North Sea as a consequence of the hydrographic conditions. Only in the deeper areas in the Norwegian Channel and the Skagerrak minor sedimentation is found. The processes dominating the nutrient budgets are recycling, resuspension and transport, whereof the first ones enable biological turnover which exceeds by far the annual in

and outflow of nutrients. From long term observations significant impacts of eutrophication of the ecosystem of the North Sea could be established. Beside increasing primary production and biomass pools, changes in species composition and decreases in species diversity as well as oxygen depletion in less flushed areas of the North Sea might be mentioned.

Socio-economic aspects and conflict potentials

Since the North Sea is largely enclosed by the European continent and by the British Isles, it is shared and influenced by a number of European nations. The actual and perceived state of the health of the North Sea has major implications and ramifications for multi-billion Euro industries within Europe. Several of the most important industrial centres of central and north-western part of Europe are connected to the North Sea constituting a major socio-economic resource for regional Europe. Together with the area around Singapore for example, the southern North Sea shows the highest ship traffic densities world-wide. Land-based industries, agriculture and the human society itself deleteriously affect the ecosystem of the North Sea by aquatic waste disposal of e.g. organic carbon and nutrients. On the other hand, land-based industries, agriculture and communities strongly depend on this avenue of disposal for economic reasons. The ecosystem of the North Sea is thus severely affected by both terrestrial and human impacts such as eutrophication by nutrients and of organic carbon (municipal waste) and by the inflow of other pollutants. The metabolism of all these substances influences the carbon cycle and, via the associated oxygen conditions, subsequently affects the quality and quantity of life within the North Sea. Fisheries and coastal tourism in turn have a fundamental interest in the health of the North Sea.

1.3. Aims of the program

The role of coastal seas in the global carbon cycle will be assessed in a pilot study in the North Sea. The hypothesis of a “continental shelf pump” for uptake of CO_2 from the atmosphere with subsequent transport to the open ocean will be tested for the North Sea as a nutrient-rich sea with high biological productivity. Interactions of the pools of C, N, P, and O_2 will be assessed also to describe the “biological CO_2 pump”.The extended field data set will be evaluated by property-property relations

and other methods to determine seasonality of river inputs, of C/N/P/O_2 inventories, and of CO_2 exchanges with the atmosphere. Attention will be given to exchanges in the Kattegat and with the North Atlantic Ocean, and notably the annual air-sea CO_2 exchange budget, finally testing the continental shelf pump hypothesis.
Furthermore, upon extension with a C-budget module, the existing ecosystem model ERSEM II, which already well describes nutrient and plankton dynamics in context of hydrography, will be used to simulate the carbon cycle processes including verification against the four seasons field data base.

1.4. Scientific objectives:

- For carbon a completely new field database will be established. The North Sea will be covered during four seasons by an adapted 1° by 1°grid corresponding to 97 stations.
- The data set will be used to assess the physical and biological processes affecting carbon storage and release. Attention will be given to the interaction between hydrography and the carbon, nitrogen and phosphorus pools, and to transport processes of carbon into and out of the North Sea. Sources and sinks to be taken into account are rivers, the North Atlantic Ocean, the atmosphere, as well as the Baltic Sea.
- Full descriptions of the carbon cycle are to be implemented into the ERSEM II ecosystem model with an eye to establishing the annual budgets for carbon and related elements N, P and O. Upon verification against the field data the ERSEM II simulations will indicate whether these coastal seas are a net source or sink for atmospheric CO_2 and for carbon in general, i.e., the “continental shelf pump” hypothesis will be tested.

1.5. Fieldwork methodology

During four cruises the size and composition of the pools of organic and inorganic carbon and nitrogen as well as of phosphate will be recorded accurately in the North Sea throughout an annual cycle.

A simultaneous record of these pools is required to study the C-cycle and its interaction with the N- and P- cycles, since there is strong evidence, that the biological changes of the C-pools cannot simply be related to those of N- and P-pools using Redfield ratios (e.g. Thomas et al., 1999). Earlier data sets (ICES, NERC North Sea programme, ZISCH, KUSTOS, NOWESP, etc.) suffer from the lack of accurate dissolved inorganic (DIC) and organic carbon (DOC) values. Simply relating former nutrient data to new carbon data would not allow to reliably assess the C-, N- and P-cycles and their interaction due to the high variability of coastal seas in both time and space. New techniques to accurately measure DIC and DOC will be applied. The field work will result in a high quality synoptic field data set of the size and composition of the pools of organic and inorganic carbon, nitrogen and phosphate in the North Sea throughout a closed annual cycle. The field data will be related to previous studies by adopting the 1° by 1° grid of the European Regional Seas Ecosystem Model II (ERSEM II). However, in the relatively homogeneous central North Sea not all gridpoints need to be sampled, whereas stations were spaced more closely in the southern North Sea and along the Norwegian coast. The location of the sampled 97 stations in the North Sea is indicated in Fig.1. At each station 8 to 12 depths were sampled. The four seasons were covered within a closed annual cycle by four 26-day cruises. The first two cruises were carried out from 18.8.2001 to 13.09.2001 (end of the productive period in late summer), 6.11.2001-29.11.2001 (late autumn/early winter season). The following two cruises were carried out from 11.2.2002 to 8.3.2002 (late winter season) and 6.5.2002 to 26.5.2002 (initial nutrient depletion by spring bloom).

The partial pressure of CO_2 (pCO_2), DIC, DOC, pH and or Alkalinity(A_T), oxygen (O_2), nitrate/nitrite (NO_3/NO_2), ammonium (NH_4), phosphate (PO_4) and silicate (SiO_4) were determined on all depths at the stations (Table 1). Particulate organic and inorganic carbon (POC, PIC), dissolved and particulate organic nitrogen (DON, PON) and chlorophyll *a* (Chl. a) and primary productivity were/will be analysed on

approximately one third of the vertical samples. Surface-water pCO_2 was determined continuously using an underway system. Temperature, salinity and fluorescence were

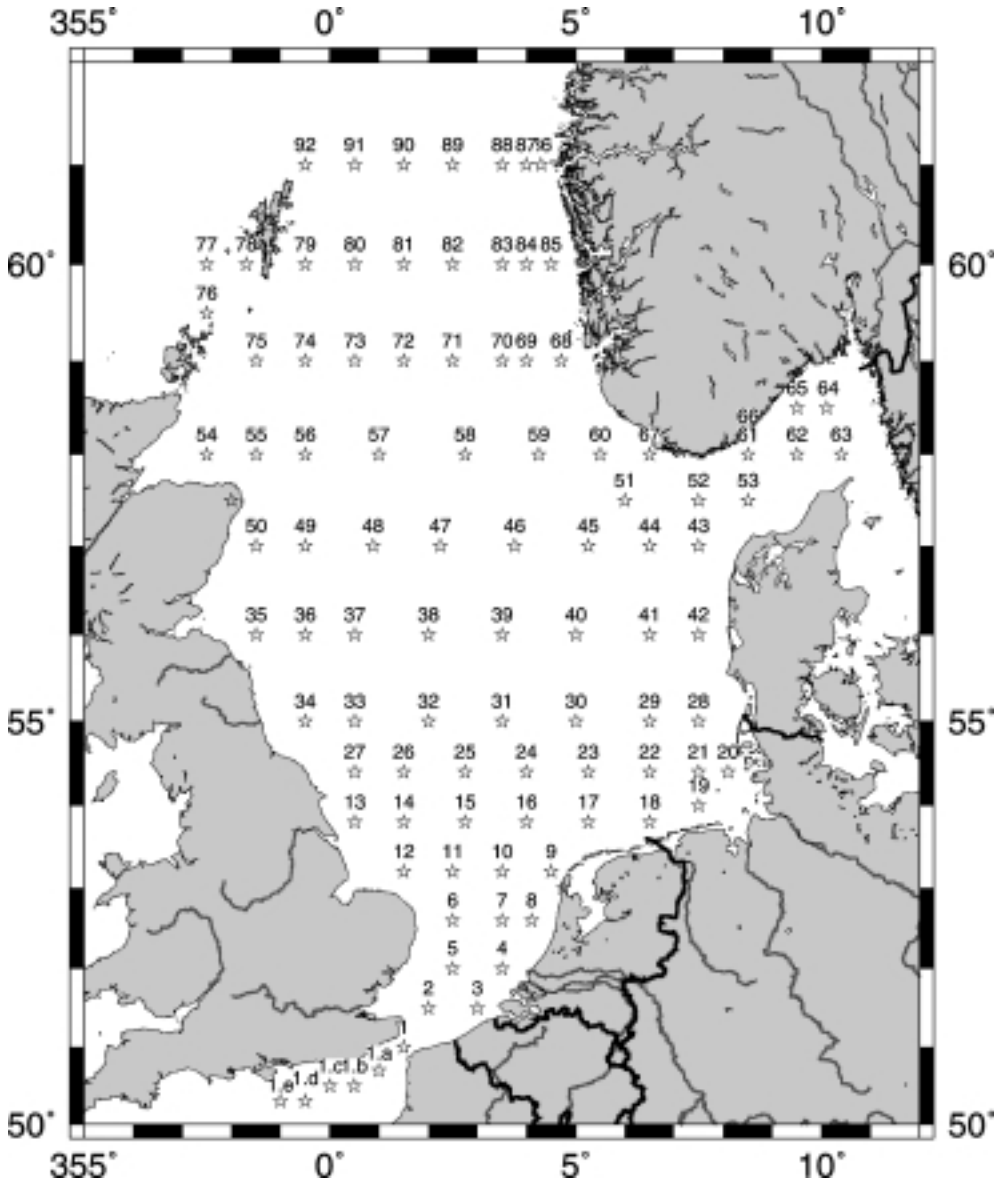

Figure 1: The CANOBA station grid. 92 stations are located in the North Sea and 5 stations (1.a-1.e) in the English Channel.

determined continuously and on stations.

Available methods for measuring the very low concentrations of organic phosphorus compounds (POP, DOP) were applied as a kind of pilot study since those methods show currently still a significant lower accuracy compared to methods for measuring C or N compounds and certification standards do not yet exist either. The internal consistency and reliability of the field data was warranted by an rigorous calibration procedure. During the measurements of each parameter was calibrated to the same

certified reference material and internationally accepted procedures will be applied (DIC Dickson standards; NOAA pCO_2 calibration gases, DOC standards Prof. Sharp USA; WOCE procedures for determining nutrients and oxygen, Quasimeme Intercalibration for nutrients, DON and DOP).

Table 1: Parameters determined during the CANOBA program

Discrete vertical samples at the stations	No.	continuous measurements
DIC, A_T, pH, pCO_2, DOC, O_2, $NO_{3/2}$, NH_4, PO_4, SiO_4	≈700	pCO_2, T, S
POC, PIC, Chl.a, DON, DOP, PON, POP	≈200	

1.6. History of CANOBA

CANOBA was intended to be an European initiative investigating carbon and nutrient cycles of the North Sea and the Baltic Sea jointly: **Ca**rbon and Nutrient Cycling in the **Nor**th Sea and the **Ba**ltic Sea. The present CANOBA currently realises this aim for the North Sea as an international effort and the corresponding counterpart for the Baltic Sea is being set-up just now.

CANOBA has been presented as pilot study at the JGOFS/LOICZ Continental Margins Task Team (CMTT) meeting held in Taipei, Taiwan in September 2001 during the Joint Geosciences Assembly.

First results of the CANOBA cruises have been presented during the European Geophysical Society's XXVII general assembly in Nice, France, 21-26 April 2002.

2. The CANOBA cruises

The four cruises of the CANOBA program 64PE184, 64PE187, 64PE190 and 64PE195 were carried out in summer and autumn 2001 and winter and spring 2002. A consecutive sampling of all four seasons was thus performed.

2.1. CANOBA I (64PE184)

The first leg of the cruise 64PE184 started on 18.08.2001 from Peterhead in Scotland and ended on 06.09.2001 at Texel (dashed line in Fig. 2) The second leg started from Texel on 08.09.2001 and was finished on 13.09.2001 at Texel (dotted line in Fig. 2).

The first leg of this cruise left northward from Peterhead passing the Orkney and Shetland Islands up to 61°N. From this most northern section the cruise headed southward sampling all stations except for the stations 9, 10 and 15-17, which had been left out for the second leg, since the Lander station (square in Fig. 2) close to the stations 16 and 17 had to be visited during the second leg. The weather conditions during the first leg were extremely good and only several hours were lost at the very beginning due to stronger winds. This allowed a good progress in sampling the CANOBA stations and it was even possible to sample additional stations in the English Channel in order to enable a more reliable quantification of the carbon exchanges between the North Sea and the Atlantic Ocean via the English Channel.

During the second leg the stations 9 and 10, which are located close to Texel, had been sampled just before we had to stop the scientific work because of a strong storm Saturday night (09.09.2001) and the entire Sunday. Under difficult weather conditions we continued working on Monday and finished the first cruise of the CANOBA program successfully.

The following days were spent for the BIVALFF program, which is documented in detail in section 5.1. The second leg and thus the CANOBA I cruise ended in the morning of the 13.09.2001 on Texel.

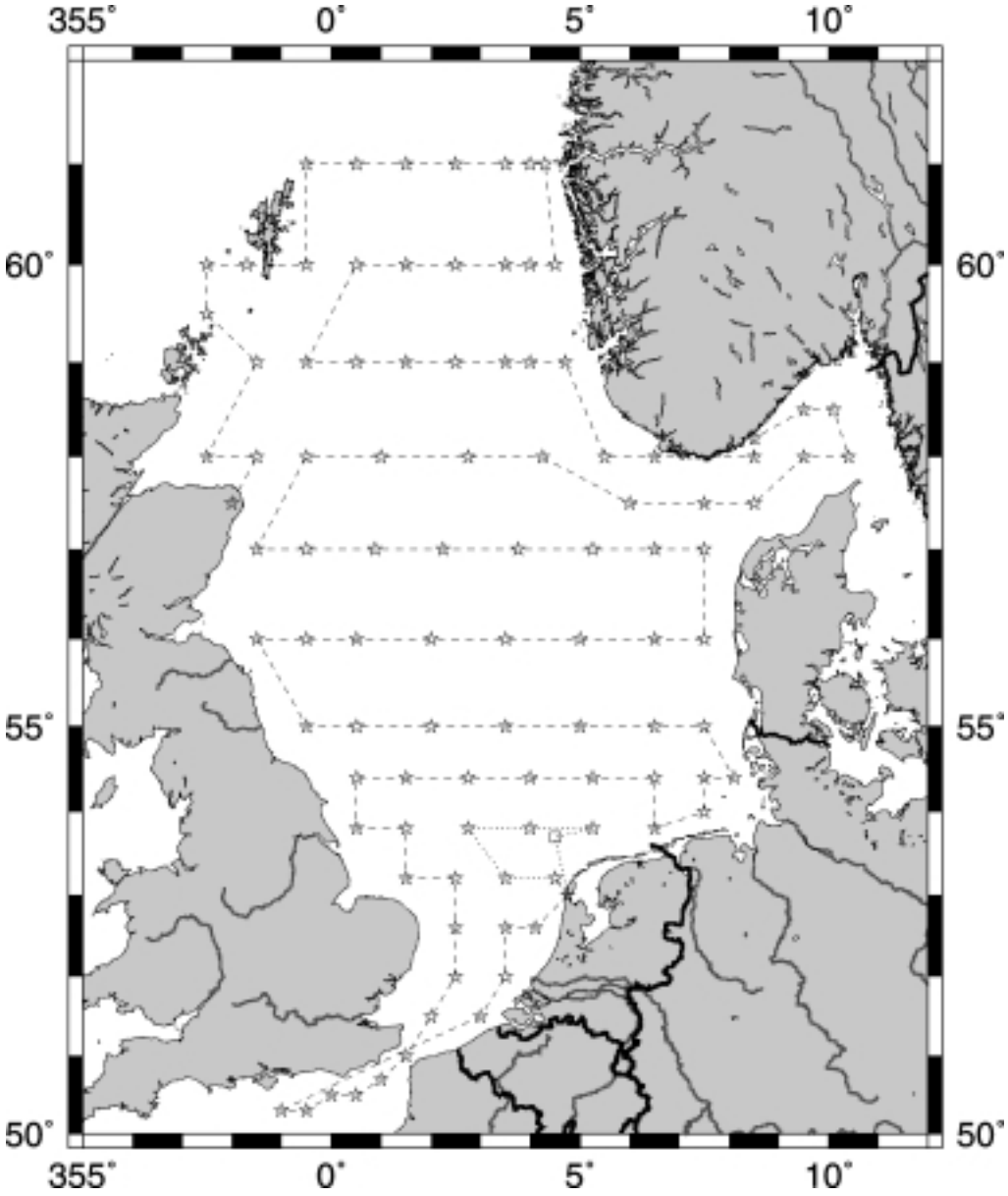

Figure 2: Cruise track of the CANOBA I cruise from 18.08.2001-13.09.2001. The dashed and dotted lines indicate the first and second leg. The diamonds indicate the CANOBA stations and the square the station of the BIVALFF program carried out during the second leg (see 5.1).

2.2. CANOBA II (64PE187)

The second CANOBA cruise started on 06.11.2001 on Texel, where it also ended on 29.11.2001 (Fig.3).The station work started near the south-eastern British coast and was continued in the central North Sea heading towards the Skagerrak were a severe storm was encountered. During a surprisingly calm period the most northern sections from 61°N to 58°N were sampled. The sampling program was finished after an 28 hours transect in the southern North Sea including the German Bight and the Channel area. Despite the late season of the year a storm-adapted cruise schedule kept the “bad

weather days" as low as possible and it was even possible to sample the stations in the English Channel again. At selected stations samples for a method intercomparison of trace metal analysis were taken (C: Schulte, AWI). On 29.11.2001 the second CANOBA cruise was finished successfully on Texel.

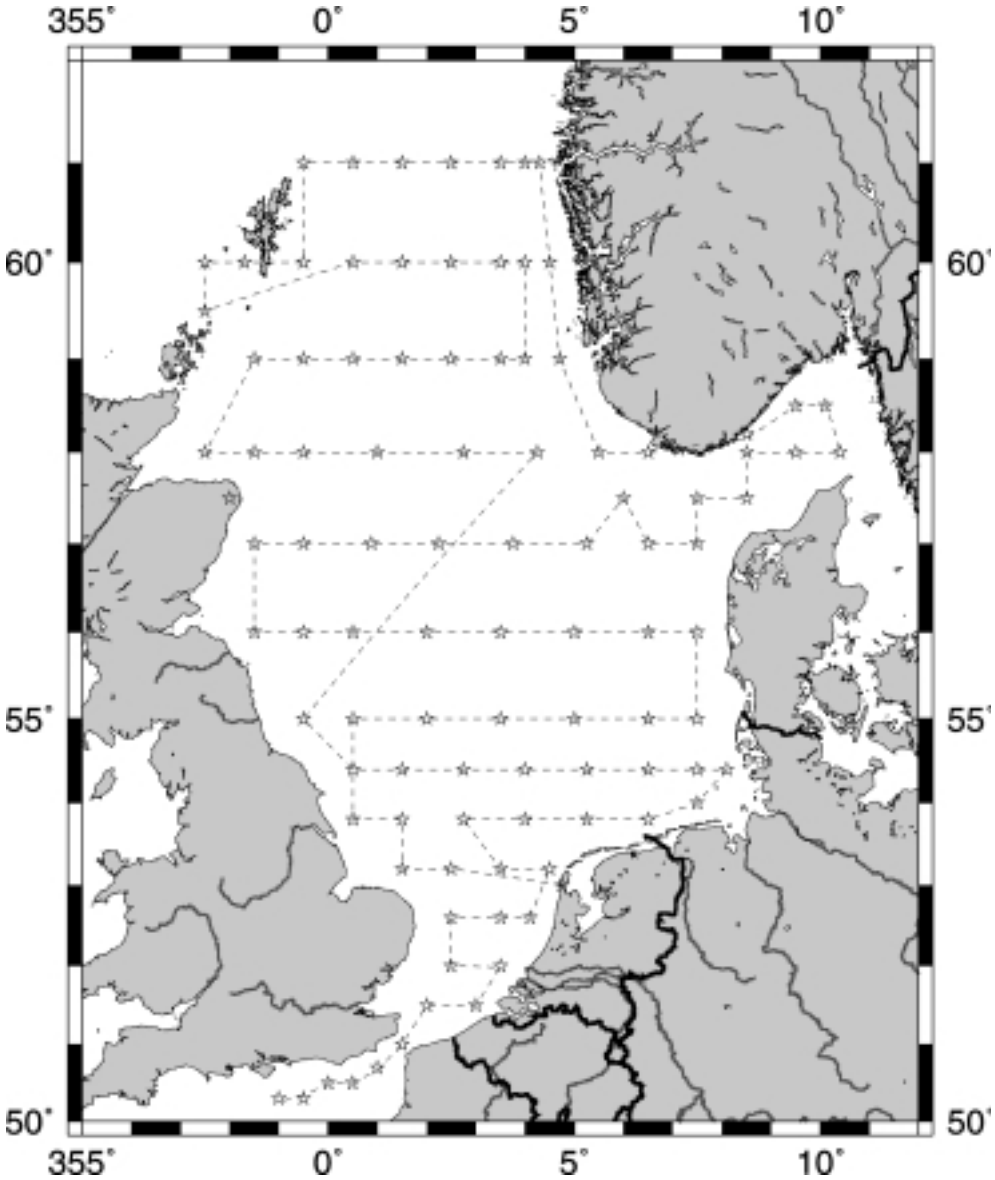

Figure 3: Cruise track of the CANOBA II cruise from 06.11.2001-29.11.2001.

2.3. CANOBA III (64PE190)

The third CANOBA cruise (Fig. 4) started on 11.02.2002 from Texel, where it also ended on 05.3.2002. Similar to the second cruise the sampling programme started in

the southern part o the central North Sea heading toward the British east coast. Along the coast we sampled all stations in northward direction until the 61°N line. Under weather conditions, which enabled continuos sampling we finished the three most northern section and the Skagerrak area. We leaving the Skagerrak area we encountered the stormy weather which influenced the Netherlands and other parts of north-western Europe almost during the entire February. We had to stop our sampling activities several times in the central North Sea on our way southward. After approximately one week of rough weather we could finalise the cruise programme in the German Bight and the southern North Sea including the English Channel. We

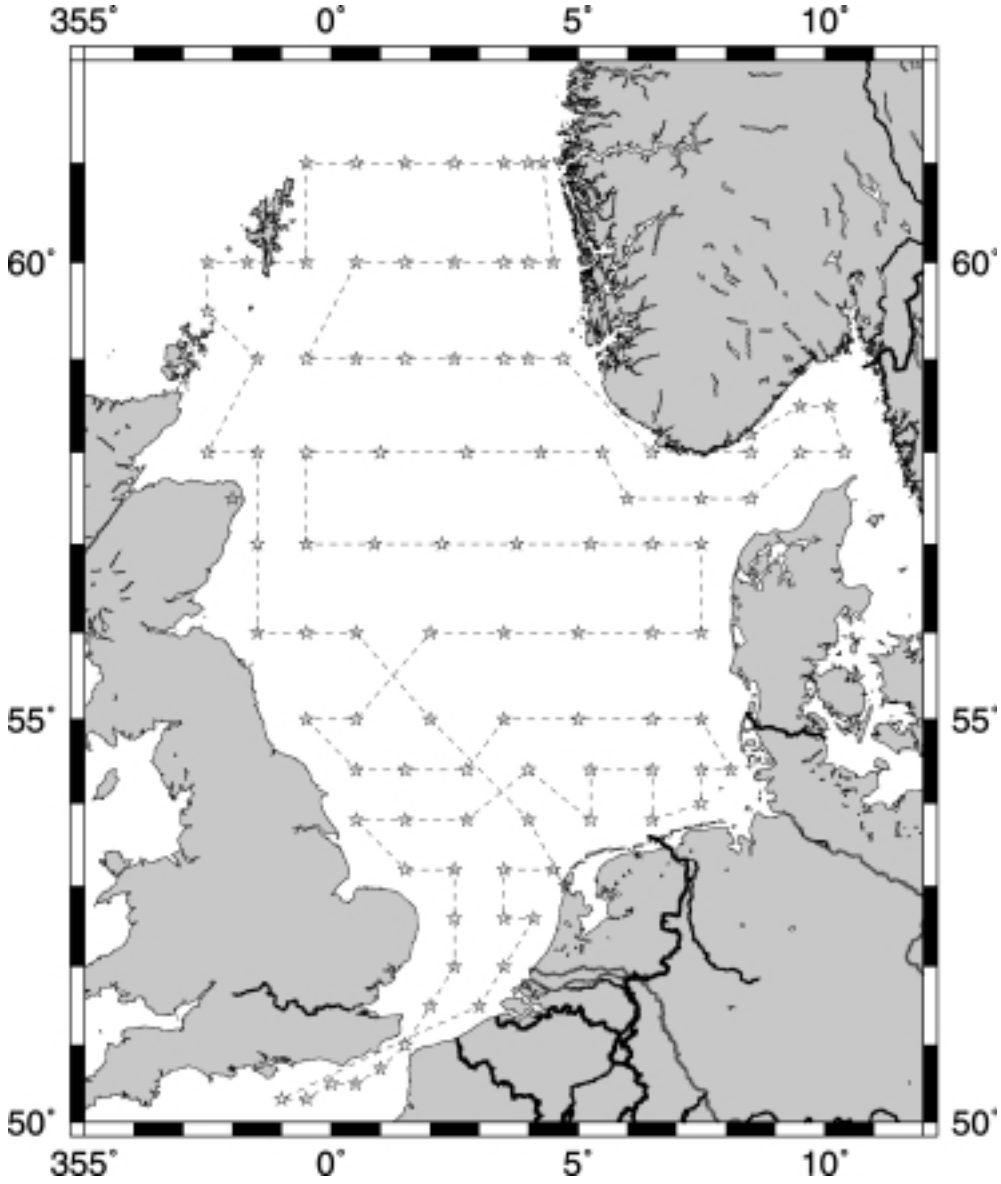

Figure 4: Cruise track of the CANOBA III cruise from 11.2.2002-5.3.2002.

finally returned on 11.02.2002 having successfully sampled all stations as during the two cruises before.

2.4. CANOBA IV (64PE195)

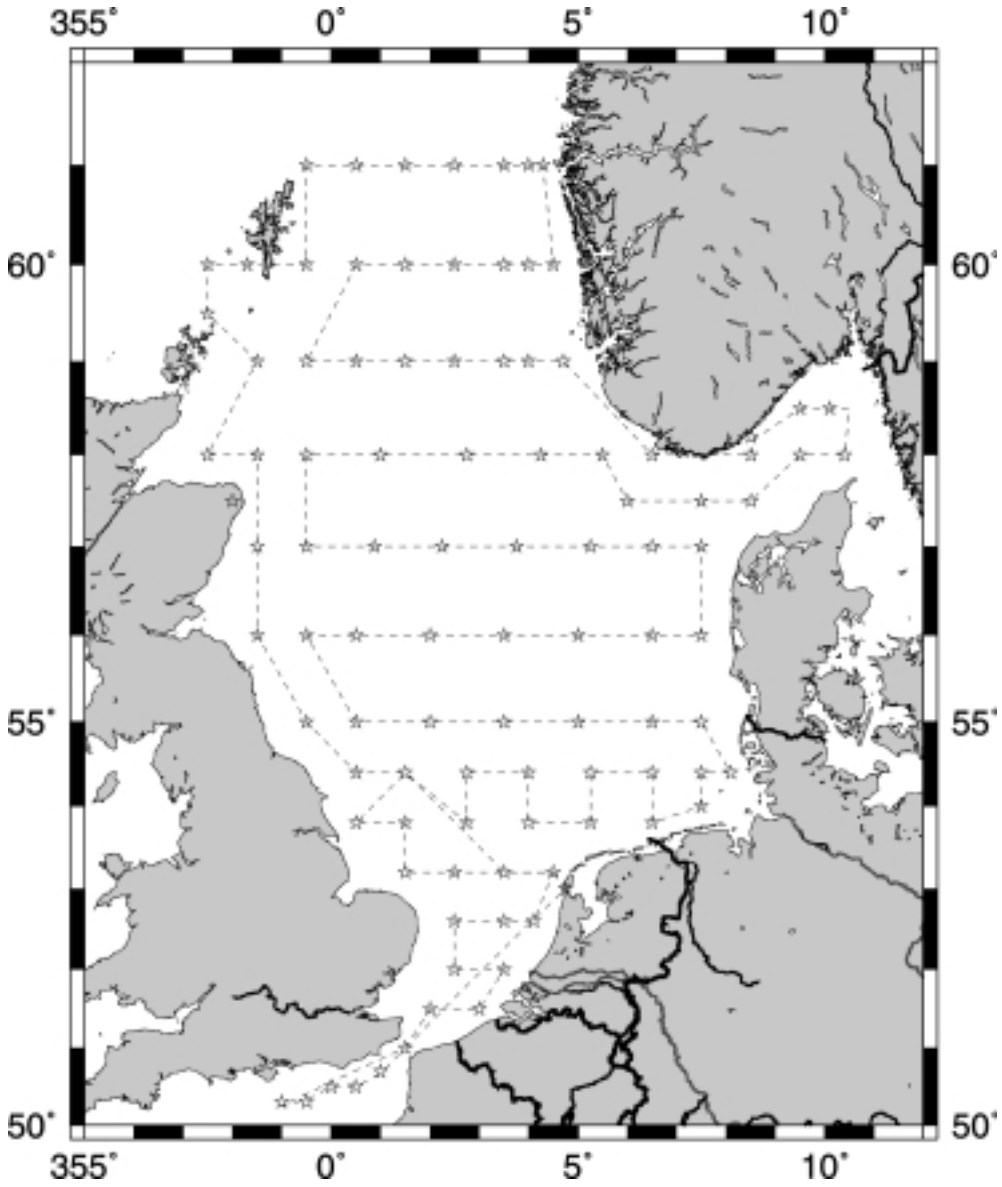

Figure 5: Cruise track of the CANOBA IV cruise from 6.5.2002-26.5.2002.

The fourth and last CANOBA cruise was performed between 06.05.2002 and 26.5.2002 again leaving and arriving from/at Texel.

As expected during the last cruise the weather conditions were significantly better than during second and third CANOBA cruise. We more or less kept the cruise track

of the third cruise and crossed the North Sea toward the British coast. Along the British coast we sampled the stations in northward direction until we approached the most northern line. We then sampled all sections and the Skagerrak area heading toward the German bight. The stations 26, 10 and 9 were sampled and second time on our way south. Only during the last stations in the English Channel we encountered rather unpleasant conditions because of large swell caused by an earlier storm at the Atlantic Ocean. Despite this minor problems we again finished the sampling programme of the fourth CANOBA cruise successfully and terminated to seagoing part of CANOBA on 26.05.2002 at Texel.

3. Methods

3.1. Onboard Measurements

3.1.1. The partial pressure of CO_2 (pCO2)

H. Thomas (C1, C2, C3, C4) [#]*, Y. Bozec (C1, C2, C3), L.-S. Schiettecatte (C2, C4), A. Borges (C2) S. Claus (C4)*

During both CANOBA cruises the partial pressure of CO_2 (pCO_2) in the surface waters was determined using an underway system with continuous flow equilibration. The water flow to the equilibrator was about 60L min^{-1} which was reduced by a bypass just before the equilibrator to 2-3L min^{-1}. The temperature difference between the equilibrator and the surface water was lower than 0.5K, usually 0.1K. The detection of pCO_2 was performed by a non-dispersive infrared spectrometer, which was calibrated against *National Oceanic and Atmospheric Administration* (NOAA) standards every 24 hours. The method is described in detail by Körtzinger et. al. (1996) with an estimated error of approximately 1 µatm. The atmospheric pCO_2 was sampled at the antenna platform of the ship and determined every 2 hours.

During CANOBA II and IV a second pCO_2 system was installed using a non-dispersive infrared gas analyser (Li-cor®, LI-6262) to measure pCO_2 in wet air equilibrated with seawater. The Li-cor® was calibrated daily using three dry gas standards: pure nitrogen (0.0 ppm; *Air Liquide Belgium*) and two gas mixtures with a CO_2 molar fraction of 360.5 and 773.8 ppm (*National Oceanic and Atmospheric Administration*). The temperature at the outlet of the equilibrator was monitored with a platinum resistance thermometer (PT100, METROHM®) with an estimated accuracy of ±0.05°C and the pCO_2 values are corrected for the temperature difference between *in-situ* seawater and water in the equilibrator, using the algorithm proposed by *Copin-Montégut* [1988]. The offset in temperature was typically ~0.5°C. The accuracy of the pCO_2 measurement by equilibration is estimated to ± 2 µatm (cumulated errors on temperature correction and instrument calibration). The equilibrator design and performance tests can be found in *Frankignoulle et al.* [2001]. A second Li-cor® was used to measure atmospheric pCO_2 sampled at the bow of the ship at approximately 10 m height.

[#] (C1 = during CANOBA I, C2 = during CANOBA II, C3 = during CANOBA III, C4 = during CANOBA IV)

3.1.2. Dissolved inorganic carbon (DIC)

H. Thomas (C1, C2, C3, C4), Y. Bozec (C1, C2, C3), E. Boelens (C3, C4), C. Treignier (C1), P. Mueller (C4)

During the CANOBA cruises dissolved inorganic carbon DIC (DIC) was determined the coulometric method by Johnson et al. (1993). The principle of coulometry relies on Faraday's law according to which 96485 Coulombs (C) correspond to 1mol of a chemical substance which electrical charge will be changed by one unit. An automated extraction line takes volumetrically a very accurate subsample which is acidified with 8.5% phosphoric acid (H_3PO_4). Due to this decrease in pH all HCO_3^-- and CO_3^{2-}- ions will be converted to $CO_{2,aqueous}$. The sample is stripped using ultra-pure nitrogen gas and the carrier gas is led into the titration cell. This cell contains a solution of Dimethylsulfoxide (DMSO), ethanolamine and a colourimetric indicator thymolphtalein. The irreversible reaction of the CO_2 gas with the ethanolamine generates the hydroxyethylcarbamic acid (1) which in turn gives a colour change of the (dark blue) indicator. The fading of the colour is detected photometrically. During the electrochemical tritation the hydroxyethylcarbamic acid is neutralised by OH^- ions (2-4). From start to end of the titration the current (*I*) is integrated over the time and the according to Faraday's law the CO_2 molecules titrated, i.e. the concentration of DIC can be computed.

$$CO_2 + HO(CH_2)_2NH_2 \rightarrow HO(CH_2)_2NHCOOH \quad (1)$$

$$2Ag^0 \rightarrow 2Ag^+ + 2e^- \quad (2)$$

$$2H_2O + 2e^- \rightarrow H_2(\uparrow) + 2OH^- \quad (3)$$

$$OH^- + HO(CH_2)_2NHCOOH \rightarrow H_2O + HO(CH_2)_2NHCOO^- \quad (4)$$

At the stations DIC was measured directly after sampling and between the stations approximately every 10 min. using the online-mode of the extraction system.

3.1.3. Nutrients

K. Bakker (C1, C3), E. van Weerlee (C2), J. van Ooijen (C4)

From all sample bottles samples were drawn for the determination of the nutrients silica, nitrite, nitrate, phosphate and ammonia. The samples were collected in polyethylene sample bottles after three times rinsing. The samples were stored dark and cool at 4°C.

Nutrients

All samples were analysed for the nutrients ammonia, phosphate, nitrate and nitrite within 10 hours with an autoanalyzer based on colorimetry. Silicate was measured every two days. The lab container was equipped with a Technicon TRAACS 800 auto-analyzer. The different nutrients were measured colorimetrical as described by Grashoff (1983). The samples, taken from the refrigerator, were directly poured into open polyethylene vials (6 ml) and put in the auto sampler-trays. A maximum of 60 samples in each run was analysed. The samples were not filtered before analysis.

The different nutrients were measured colorimetrical as described by Grashoff (1983);

- Silicate reacts with ammoniummolybdate to a yellow complex, after reduction with ascorbic acid the obtained blue silica-molybdenum complex was measured at 800nm (oxalic acid was used to prevent formation of the blue phosphate-molybdenum).
- Phosphate reacts with ammoniummolybdate at pH 1.0, and potassiumantimonyltartrate was used as an inhibitor. The yellow phosphate-molybdenum complex was reduced by ascorbic acid to blue and measured at 880nm.
- Nitrate was mixed with a buffer imidazole at pH 7.5 and reduced by a copperized-cadmium coil (efficiency> 98%) to nitrite, and measured as nitrite (see nitrite). The reduction-efficiency of the cadmium-column was measured in each run.
- Nitrite was diazotated with sulphanilamide and naftylethylenediamine to a pink coloured complex and measured at 550nm.
- The difference of the last two measurements gave the nitrate content

Standards were prepared by diluting stock solutions of the different nutrients in the same nutrient depleted surface ocean water as used for the baseline water. The standards were kept dark and cool in the same refrigerator as the samples. Standards were prepared fresh every two days. Each run of the system had a correlation coefficient for the standards off at least 0.9998. The samples were measured from the surface to the bottom to get the smallest possible carry-over-effects. In every run a

mixed nutrient standard containing silicate, phosphate and nitrate in a constant and well known ratio, a so-called nutrient-cocktail, was measured in duplicate. This cocktail is used as a guide to check the performance of the analysis. The reduction-efficiency of the cadmium-column in the nitrate lane was measured in each run.

3.1.4. Dissolved oxygen (O_2)

L.-S. Schiettekatte (C2, C3, C4), S. Claus (C3, C4), C. Harms (C1), T. Reinthaler (C1), A. Borges (C2), A. Tena (C3), N. Richard (C4)

Details for the oxygen determination during the first CANOBA cruise are given under 5.3.

During the last three CANOBA cruise dissolved oxygen concentration was measured by the Winkler method using a potentiometric end-point determination with an estimated accuracy of ± 2 mmol kg^{-1} (± 0.5% of level of saturation). The oxygen saturation level (%O_2) is calculated from the observed concentration of dissolved O_2 and the concentration of O_2 at saturation using the algorithm proposed by *Benson and Krause* [1984].

3.1.5. Dissolved organic nitrogen and phosphorus (DON/DOP)

K. Bakker (C1, C3), M. Behrens (C1), S. Grobe (C2, C3), R. de Jonge (C1), M. Keij (C1), N. Lohrmann (C1, C2, C4), C. Schulte (C2), S. Spohr (C2), E. van Weerlee (C2), B. Blume (C3), K. Mueller (C3), S. Truemper (C3), C. Hartmann (C4), S. Scherding (C4), S. Behringer (C4), J. van Ooijen (C4)

For the determination of dissolved organic nitrogen (DON) and dissolved organic phosphorus (DOP) 20ml of filtered seawater sample (through pre-combusted Whatman GF/F glass fiber filters) were collected in pre-combusted Teflon bottles. The DON and DOP analyses were performed simultaneously according to the method of Valderrama (1981) which has been modified for by K. Bakker and G. Kramer (NIOZ). This procedure is based on an alkaline persulphate digestion (at 120°C in an autoclave for 90min) over a wide pH range starting at pH 9 and ending at pH 4 using boric acid and sodium hydroxide. The resulting total nitrate and total phosphate concentrations were measured using the auto-analzyer for inorganic nutrient determination as described above (see 3.1.3.). Subtracting the inorganic nitrogen (NH_4^++NO_3^-+NO_2^-) and phosphate concentrations measured from the same sample the corresponding DON and DOP concentrations were calculated.

In order to verify the recovery of the DON and DOP measurements a cocktails containing various organic N- and P-compounds dissolved in MilliQ water and seawater was measured routinely with the samples. An example of the recovery measurements is given below for 45min. digestion time and 90 min. digestion tome (Tab. 2.a, b). For the shipboard measurements 90mn. digestion time was applied, since the digestion of certain P-compounds appeared to be incomplete when digesting only 45min.. Additionally an intercalibration with Quasimeme samples was performed.

Table 2a: Recoveries of various organic N- and P-compounds after 45min digestion.

Substance	**recovery (%) in MQ**		**Recovery (%) in SUB**	
	P • M	**N • M**	**P • M**	**N • M**
ATP	44.17	88.42	52.87	85.23
DAMP	89.30	81.70	76.88	88.99
2-AEP	85.85	88.62	65.57	82.85
P-L-tyr	100.79	99.24	97.07	97.19
PFA	92.22		80.71	
DL-α-GyP	92.13		87.59	
RuBP	72.90		69.78	
TDP	41.96	91.69	39.56	71.04
Glyc		100.05		94.62
gluc-6-P			81.53	
Average		**92.53**		**87.19**

SUB = nutrients depleted seawater

Table 2b: Recoveries of various organic N- and P-compounds after 90min digestion.

Substance	**element**	**90 min**		**45 min**	
		MQ	**SUB**	**MQ**	**SUB**
P-L-tyr	**P**	104.9	102.3	100.8	97.1
	N	122.9*	n.d.	99.2	97.2
Cocktail	**P**	93.9	95.4	88.4	73.1
	N	92.3	n.d.	97.9	90.4

*contamination of the sample

This test indicates that the recovery for nitrogen is not changing with the longer time of destruction and that the recovery for phosphorous is increasing, also in substances

where the recovery was good after 45min. of destruction (P-L- tyr). Thus, 90min. digestion time has been applied during the CANOBA program.

3.1.6. CTD and aquaflow

J. Derksen (C1, C3), T. Bauer (C1), A. Asjes (C2, C4), R. Groenewegen (C1)

A 24 position rosette sampler was used, fitted with 22 10litre NOEX sampler bottles. A multi-valve system, developed at NIOZ, allowed closing the sampler bottles by computer command from the CTD operator. The CTD was equipped with a S/N1219 temperature sensor, a S/N1204 conductivity sensor, a chelsea flourimeter 88/725/042, a pressure sensor 48349, an oxygen sensor 430234, a seapoint turbidity meter 1737, an irradiance sensor (PAR) 4410, a transmissometer 178D and a surface irradiance sensor.

For the data collection the Seasave software, produced by SBE, was used. The CTD data were recorded with a frequency of 24 data cycles per second. After each CTD cast the data were copied to a hard disk of the ship's computer network, and a daily back-up copy was made on tape. On board the up-cast data files were sub-sampled to produce files with CTD data corresponding to each water sample, taken with the rosette sampler. The CTD data were processed with the preliminary calibration data, and reduced to 0.5 s average ASCII files, which were used for the preliminary analysis of the data. Full data processing with the final calibration values will be completed at NIOZ, Texel.

The sea surface temperature, salinity and fluorescence were measured continuously with an AQUAFLOW thermo-salinograph with the water intake at a depth of about 3m. Temperature and salinity data were (are to be) calibrated vs. the CRD measurements.

3.1.7. Alkalinity

L.-S. Schiettekatte (C2, C3, C4), S. Claus (C3, C4), J. Hegeman (C1), A. Borges (C2), A. Tena (C3), N. Richard (C4)

During CANOBA I samples for the determination of total Alkalinity (A_T) were filtered through GF/F filters and stored at 4°C for the final determination in the laboratory using the classical Gran electro-titration method.

During CANOBA II-IV A_T was determined onboard using the classical Gran electro-titration method, on 100 ml GF/F filtered samples. The reproducibility of A_T measurements performed on board is ± 4 µmol kg^{-1}.

3.1.8. pH

L.-S. Schiettekatte (C2, C3, C4), S. Claus (C3, C4), A. Borges (C2), A. Tena (C3), N. Richard (C4)

During CANOBA I no pH measurements were performed.

During CANOBA II-IV the measurement of pH was obtained using a Ross combination electrode (ORION®) for discrete samples and a METROHM combination electrode for underway samples, both calibrated on the Total Hydrogen Ion Concentration Scale (mol kg SW^{-1}), using the TRIS and AMP buffers proposed by *Dickson* [1993]. The reproducibility of pH measurement is estimated to be ± 0.004 pH units.

3.2. Sampling procedures

3.2.1. DOC, POC, PON, PIC, POP

M. Behrens (C1), S. Grobe (C2, C3), R. de Jonge (C1), M. Keij (C1), N. Lohrmann (C1, C2, C4), C. Schulte (C2), S. Spohr (C2), B. Blume (C3), K. Mueller (C3), S. Truemper (C3), C. Hartmann (C4), S. Scherding (C4), S. Behringer (C4)

During all CANOBA cruises samples for dissolved organic carbon (DOC), particulate organic carbon (POC), particulate organic nitrogen (PON), particulate organic phosphorus (POP) and particluate inorganic carbon (PIC) were taken. Water samples were filtered through precombusted GFF filters. From the filtrate acidified samples of 8ml were frozen for later DOC measurements. The residual filters were frozen for the remaining measurements.

3.2.2. Chlorophyll *a*

J. Hegeman (C1, C4)

Samples for the later determination of Chlorophyll a (Chl. *a*) were taken for the surface layer sample of most of the stations. Together with the determination of

primary production (see below) at selected stations Chl. *a* was sample at different depth.

3.2.3. Primary Production

J. Hegeman (C1, C4)

Phytoplankton primary productivity was measured at each dawn station using 14C labelled bicarbonate as inorganic tracer. Samples were taken and incubated for 24 hours in a deck incubator which was flushed continuously with seawater in order to generated the temperature conditions of the ambient surface waters. In order to obtain depth profiles of primary productivity, the incubation were carried out at different light conditions between 85% down to 0.6% of the surface incident irradiance. After incubation samples were filtrated gently through GFF-filters. The filters were fumed shortly (5 min) in fuming hydrochloric acid and frozen for the later determination of 14C-organic carbon on the filter in a liquid scintillation counter using the standard procedure.

4. First results

4.1. Surface temperature and salinity

4.1.1. Surface temperature

During the late summer cruise CANOBA I highest temperatures (Fig. 6a) between 18°C and 20°C were observed in the southern and south-eastern areas, i.e., in the areas which show the strongest coastal influences and freshwater inputs. These high temperatures were also observed in the Skagerrak area: The northern and north-western parts were characterised by temperature of approximately 13°C-15°C and the temperature distribution might indicate the water input from the North Atlantic Ocean via the northern boundary of the North Sea. A rather clear boundary between the colder waters from the north and the warmer waters from the south might be found at approximately 53°N. The data of the November (autumn) cruise (Fig. 6b) show clearly the inflow of cold water from the north, whereas all coastal areas except for the German Bight and the Skagerrak still reveal temperatures above 10°C as the waters do, which come from the Atlantic Ocean via the English Channel. During the winter cruise in February (Fig. 6c) the entire North Sea is characterised by cold waters of approximately 5°C-7°C. Only close to the boundaries to the North Atlantic Ocean slightly higher temperatures have are observed, where the input of ocean water apparently buffers the continental cooling of the North Sea water during winter. During the spring cruise in May (Fig. 6d) still cold waters of approximately 10°C were observed in the north-western and northern areas of the North Sea, whereas the southern and coastal areas already reveal temperatures of 12°C to 15°C.

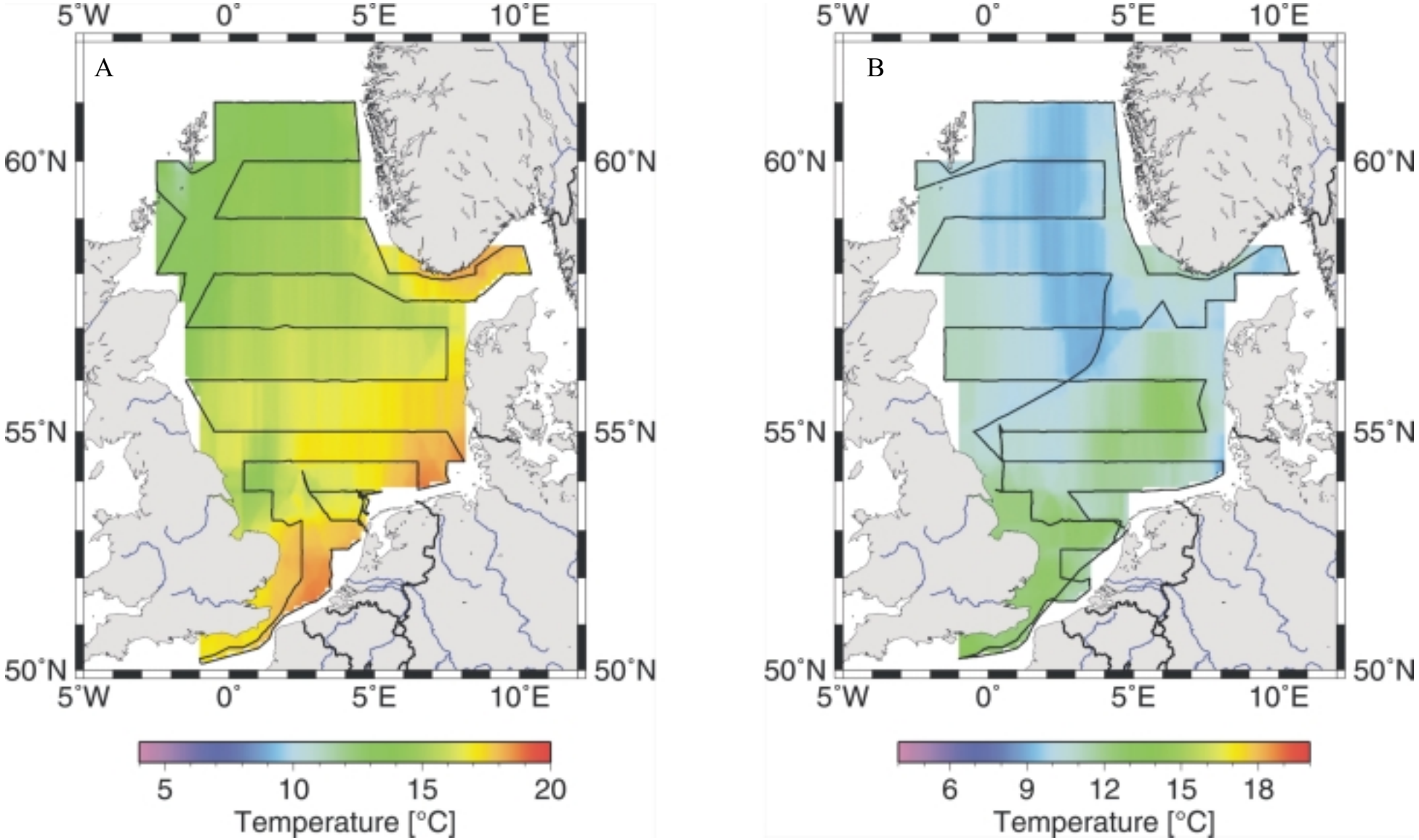

Figure 6: Surface temperature during CANOBA I (A) and II (B)

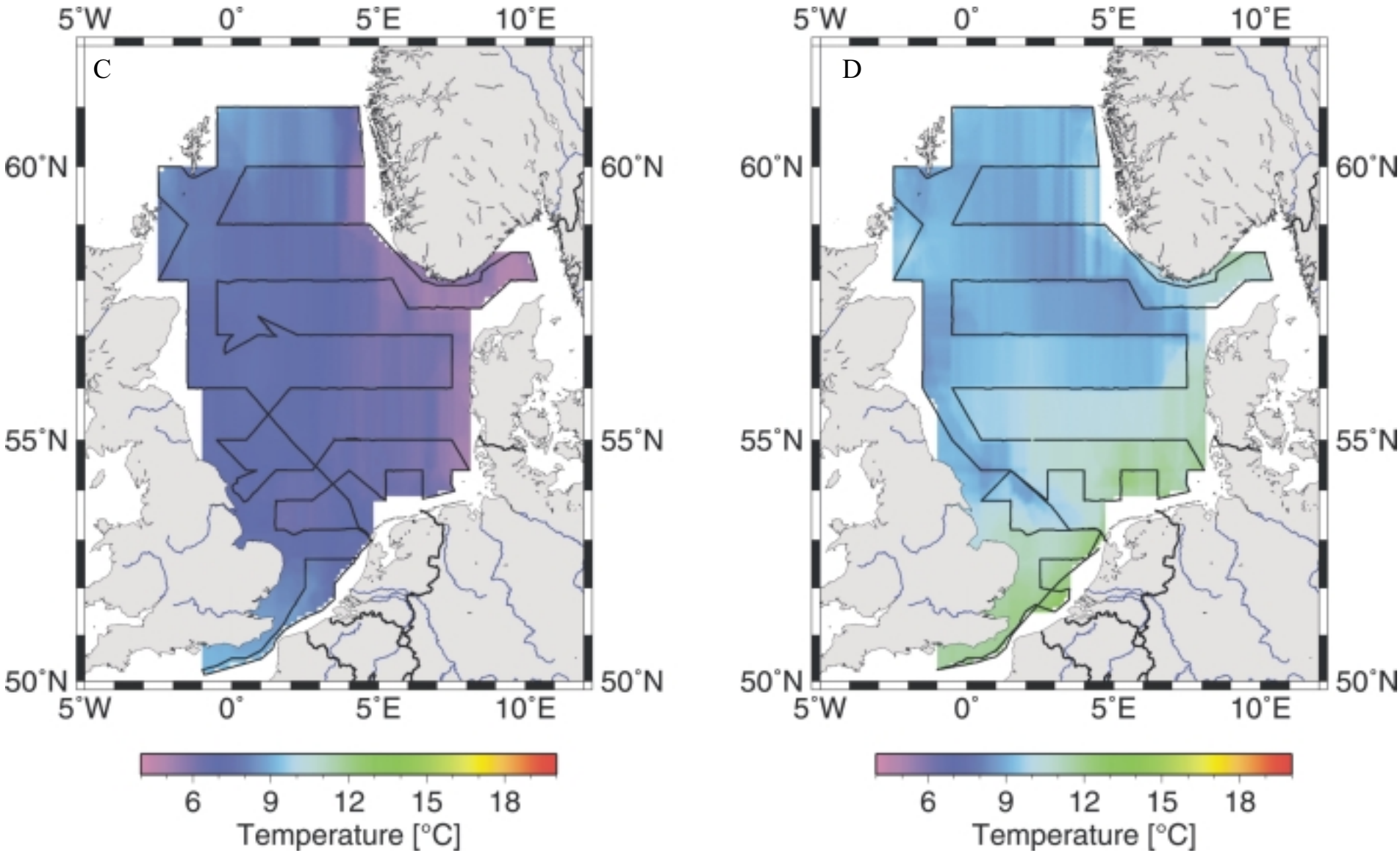

Figure 6 (cont.): Surface temperature during CANOBA III (C) and IV (D)

4.1.2. Surface salinity

The distribution of the surface salinity (Fig. 7) is briefly indicated sing the data of the May cruise. The distribution pattern was very similar during all cruises, but most elaborated during the May cruise, since the fresh water inputs and imprints are highest

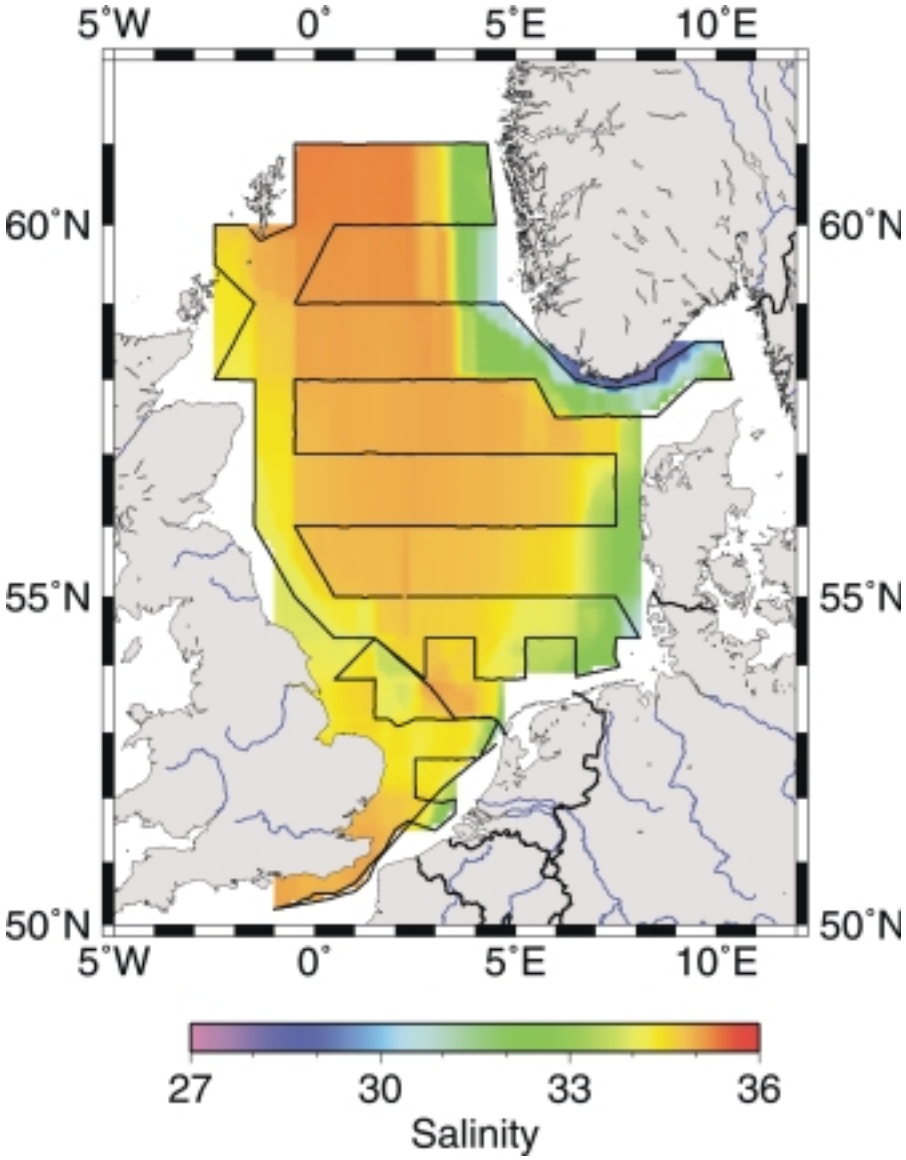

Figure 7: Surface salinity observed in the North during the spring cruise CANOBA IV.

during spring. Highest salinities were observed close to the North Sea's boundaries with the Atlantic Ocean in the north and in the English Channel. Fresher waters were found in the German Bight and the adjacent south-eastern North Sea, respectively. Close to the British coat the salinity was approximately 34psu and thus lower than the North Atlantic water. However, here the fresh water imprint was less pronounced than at the eastern part of the North Sea. The most pronounced fresh water inputs were found in the Skagerrak area along the Norwegian south coast revealing salinties below

30psu because of intense fresh water input from the Scandinavian landmass and the Baltic Sea. Along the Norwegian west coast the outflow of fresher water in northern direction is clearly visible, whereas at the western part the high salinity water from the North Atlantic Ocean is entering the North Sea.

4.2. The CO_2 system

The pCO_2 data discussed below are preliminary data generated with the NIOZ system given in dry air.

During the summer cruise two different features of the partial pressure of CO_2 (pCO_2) in the surface waters were observed, separating the North Sea in a southern and northern region. In the southern region the surface waters were strongly oversaturated with respect to CO_2, whereas in the northern region the North Sea reveals a strong CO_2-undersaturation. (Fig. 8a). These features can be explained with reference to the water column properties observed during the summer cruise. The southern part showed even in summer no stratification avoiding any export of organic matter. This means, the organic matter is remineralised in the mixed layer not allowing a net biological CO_2 drawdown during the productive period. Both the pCO_2 and the dissolved in organic carbon (DIC) (Fig. 9) remain thus still high during summer and the high water temperatures further enhance the high pCO_2 levels. The two stations from the southern North Sea and the English Channel clearly show both the mixed water column and the correspondingly high DIC concentrations. In contrast, the northern region showed a strong under-saturation with pCO_2 values between 200 and 300µatm. These low pCO_2 values are most probably caused by biological CO_2 drawdown with subsequent export of the organic matter to the deeper layers. The two profiles of the northern North provide evidence for this processes both revealing very low DIC concentrations in the surface layer, but increased DIC concentrations in the deeper layer (Fig. 9). This increase is caused by remineralisation of organic matter, which has been exported to the deeper layers during the productive season and is stored there until the autumn convection starts deepening the mixed layer. With the onset of the autumn season and storms and decreasing temperatures deepened the water column of the North Sea vanishing its stratification (Fig. 10). During the second cruise in November the summer thermocline thus could not be observed anymore and almost all stations were mixed.

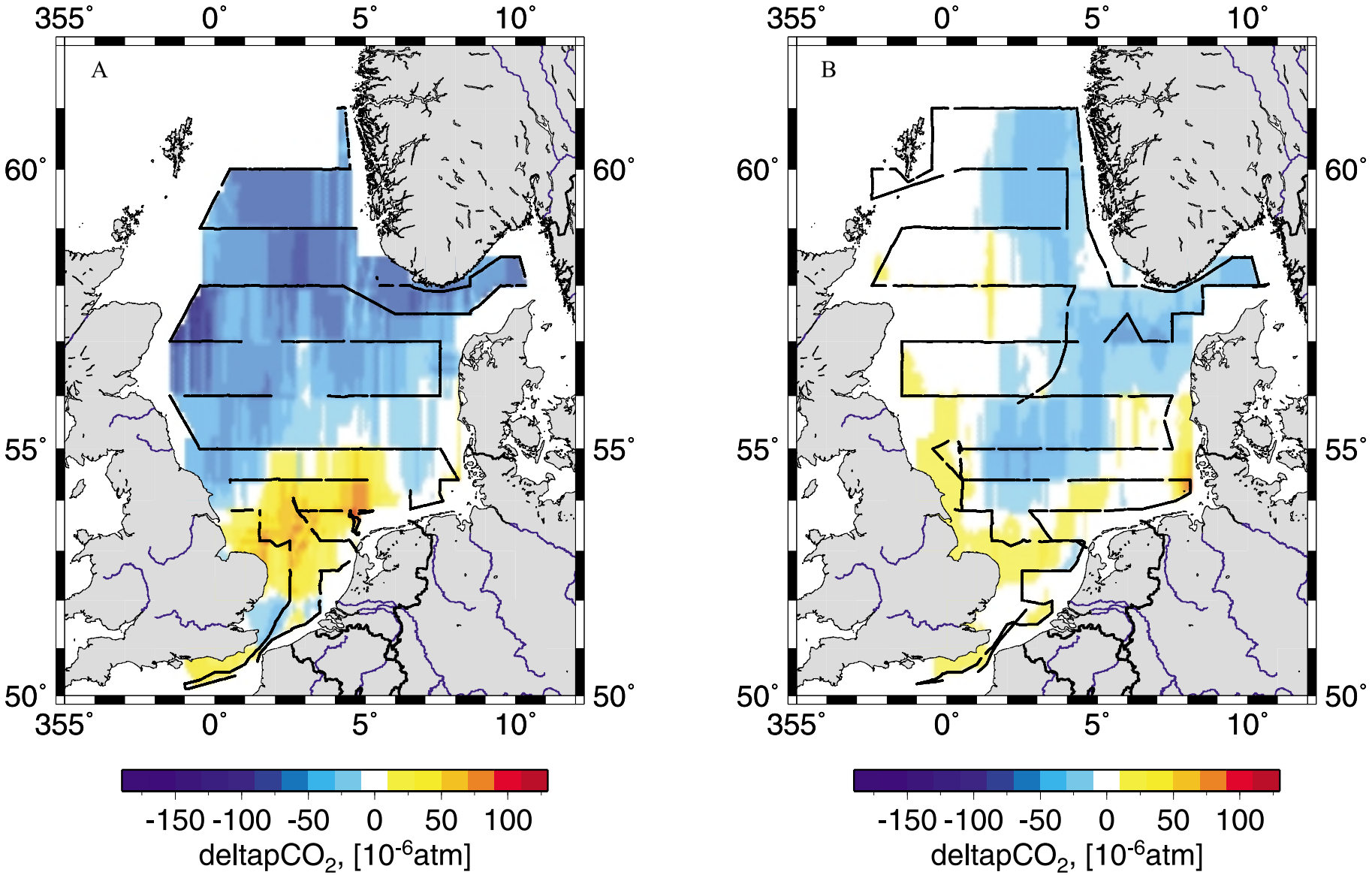

Figure 8: pCO2 distribution during CANOBA I (A) and CANOBA II (B). The same colour scale applies to all four plots.

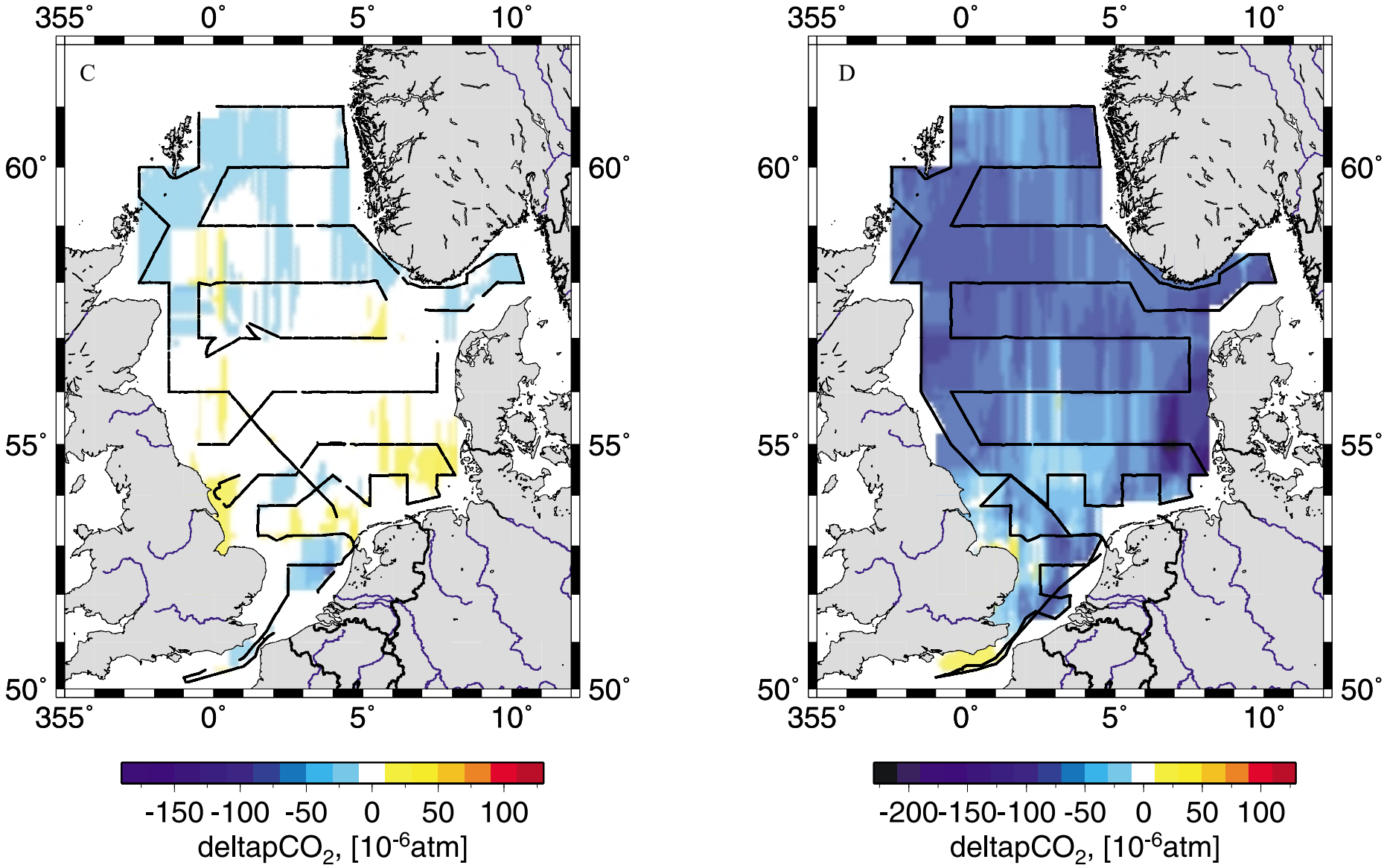

Figure 8 (cont.): pCO2 distribution during CANOBA III(C) and CANOBA IV (D). The same colour scale applies to all four plots.

The pCO_2 showed an almost homogeneous distribution close to equilibrium with the atmosphere (Fig. 8b). In detail, the northern and central parts are still slightly undersaturated most probably because of the decreasing water temperatures. The southern and coastal regions still showed a slight supersaturation. During the winter cruise CANOBA III the pCO_2 (Fig. 8c) showed an even more homogenous distribution. In large areas of the North Sea the pCO_2 was equilibrated or showed only slight under- or supersaturation. This "equilibration" might be caused in the northern part by further uptake of atmospheric CO_2, and the further deepening of the water column caused input of DIC from the deeper waters both finally vanishing the pCO_2 gradient. In the southern part continuous release of CO_2 to the atmosphere and the decreasing temperatures reduced the pCO_2 supersaturation.

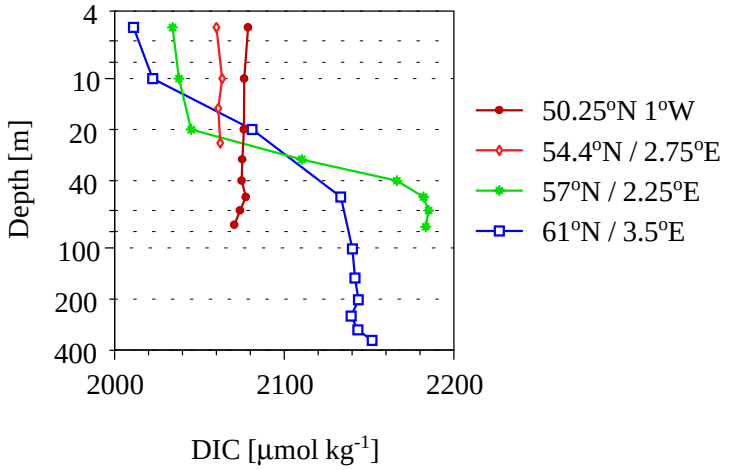

Figure 9: DIC profiles recorded during CANOBA I.

During the spring cruise CANOBA IV (Fig. 8d) almost all parts of the North Sea were undersaturated with respect to CO_2 expect for the English Channel and a location close to the British south-east coast. It should be note here, that even the mixed southern part which showed strong supersaturation during summer, is still undersaturated during spring (Fig. 8d). Strong biological activity decreased the surface DIC concentrations and thereby the pCO_2. Lowest values (<200ppm) were observed in the German Bight.

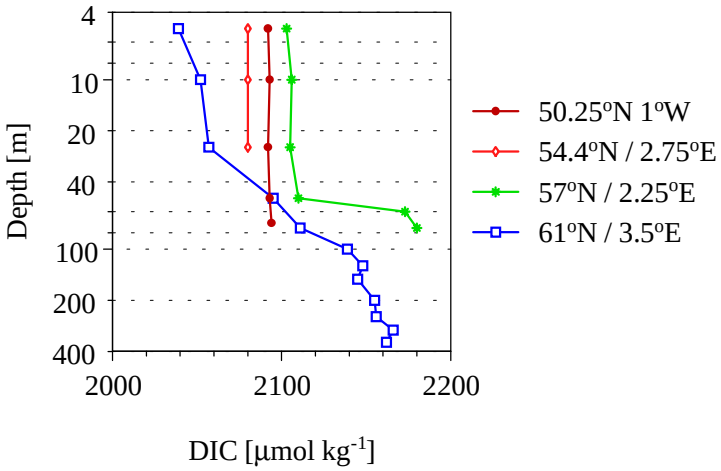

Figure 10: DIC profiles recorded during CANOBA II.

5 Non-CANOBA programs

5.1. BIVALFF

M. Bergman (C1), T. Amaro (C1), R. Groenewegen (C1), I. Magalhães (C1)

The resilience of North Sea macrobenthos depends on the recruitment rate and dispersal capacities of the species involved, and of the processes preceding recruitment such as reproductive output, larval supply and settlement success. In 2001 a pilotstudy is carried out to measure larval supply by using autonomous moored instruments, and more precisely a newly developed larvae pump fixed in a moored frame in the Frisian Front. The pump is mounted in a lander frame which carries auxiliary devices to collect data on current speed, fluorescence, temperature, and suspended matter. Video imaging is carried out as well.

In week 37 the frame was retrieved after a deployment of 7 weeks. Data were collected and the instruments were serviced and programmed for another 12 weeks measuring period, starting in week 38. Next to this a benthic sampling program was performed around the position of the moored frame. The settlement of benthic larvae and the reproductive stage of adult bottomfauna were determined from samples taken with boxcorer and bottomdredge (Triple-D). A selection of specimens caught in the Triple-D was processed on board to enable a further analysis in the laboratory. Measurements of their species-specific N-isotope ratio's will reveal the trophic level of the species in the foodweb

5.2. Metabolic activity of major phylogenetic bacterioplankton groups in the North Sea

H. Pirker (C1)

The activity of the major phylogenetic groups of bacterioplankton - alpha-, beta-, gamma-Proteobacteria and Cytophaga-Flavobacter-Bacteroides - was assessed by

fluorescence *in situ* hybridization (FISH) with rRNA-targeted oligonucleotides probes in combination with microautoradiography (MICRO-FISH).

Despite the overall importance of bacterioplankton for the biogeochemical cycles in the ocean, information on the distribution and succession of bacterial groups is rather limited. Since most of the bacterial species are not cultivable at the moment due to unknown substrate requirements, culture-independent methods have to be used for their phylogenetic characterization.

At 20 stations (76, 92, 88, 86, 81, 70, 74, 67, 64, 52, 59, 56, 49, 46, 43, 41, 36, 33, 30, 14) seawater was collected at 1 m and 5 m depth and 100 ml of the sample was immediately filtered through 5 µm pore-size filters.

Samples were incubated with either D-[6-^{3}H]Glucose (specific activity, 30.0 Ci/mmol, Amersham) or with L-[4,5-^{3}H]Leucine (specific activity, 73.0 Ci/mmol, Amersham) at final concentration of 10 nM for 4 hours. Thereafter, samples were fixed with freshly prepared, phosphate-buffered saline (pH 7.2) 4 % paraformaldehyde (PFA) (Sigma) solution at room temperature. Two killed controls were prepared by treatment with PFA for 15 min prior to adding the radiolabeled compound. Aliquots (10 ml) of the samples and the blanks were filtrated onto 0.2-µm-pore-size polycarbonate filters, supported by 0.45-µm nitrocellulose filters.

Cells collected on the filter were transferred onto glass cover slips freshly treated with a 2% solution of 3-aminopropyltriethoxysilane (Sigma) by placing the filter upside-down onto the cover slip. Each filter was placed between 2 glass slides with a clip and left overnight at room temperature. Subsequently, filters were peeled off from the slide and the slide stored frozen by –20 °C.

These samples are currently analyzed in the lab under the microscope to determine the distribution of activity among the different major phylogenetic bacterioplankton groups.

5.3. Bacterial growth efficiency and the respiration quotient

T. Reinthaler (C1)

Introduction

A realistic bacterial growth efficiency (BGE) is needed to obtain better estimates of organic carbon fluxes in the microbial loop (Rivkin and Legendre 2001). Bacterial production (BP) and bacterial respiration (BR) was measured which allows us to

determine the BGE currently under debate (BGE=BP/(BP+BR). In literature generally a range from 25-50% is assumed but values of less than 5% up to 80% are reported in some studies. Moreover in most of the studies a respiratory quotient (the ratio of CO_2 produced/O_2 utilized) of 1 is assumed. We aimed to determine the RQ by measuring simultaneously, oxygen consumption and CO2 production by bacterioplankton.

Material and methods

Sampling. During the CANOBA cruise 64 Stations were sampled for bacterial oxygen demand measurements, CO_2 production and bacterial production. The depth of sampling was 5 m. Water samples were taken from a 10 l Niskin bottle mounted on a CTD rosette. Subsequently the sampled water was gently filtered over 0.8 µm polycarbonate filters to remove phytoplankton.

Bacterial secondary production. Bacterial production was measured by [^{14}C]Leucine incorporation (specific activity: 295 Ci mmol^{-1}; final concentration: 10 nM). Samples were incubated in duplicates with 1 blank in the dark; the blank was fixed with concentrated formaldehyde (final conc. 4%, v/v) 10 min. before adding the tracer. After incubating for 60 min., the samples were filtered onto 0.45 µm cellulose nitrate filters (Millipore HA, 25 mm diameter filter) and rinsed twice with 5 ml ice-cold 5% trichloracetic acid (Sigma Chemicals) for 5 min. The filters were dissolved in 1 ml ethylacetate and after 10 min, 8 ml of scintillation cocktail (Insta-Gel Plus, Canberra Packard) were added. The radioactivity incorporated into bacterial cells was counted in a Canberra Packard Tricarb 2000 and the desintegrations per minute converted to the actual amount of substrate incorporated.

Bacterial enumeration. 10 ml subsamples were fixed with 37% formaldehyde (4% final conc.) and the bacterial abundance was subsequently determined by acridine orange staining and epifluorescence microscopy (Hobbie et al. 1977).

Bacterial oxygen demand. The 0.8 µm filtrate was carefully transferred to bacterial oxygen demand bottles (BOD) -bottles of a volume ~116 ml by a sipper system with polyvinyl chloride tubing to avoid introduction of O_2 bubbles. T_0 BOD - bottles were fixed immediately with Winkler reagents, t_{24} incubations were stopped after 24 h. All

BOD -bottles were immersed in a water bath and kept in the dark under in situ temperature (13 ± 1ºC). All incubations were done in triplicates.

Bacterial oxygen demand bacterial respiration respectively, was measured by spectrophotometric oxygen analysis (Pai et al. 1993; Roland et al. 1999) which principally follows the standard protocol for the determination of O_2 by Winkler titration (Parsons et al. 1984). The amount of total iodine was determined spectrophotometrically at a wavelength of 456 nm.

Samples were withdrawn from the BOD -bottles by a sipper system. The end of the narrow inlet tube was placed near the bottom of the bottles to avoid possible loss of volatile iodine. The instrument was zeroed against Milli-Q water. Measurements were done on a Hitachi U-1000 spectrophotometer using a 1 cm flow-through cuvette. Calibration was performed by standard additions of iodate to distilled water resulting in an empirical coefficient of 0.001091 nm cm^{-1} at 456 nm. A four digit voltmeter (Metex M4650) was connected to the spectrophotometer to increase the sensitivity of the absorption readings.

Bacterial CO_2 production. The dissolved inorganic carbon content was measured according to the method described in more detail by Johnson et al. 1993 (see section 3.1.2). The 0.8 µm filtrate was transferred to 250 ml glass stoppered bottles. T_0 was measured immediately, other bottles were incubated for 24, 36 and 48 h respectively.

Preliminary results

The BGE ranged from 3.5 up to 97% with a mean value of 61%. The oxygen values are not yet corrected for the respiration quotients (RQ), thus an RQ of 1 was applied. The BGE values are at the top end of reported BGEs from other studies due to rather high production values (mean of 1.2 µmol C l^{-1} d^{-1} ± 1) to a comparable low bacterial respiration of ~0.6 µmol O_2 l^{-1} d^{-1}. Bacterial respiration varies in a more or less narrow range, whereas the variation in bacterial production can be quite high. Whether locally high dissolved organic carbon (DOC) values lead to an enhanced production has still to be assessed.

In conjunction with other data obtained on the cruise, e.g. hydrographical parameters, DOC, chlorophyll a and net primary production, we try to gain a spatial resolution of the bacterial growth efficiency and its dependencies between the heterotrophic community and the environment.

5.4 Genetic structure in a marine zooplankton species from the North Sea?

Katja T.C.A. Peijnenburg (C1)

The pelagic environment is generally regarded as homogeneous with few barriers to gene flow, therefore speciation rates of marine organisms, particularly plankton or organisms with planktonic larvae, are considered to be slow. However, recent studies of genetic variation in plankton and other marine organisms have indicated that we cannot be certain of the generality of this perspective. Is the pelagic environment that is perceived by us as homogeneous really as homogeneous to a planktonic organism?

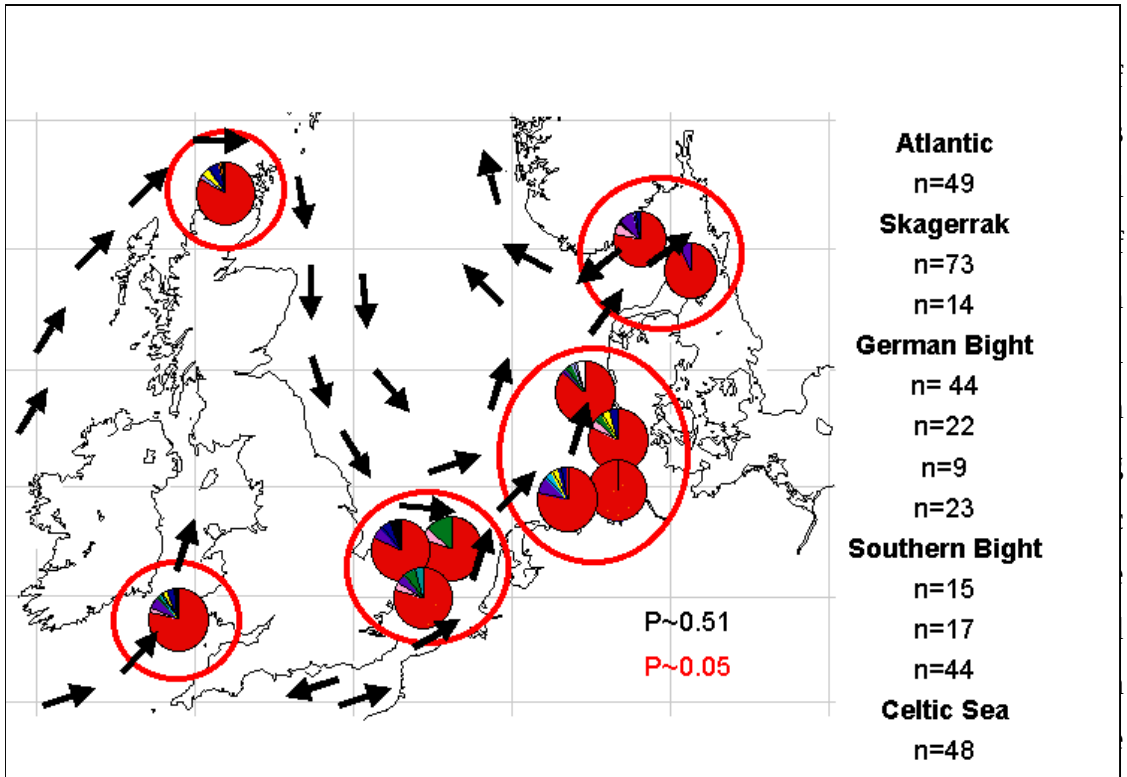

Figure 11: Genetic variation within North Sea *Sagitta setosa* samples from 1999. The different colours in the pie charts denote different mtDNA COII haplotypes (genetic varieties) and their frequency of occurrence. The arrows indicate the general circulation pattern in the North Sea. Sample sizes are indicated in the right colum, each piechart denotes a single population sample. When samples are ungrouped no significant heterogeneity is found (P=0.51), however, a significant indication of heterogeneity is found when samples are grouped in 5 main areas (denoted by red circles).

During the CANOBA I cruise 34 stations in the North Sea were sampled (see table and sampling map; Fig. 12). Vertical hauls were taken using a plankton net with a diameter of 1 meter and a mesh size of 500 µm. Sampling depth varied between 510 meter (one haul in the northern North Sea) and 20 meter, depending on the depth of the station and the density of the plankton. The net was hauled at a speed of 15 to 20 m/min. When back on board the catch was carefully washed into a bucket with a gentle flow of seawater. The organisms in the sample were concentrated by pouring the contents of the bucket through a sieve. Live and intact specimens of chaetognaths were preserved individually in lysis buffer for future DNA analyses. Damaged, parasitized and unidentified individuals were preserved in formalin (4%) for morphological studies. From many stations a complete plankton sample was also preserved in formalin.

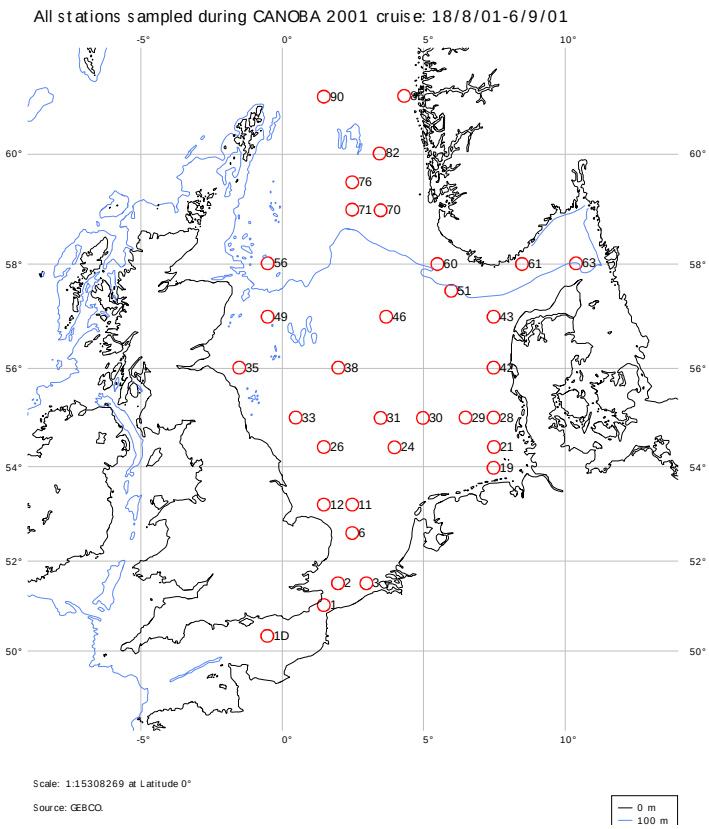

Figure 12: Sampling location of vertical plankton hauls during CANOBA I.

As was found during the HIC TBT cruise in 1999 (Fig. 11) the north-western part of the North Sea is dominated by the chaetognath *Sagitta elegans* whereas the coastal areas to the east (Danish, German, Dutch coasts and English Channel) were dominated by the chaetognath *S. setosa*. This year *S. elegans* was the dominant chaetognath species in the Central North Sea, possibly indicative of an extensive inflow from the North Atlantic. Other species of chaetognath were also found. In the northern North Sea specimens of *Sagitta serratodentata*, *Sagitta lyra* and *Eukrohnia hamata* were encountered, albeit in low numbers. In the Skagerrak the highest

diversity in chaetognaths was found with high numbers of *S. setosa, S. elegans* and *Eukrohnia hamata* (stations 61 and 63).

In conclusion, I am very happy with the successful sampling during the CANOBA cruise. This means that I have large numbers of the chaetognath *S. setosa* ready for DNA analyses to compare with the results obtained from samples of 1999.

5.5 Nitrogen fixation in the southern North Sea

M. Staal (C1)

Nitrogen fixation was measured on 6 stations on the grid (stations 9, 10,15,16,17 and the Lander station, see Fig. 1) during the period 8-13 September using the acetylene reduction technique. Water samples were taken with the aqua flow water supply which were filtered on GF/F filters. In total 3 treatments were incubated, dark aerobic, light aerobic and light anaerobic. No acetylene reduction was found for the stations 9 and 10 and 17. Traces of acetylene reduction were found for the stations 15 and 16, but values found were low, even compared to the ocean, and just above the detection limit. The acetylene reduction rates seemed highest when the samples were incubated aerobically in the light. Some water samples were brought home to try to isolate nitrogen fixers. The N:P ratio's for the total cruise showed that in the northern and middle part of the north sea the conditions were favourable for nitrogen fixation. In these parts N:P ratio's were mostly below 5 while a ratio below 20 is assumed to be favourable for nitrogen fixing organisms. That we did not find high rates of nitrogen fixation can be because the deep mixing of the water column causing an input of biological available nitrogen, what normally is supposed to inhibit nitrogen fixation.

6. Acknowledgements and General remarks

The CANOBA program has been funded jointly by the Royal Netherlands Institute for Sea Research (NIOZ) and the Netherlands Organisation for Scientific Research, section Earth and Life Sciences by the grants NWO/ALW ALW810.33.004 and ALW810.33.007 within the framework of the project: “The continental shelf pump hypothesis: A pilot study in the North Sea”. The co-operation between and NIOZ the Alfred-Wegener-Institute for Polar and Sea Research (AWI), Bremerhaven has been established in the framework of the bilateral Dutch-German NEBROC co-operation.

The co-operation between the scientific and ship’s crews was excellent enabling a pleasant and efficient working atmosphere during all cruises under good and bad weather conditions. Any requests by the scientific crews were handled as spontaneous as possible.

The technical NIOZ departments, notably DZT, supported efficiently the preparation of the cruises.

Problems occurred regularly with the aquaflow system, of which data quality could be better. Comparisons with CTD data showed in part larger irregular deviations notably of the salinity sensor, but also of the temperature sensor. I would recommend a regular daily (or even more frequent) control mechanism as essential part of the CTD/electronic work, since the later recalibration of the data might cause problems.

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8. Participants

8.1. CANOBA I

Leg 1, 18.08.2001 – 06.09.2001

Name	**Institution**	**Responsibility**
Scientific crew		
Thomas, Helmuth, Dr.	NIOZ	Chief Scientist, CO_2 analysis
Bakker, Karel	NIOZ	nutrient analysis
Bauer, Thomas	NIOZ	CTD
Behrens, Melanie	AWI	DOM, POM
Bozec, Yann	NIOZ	CO_2 analysis
Derksen, Jan	NIOZ	CTD, electronics
Harms, Corinna	AWI	oxygen analysis
Hegeman, Jan	NIOZ	Prim. production, Chl. *a*
deJonge, Renske	NIOZ	DOM, POM
Keij, Menno	NIOZ	DOM, POM
Lohrmann, Nicole	AWI	DOM, POM
Peijnenberg, Katja	UvA	Phytoplankton genetics
Pirker, Heidemarie	NIOZ	Bacterioplankton
Reinthaler, Thomas	NIOZ	Bacterioplankton
Treignier, Claire	NIOZ	CO_2 analysis
ship's crew		
Groot, Johannes C.		captain
Puyman, Engbert A.		first mate
Vlek, Erik-Jan		second mate
Seepma, Jacob		chief engineer
deRidder, Johannis P.A.		second engineer
van der Heide, Roelof		ship's technician
Maas, Jacobus J.M.		sailor AB
van der Slikke, Ronny		sailor AB
Cardosa, Santos G.		sailor AB
Mik, Garlinus		cook

CANOBA I, Leg 2: 08.09.2001 – 13 .9.2001

Name	**Institution**	**Responsibility**
Thomas, Helmuth, Dr.	NIOZ	Chief Scientist, CO_2 analysis
Amaro, Teresa	NIOZ	Benthic larvae
Bakker, Karel	NIOZ	nutrient analysis
Behrens, Melanie	AWI	DOM, POM
Bergman, Madga	NIOZ	Benthic larvae
Bozec, Yann	NIOZ	CO_2 analysis
Groenewegen, Ruud	NIOZ	CTD, electronics
Harms, Corinna	AWI	oxygen analysis
Hegeman, Jan	NIOZ	Prim. production, Chl. *a*
Magalhães, Isabel	NIOZ	Benthic larvae
Lohrmann, Nicole	AWI	DOM, POM
Rijkenberg, Micha	NIOZ	CO_2 analysis
Staal, Marc	NIOO-CEMO	nitrogen fixation
ship's crew		
Ellen, Johnny C.		captain
van Duyn, Marco D.		first mate
Vlek, Erik-Jan		second mate
Hogeweg, Menno T.		chief engineer
Brandsma, Jeffrey		second engineer
Stevens, Cornelis T.		ship's technician
Cardosa, Santos G.		sailor AB
Meijer, Niels O.		sailor AB
Betsema, Gerrit L.J.		sailor AB
Prins, Felix		cook

8.2. CANOBA II

Name	**Institution**	**Responsibility**
Thomas, Helmuth, Dr.	NIOZ	Chief Scientist, CO_2 analysis
Asjes, Sander	NIOZ	CTD, electronics
Borges, Alberto	ULg	CO_2 and oxygen analysis
Bozec, Yann	NIOZ	CO_2 analysis
Grobe, Susann	AWI	DOM, POM
Lohrmann, Nicole	AWI	DOM, POM
Schiettecatte, Laure-Sophie	ULg	CO_2 and oxygen analysis
Schulte, Christian	AWI	DOM, POM
Spohr, Stefan	AWI	DOM, POM
vanWeerlee, Evaline	NIOZ	nutrient anaysis
ship's crew		
Ellen, Johnny C.		captain
van Duyn, Marco D.		first mate
Meire, Idesbald		second mate
Hogeweg, Menno T.		chief engineer
Brandsma, Jeffrey		second engineer
Stevens, Cornelis T.		ship's technician
Cardosa, Santos G.		sailor AB
Meijer, Niels O.		sailor AB
Betsema, Gerrit L.J.		sailor AB
Prins, Felix		cook

8.3 CANOBA III

Name	**Institution**	**Responsibility**
Thomas, Helmuth, Dr.	NIOZ	Chief Scientist, CO_2 analysis
Bakker, Karel	NIOZ	nutrient anaylsis
Blume, Bodo	AWI	DOM, POM
Boelens, Ellen	NIOZ	CO_2 analysis
Bozec, Yann	NIOZ	CO_2 analysis
Claus, Simon	ULg	CO_2 and oxygen analysis
Derksen, Jan	NIOZ	CTD, electronics
Grobe, Susann	AWI	DOM, POM
Müller, Kai	AWI	DOM, POM
Schiettecatte, Laure-Sophie	ULg	CO_2 and oxygen analysis
Tena, Augustina	ULg	CO_2 and oxygen analysis
Trümper, Sören	AWI	DOM, POM
ship's crew		
Groot, Johannes C.		captain
van Duyn, Marco D.		first mate
Khan, Akber J.		second mate
Seepma, Jacob		chief engineer
Brandsma, Jeffrey		second engineer
van der Heide, Roelof		ship's technician
Cardosa, Santos G.		sailor AB
Maas, Jacobus J.M.		sailor AB
Meijer, Niels O.		sailor AB
Mik, Garlinus		cook

8.4. CANOBA IV

Name	**Institution**	**Responsibility**
Thomas, Helmuth, Dr.	NIOZ	Chief Scientist, CO_2 analysis
Asjes, Sander	NIOZ	CTD, electronics
Behringer, Steffen	AWI	DOM, POM
Claus, Simon	ULg	CO_2 and oxygen analysis
Hartmann, Carmen	AWI	DOM, POM
Hegeman, Jan	NIOZ	Prim. production, Chl. *a*
Lohrmann, Nicole	AWI	DOM, POM
Müller, Philip	AWI	DOM, POM
Richard, Nolwenn	ULg	CO_2 and oxygen analysis
vanOoijen, Jan	NIOZ	nutrient analysis
Scherdin, Sebastian	AWI	DOM, POM
Schiettecatte, Laure-Sophie	ULg	CO_2 and oxygen analysis
ship's crew		
Groot, Johannes C.		captain
van Duyn, Marco D.		first mate
Ristjouw, Robin		second mate
Seepma, Jacob		chief engineer
Brandsma, Jeffrey		second engineer
van der Heide, Roelof		ship's technician
Cardosa, Santos G.		sailor AB
Maas, Jacobus J.M.		sailor AB
Meijer, Niels O.		sailor AB
Mik, Garlinus		cook

8.5. Participating Institutions and principal investigators

AWI:
Alfred-Wegener-Institute for Polar and Marine Research
Chemical Oceanography
Am Handelshafen 12, D-27570 Bremerhaven, Germany
Dr. Gerhard Kattner

NIOO-CEMO
Nederlands Instituut voor Oecologisch Onderzoek
Centre for Estuarine and Coastal Ecology
Postbus 1299, 3600 BG Maarssen, The Netherlands
Marc Staal

NIOZ:
Royal Netherlands Institute for Sea Research (NIOZ)
P.O. Box 59, NL-1790 AB Den Burg, Texel, The Netherlands
Dr. Helmuth Thomas
Madga Bergman
Prof. Dr. Hein J.W. deBaar
Prof. Dr. Gerhard. J. Herndl

ULg:
Université de Liège
Unité d'Océanographie Chimique (B5), B 4000 Sart Tilman - Belgique
Dr. Michel Frankignoulle

UvA:
Institute for Biodiversity and Ecosystem Dynamics
Faculty of Science, University of Amsterdam
P.O. 94062, 1090 GB Amsterdam, The Netherlands
Katja Peijnenberg

9. Station lists

9.1. CANOBA I

Station No.	Station label	Cast No.	Cast type	Begin station	Position (°N)	Position (°E)
1	**55**	1	CTD	8/18/01 17:48	58.00	-1.49
2	**54**	1	CTD	8/18/01 21:12	57.99	-2.50
3	**75**	1	CTD	8/19/01 4:17	59.00	-1.50
4	**76**	1	CTD	8/19/01 9:16	59.49	-2.49
4	**76**	2	VN500	8/19/01 9:35	59.49	-2.48
5	**77**	1	CTD	8/19/01 13:11	60.00	-2.50
6	**78**	1	CTD	8/19/01 16:50	60.00	-1.70
7	**79**	1	CTD	8/19/01 22:59	60.00	0.49
8	**92**	1	CTD	8/20/01 5:18	61.00	0.50
9	**91**	1	CTD	8/20/01 8:53	61.00	0.50
10	**90**	1	CTD	8/20/01 12:21	60.99	1.50
10	**90**	2	VN500	8/20/01 12:46	60.99	1.51
11	**89**	1	CTD	8/20/01 17:59	61.00	2.50
12	**88**	1	CTD	8/20/01 23:13	61.00	3.49
13	**87**	1	CTD	8/21/01 4:10	60.00	4.00
14	**86**	1	CTD	8/21/01 9:01	61.00	4.33
14	**86**	2	VN500	8/21/01 9:36	61.00	4.33
15	**85**	1	CTD	8/21/01 17:32	60.00	4.49
16	**84**	1	CTD	8/21/01 22:37	59.99	3.99
17	**83**	1	CTD	8/22/01 3:59	60.00	3.50
18	**82**	1	CTD	8/22/01 9:03	60.00	2.49
18	**82**	2	VN500	8/22/01 9:25	60.00	2.50
19	**81**	1	CTD	8/22/01 12:45	59.99	1.49
20	**80**	1	CTD	8/22/01 16:05	59.99	0.49
21	**74**	1	CTD	8/22/01 23:14	58.99	-0.49
22	**73**	1	CTD	8/23/01 2:34	58.99	0.49
23	**72**	1	CTD	8/23/01 5:59	59.00	1.49
24	**71**	1	CTD	8/23/01 9:51	58.99	2.49
24	**71**	2	VN500	8/23/01 10:12	59.00	2.50
25	**70**	1	CTD	8/23/01 13:53	58.99	3.50
26	**70**	2	VN500	8/23/01 14:15	58.99	3.50
27	**69**	1	CTD	8/23/01 18:58	59.00	3.99
28	**68**	1	CTD	8/24/01 0:00	59.00	4.69
29	**60**	1	CTD	8/24/01 7:10	57.99	5.50
29	**60**	2	VN500	8/24/01 7:37	58.00	5.49
30	**67**	1	CTD	8/24/01 11:20	58.00	6.49
31	**61**	1	CTD	8/24/01 19:13	58.00	8.49
31	**61**	2	VN500	8/24/01 19:47	58.00	8.49
31	**61**	3	VN500	8/24/01 20:29	57.99	8.49
32	**66**	1	CTD	8/24/01 23:02	58.15	8.49
33	**65**	1	CTD	8/25/01 3:58	58.50	9.49
34	**64**	1	CTD	8/25/01 8:59	58.50	10.14
35	**63**	1	CTD	8/25/01 13:30	58.00	10.24
35	**63**	2	VN500	8/25/01 13:50	58.00	10.24
35	**63**	3	VN500	8/25/01 14:05	58.00	10.24
36	**62**	1	CTD	8/25/01 17:30	57.00	9.50
37	**53**	1	CTD	8/25/01 22:44	57.50	8.50
38	**52**	1	CTD	8/26/01 4:03	57.50	7.49
39	**51**	1	CTD	8/26/01 9:18	57.49	5.99
39	**51**	2	VN500	8/26/01 9:32	57.50	6.00
40	**59**	1	CTD	8/26/01 16:04	58.00	4.25
41	**58**	1	CTD	8/26/01 21:19	58.00	2.75
42	**57**	1	CTD	8/27/01 3:40	58.00	1.00
43	**56**	1	CTD	8/27/01 9:29	58.00	-0.48
43	**56**	2	VN500	8/27/01 9:48	58.00	-0.49
44	**50**	1	CTD	8/27/01 16:50	56.98	-1.50
45	**49**	1	CTD	8/27/01 20:12	57.00	-0.50
45	**49**	2	VN500	8/27/01 20:28	57.00	0.50
46	**48**	1	CTD	8/28/01 1:00	57.00	0.86
47	**47**	1	CTD	8/28/01 5:38	56.98	2.25
48	**46**	1	CTD	8/28/01 10:37	56.98	3.68
48	**46**	2	VN500	8/28/01 10:51	56.98	3.70
49	**45**	1	CTD	8/28/01 16:29	56.98	5.25
50	**44**	1	CTD	8/28/01 20:45	57.00	6.48
51	**43**	1	CTD	8/29/01 0:19	56.98	7.50
51	**43**	1	CTD	8/29/01 0:36	56.98	7.48

51	**43**	2	VN500	8/29/01 0:46	57.00	7.48
51	**43**	3	VN500	8/29/01 0:54	57.00	7.48
52	**42**	1	CTD	8/29/01 6:27	56.00	7.49
52	**42**	2	VN500	8/29/01 6:39	55.99	7.49
52	**42**	3	VN500	8/29/01 6:45	56.00	7.49
53	**41**	1	CTD	8/29/01 10:09	55.99	6.49
54	**40**	1	CTD	8/29/01 18:58	55.98	5.00
55	**39**	1	CTD	8/30/01 0:11	55.98	3.48
56	**38**	1	CTD	8/30/01 5:17	56.00	2.00
56	**38**	2	VN500	8/30/01 5:31	56.00	2.00
57	**37**	1	CTD	8/30/01 10:37	55.99	0.50
58	**36**	1	CTD	8/30/01 14:35	56.00	-0.49
59	**35**	1	CTD	8/30/01 18:07	56.00	-1.49
59	**35**	2	VN500	8/30/01 18:22	56.00	-1.50
60	**34**	1	CTD	8/31/01 1:12	55.00	-0.49
61	**33**	1	CTD	8/31/01 4:37	54.99	0.50
61	**33**	2	VN500	8/31/01 4:53	55.00	0.50
62	**32**	1	CTD	8/31/01 10:04	55.00	1.98
63	**31**	1	CTD	8/31/01 15:13	54.99	3.49
63	**31**	2	VN500	8/31/01 15:22	54.99	3.50
64	**30**	1	CTD	8/31/01 20:15	55.00	5.00
64	**30**	2	VN500	8/31/01 20:32	54.99	5.00
65	**29**	1	CTD	9/1/01 1:35	55.00	6.50
65	**29**	2	VN500	9/1/01 1:50	55.00	6.49
66	**28**	1	CTD	9/1/01 5:23	54.99	7.50
66	**28**	2	VN500	9/1/01 5:34	55.00	7.50
66	**28**	3	VN500	9/1/01 5:40	54.99	7.50
67	**20**	1	CTD	9/1/01 9:36	54.39	8.09
68	**21**	1	CTD	9/1/01 12:13	54.39	7.50
68	**21**	2	VN500	9/1/01 12:29	54.40	7.49
68	**21**	3	VN500	9/1/01 12:34	54.40	7.49
69	**19**	1	CTD	9/1/01 15:36	53.97	7.49
69	**19**	2	VN500	9/1/01 15:45	53.97	7.50
69	**19**	3	VN500	9/1/01 15:52	53.97	7.50
70	**18**	1	CTD	9/1/01 20:01	53.83	6.50
71	**22**	1	CTD	9/1/01 23:58	54.39	6.50
72	**23**	1	CTD	9/2/01 4:38	54.40	5.25
73	**24**	1	CTD	9/2/01 10:34	54.39	3.99
73	**24**	2	VN500	9/2/01 10:45	54.40	3.99
74	**25**	1	CTD	9/2/01 16:31	54.40	2.75
75	**26**	1	CTD	9/2/01 21:42	54.40	1.49
75	**26**	2	VN500	9/2/01 21:58	54.38	1.52
76	**27**	1	CTD	9/3/01 1:33	54.39	0.50
77	**13**	1	CTD	9/3/01 5:06	53.80	0.50
78	**14**	1	CTD	9/3/01 8:30	53.80	1.50
79	**12**	1	CTD	9/3/01 12:28	53.20	1.49
79	**12**	2	VN500	9/3/01 12:40	53.20	1.49
79	**12**	3	VN500	9/3/01 12:47	53.20	1.48
80	**11**	1	CTD	9/3/01 17:08	53.20	2.50
80	**11**	2	VN500	9/3/01 17:17	53.19	2.50
80	**11**	3	VN500	9/3/01 17:23	53.19	2.50
81	**6**	1	CTD	9/3/01 20:51	52.58	2.50
81	**6**	2	VN500	9/3/01 21:01	52.59	2.50
81	**6**	3	VN500	9/3/01 21:09	52.59	2.49
82	**5**	1	CTD	9/4/01 0:30	52.00	2.49
83	**2**	1	CTD	9/4/01 5:17	51.49	1.99
83	**2**	2	VN500	9/4/01 5:32	51.50	1.99
83	**2**	3	VN500	9/4/01 5:39	51.50	1.99
84	**1**	1	CTD	9/4/01 8:37	51.02	1.49
84	**1**	2	VN500	9/4/01 8:51	51.01	1.48
85	**1A**	1	CTD	9/4/01 11:33	50.66	1.00
86	**1B**	1	CTD	9/4/01 13:53	50.49	0.49
87	**1C**	1	CTD	9/4/01 15:47	50.50	0.00
88	**1D**	1	CTD	9/4/01 17:49	50.33	-0.50
88	**1D**	2	VN500	9/4/01 17:59	50.33	-0.50
89	**1E**	1	CTD	9/4/01 20:13	50.25	-1.00
90	**3**	1	CTD	9/5/01 15:36	51.50	3.00
90	**3**	2	VN500	9/5/01 15:47	51.50	3.00
91	**4**	1	CTD	9/5/01 19:39	51.98	3.50
92	**7**	1	CTD	9/6/01 0:19	52.60	3.50
93	**8**	1	CTD	9/6/01 3:00	52.60	4.10

94	**9**	1	CTD	9/8/01 12:06	53.20	4.50
95	**10**	2	CTD	9/8/01 17:35	53.20	3.50
96	**15**	1	CTD	9/10/01 8:29	53.78	2.75
97	**16**	1	CTD	9/10/01 13:29	53.80	4.00
98	**17**	1	CTD	9/10/01 18:48	54.80	5.25
99	**8b***	01	BC	9/11/01 6:27	53.72	4.50
99	**8b***	02	BC	9/11/01 6:58	53.72	4.50
100	**2b***	01	BC	9/11/01 7:27	53.75	4.50
100	**2b***	02	BC	9/11/01 7:49	53.75	4.50
101	**7b***	01	BC	9/11/01 8:31	53.77	4.50
101	**7b***	02	BC	9/11/01 8:42	53.77	4.50
102	**1b***	01	BC	9/11/01 9:10	53.80	4.50
102	**1b***	02	BC	9/11/01 9:20	53.80	4.50
103	**3b***	01	BC	9/11/01 11:20	53.70	4.46
103	**3b***	02	BC	9/11/01 11:30	53.70	4.46
104	**6b***	01	BC	9/11/01 12:05	53.67	4.50
104	**6b***	02	BC	9/11/01 12:22	53.67	4.50
105	**4b***	01	BC	9/11/01 12:59	53.70	4.50
105	**4b***	02	BC	9/11/01 13:21	53.70	4.50
105	**4b***	03	BC	9/11/01 13:35	53.70	4.50
106	**6b***	01	BC	9/11/01 14:14	53.70	4.58
106	**6b***	02	BC	9/11/01 14:24	53.70	4.58
107	**8b***	1	CTD	9/11/01 15:13	53.72	4.50
108	**2b***	1	CTD	9/11/01 15:41	53.75	4.50
109	*	Begin	SC	9/12/01 6:55	53.794	4.491
109	*	End	SC	9/12/01 6:55	53.798	4.496
110	*	Begin	SC	9/12/01 7:36	53.794	4.491
110	*	End	SC	9/12/01 7:36	53.798	4.497
111	*	Begin	SC	9/12/01 8:11	53.794	4.490
111	*	End	SC	9/12/01 8:11	53.798	4.497
112	*	Begin	SC	9/12/01 8:45	53.794	4.490
112	*	End	SC	9/12/01 8:45	53.797	4.497

***** = stations of the BIVALFF program

VN500 = vertical haul wit phytoplankton net 500µm mesh size

SC = dredge

9.2. CANOBA II

Station No.	Station label	Cast No.	Cast type	Begin station	Position (°N)	Position (°E)	Trace metal sampling
1	**11**	1	CTD	11/7/01 7:12	53.2	2.5	
2	**12**	1	CTD	11/7/01 12:54	53.1833	1.5	
3	**14**	1	CTD	11/7/01 18:04	53.7833	1.48333	
4	**13**	1	CTD	11/8/01 5:58	53.7833	0.48333	
5	**33**	1	CTD	11/9/01 12:04	54.9833	0.5	
6	**32**	1	CTD	11/9/01 18:14	54.9833	1.98333	
7	**31**	1	CTD	11/10/01 0:01	55.0007	3.50378	
8	**30**	1	CTD	11/10/01 5:34	55.0006	5.0009	
9	**29**	1	CTD	11/10/01 10:55	55	6.5	
10	**28**	1	CTD	11/10/01 14:42	54.9998	7.50073	TM
11	**42**	1	CTD	11/10/01 21:56	56	7.5	
12	**41**	1	CTD	11/11/01 5:03	56.0001	6.50182	
13	**40**	1	CTD	11/11/01 12:18	56.0003	4.99958	
14	**39**	1	CTD	11/11/01 19:02	56	3.48333	
15	**38**	1	CTD	11/12/01 0:56	56	2	
16	**37**	1	CTD	11/12/01 7:15	56	0.5	
17	**36**	1	CTD	11/12/01 10:52	55.9833	-0.5	
18	**35**	1	CTD	11/12/01 14:37	-0.0656	57	
19	**50**	1	CTD	11/12/01 23:03	56.9833	0	
20	**49**	1	CTD	11/13/01 3:11	57.0002	-0.4998	
21	**48**	1	CTD	11/13/01 8:03	57	0.86667	
22	**47**	1	CTD	11/13/01 13:11	56.9995	2.24948	
23	**46**	1	CTD	11/13/01 18:35	56.9988	3.7501	
24	**45**	1	CTD	11/14/01 0:02	56.9995	5.24968	
25	**51**	1	CTD	11/14/01 5:28	57.4997	6.0011	
26	**44**	1	CTD	11/14/01 9:12	56.9833	6.48333	
27	**43**	1	CTD	11/14/01 12:46	57.0003	7.49825	TM
28	**52**	1	CTD	11/14/01 15:58	57.5002	7.50117	
29	**53**	1	CTD	11/14/01 19:13	57.4833	8.5	

30	**61**	1	CTD	11/14/01 22:33	58	8.5	
31	**62**	1	CTD	11/15/01 2:13	57.9993	9.50368	
32	**63**	1	CTD	11/15/01 16:09	57.9997	10.401	
33	**64**	1	CTD	11/15/01 19:50	58.5	10.1333	
34	**65**	1	CTD	11/15/01 22:38	58.4833	9.5	
35	**66**	1	CTD	11/16/01 3:12	-0.0656	57	
36	**67**	1	CTD	11/16/01 10:40	58	6.5	
37	**60**	1	CTD	11/16/01 14:28	57.9992	5.50093	
38	**68**	1	CTD	11/16/01 21:35	59	4.7	
39	**85**	1	CTD	11/17/01 4:30	59.9833	4.5	
40	**86**	1	CTD	11/17/01 10:47	61	4.31667	
41	**87**	1	CTD	11/17/01 12:30	60.9833	4	
42	**88**	1	CTD	11/17/01 14:57	60.9993	3.49905	
43	**89**	1	CTD	11/17/01 18:34	61	2.5023	
44	**90**	1	CTD	11/17/01 22:04	61	1.5	
45	**91**	1	CTD	11/18/01 1:39	60.9997	0.50087	
46	**92**	1	CTD	11/18/01 5:59	60.9988	-0.503	
47	**79**	1	CTD	11/18/01 13:19	59.9999	-0.4998	
48	**78**	1	CTD	11/18/01 17:37	60.0001	-1.7003	
49	**77**	1	CTD	11/18/01 20:12	60	0	
50	**76**	1	CTD	11/18/01 23:31	59.4999	-2.4995	
51	**80**	1	CTD	11/19/01 9:33	60	0.5	
52	**81**	1	CTD	11/19/01 12:39	60.0004	1.49993	TM
53	**82**	1	CTD	11/19/01 15:48	60.0008	2.49845	
54	**83**	1	CTD	11/19/01 18:53	59.9997	3.49942	
55	**84**	1	CTD	11/19/01 20:48	60	3.98333	
56	**69**	1	CTD	11/20/01 3:11	59.001	3.9998	
57	**70**	1	CTD	11/20/01 5:10	58.9994	3.50278	
58	**71**	1	CTD	11/20/01 8:39	59	2.48333	
59	**72**	1	CTD	11/20/01 12:07	59	1.5	
60	**73**	1	CTD	11/20/01 15:48	59.0003	0.50038	
61	**74**	1	CTD	11/20/01 20:25	59	-0.4833	
62	**75**	1	CTD	11/21/01 0:37	-0.0656	57	
63	**54**	1	CTD	11/21/01 9:09	58	0	
64	**55**	1	CTD	11/21/01 12:23	58	0	
65	**56**	1	CTD	11/21/01 15:35	57.9994	-0.4982	
66	**57**	1	CTD	11/21/01 20:28	58	1	
67	**58**	1	CTD	11/22/01 3:04	57.9973	2.7476	
68	**59**	1	CTD	11/22/01 8:46	57.9833	4.23333	
69	**34**	1	CTD	11/23/01 11:38	55	-0.4833	
70	**27**	1	CTD	11/23/01 16:47	54.4	0.48333	TM
71	**26**	1	CTD	11/23/01 20:10	54.4	1.5	
72	**25**	1	CTD	11/24/01 0:29	54.3999	2.75013	
73	**24**	1	CTD	11/24/01 4:36	54.4003	4.00053	
74	**23**	1	CTD	11/24/01 9:10	54.4	5.23333	
75	**22**	1	CTD	11/24/01 13:32	54.3993	6.50047	
76	**21**	1	CTD	11/24/01 16:44	54.4004	7.50012	
77	**20**	1	CTD	11/24/01 18:53	54.3993	8.09963	
78	**19**	1	CTD	11/24/01 22:51	53.9667	7.48333	
79	**18**	1	CTD	11/25/01 2:48	53.8331	6.50113	
80	**17**	1	CTD	11/25/01 7:26	53.8	5.25	
81	**16**	1	CTD	11/25/01 12:03	53.8	4	TM
82	**15**	1	CTD	11/25/01 17:06	53.7992	2.75107	
83	**10**	1	CTD	11/25/01 21:21	53.1833	3.5	
84	**9**	1	CTD	11/26/01 1:03	53.1999	4.49962	
85	**8**	1	CTD	11/26/01 5:27	52.6009	4.10018	
86	**7**	1	CTD	11/26/01 7:56	52.5833	3.5	
87	**6**	1	CTD	11/26/01 12:00	52.601	2.50055	TM
88	**5**	1	CTD	11/26/01 15:49	52	2.49883	
89	**4**	1	CTD	11/26/01 19:43	51.9667	3.48333	
90	**3**	1	CTD	11/26/01 23:50	51.4833	3	
91	**2**	1	CTD	11/27/01 3:45	51.5	2.00157	
92	**1**	1	CTD	11/27/01 6:54	51.0106	1.50167	
93	**1A**	1	CTD	11/27/01 10:11	50.65	0.98333	TM
94	**1B**	1	CTD	11/27/01 12:52	50.5	0.50095	TM
95	**1C**	1	CTD	11/27/01 16:06	50.5018	0.00207	
96	**1D**	1	CTD	11/27/01 20:52	50.3167	-0.4833	
97	**1E**	1	CTD	11/27/01 23:09	50.2333	0	

9.3. CANOBA III

Station No.	Station label	Cast No.	Cast type	Begin station	Position (°N)	Position (°E)
1	**16**	1	CTD	2/11/02 19:37	53.80	4.00
2	**32**	1	CTD	2/12/02 8:05	55.00	2.00
3	**37**	1	CTD	2/12/02 18:30	56.00	0.50
4	**36**	1	CTD	2/12/02 22:03	56.00	-0.50
5	**36**	1	CTD	2/12/02 22:32	56.00	-0.50
6	**35**	1	CTD	2/13/02 2:06	55.98	-1.50
7	**50**	1	CTD	2/13/02 8:40	57.00	-1.50
8	**55**	1	CTD	2/13/02 16:53	58.00	-1.50
9	**54**	1	CTD	2/13/02 20:13	58.00	-2.50
10	**75**	1	CTD	2/14/02 3:29	59.00	-1.50
11	**76**	1	CTD	2/14/02 7:50	59.50	-2.50
12	**77**	1	CTD	2/14/02 11:21	60.00	-2.50
12	**77**	1	CTD	2/14/02 11:21	60.00	-2.49
13	**78**	1	CTD	2/14/02 14:01	59.98	0.00
14	**79**	1	CTD	2/14/02 19:33	60.00	-0.50
15	**92**	1	CTD	2/15/02 2:29	61.00	-0.50
16	**91**	1	CTD	2/15/02 5:52	61.00	0.50
17	**90**	1	CTD	2/15/02 9:04	61.00	1.50
18	**89**	1	CTD	2/15/02 12:09	61.00	2.50
19	**88**	1	CTD	2/15/02 15:25	61.00	3.50
20	**87**	1	CTD	2/15/02 17:59	61.00	4.00
21	**86**	1	CTD	2/15/02 20:53	61.00	4.32
22	**85**	1	CTD	2/16/02 5:20	60.00	4.50
23	**84**	1	CTD	2/16/02 7:47	60.00	4.00
24	**83**	1	CTD	2/16/02 10:34	60.00	3.50
25	**82**	1	CTD	2/16/02 15:23	60.00	2.50
26	**81**	1	CTD	2/16/02 20:45	60.00	1.50
27	**80**	1	CTD	2/17/02 1:40	60.00	0.49
28	**74**	1	CTD	2/17/02 9:31	59.00	-0.50
29	**73**	1	CTD	2/17/02 12:49	59.00	0.51
30	**72**	1	CTD	2/17/02 16:11	59.00	1.50
31	**71**	1	CTD	2/17/02 19:21	59.00	2.50
32	**70**	1	CTD	2/17/02 22:34	59.00	3.50
33	**69**	1	CTD	2/18/02 1:43	59.00	4.01
34	**68**	1	CTD	2/18/02 4:37	59.00	4.70
35	**67**	1	CTD	2/18/02 13:02	57.99	6.50
36	**61**	1	CTD	2/18/02 19:50	58.00	8.50
37	**66**	1	CTD	2/18/02 22:05	58.15	8.50
38	**65**	1	CTD	2/19/02 2:39	58.50	9.50
39	**64**	1	CTD	2/19/02 5:59	58.50	10.13
40	**63**	1	CTD	2/19/02 9:34	58.00	10.40
41	**62**	1	CTD	2/19/02 13:15	58.00	9.50
42	**53**	1	CTD	2/19/02 18:48	57.50	8.50
43	**52**	1	CTD	2/19/02 22:40	57.50	7.50
44	**51**	1	CTD	2/20/02 5:36	57.50	6.00
45	**60**	1	CTD	2/20/02 9:20	58.02	5.49
46	**59**	1	CTD	2/20/02 13:46	58.00	4.25
47	**58**	1	CTD	2/20/02 18:47	58.00	2.75
48	**57**	1	CTD	2/21/02 0:38	58.00	1.00
49	**56**	1	CTD	2/21/02 6:06	58.00	-0.50
50	**49**	1	CTD	2/21/02 12:57	57.00	-0.50
51	**48**	1	CTD	2/22/02 8:49	57.00	0.87
52	**47**	1	CTD	2/23/02 11:38	57.00	2.25
53	**46**	1	CTD	2/23/02 16:41	57.00	3.75
54	**45**	1	CTD	2/23/02 21:38	57.00	5.25
55	**44**	1	CTD	2/24/02 2:07	57.00	6.51
56	**43**	1	CTD	2/24/02 5:28	57.00	7.50
57	**42**	1	CTD	2/24/02 11:40	56.00	7.50
58	**41**	1	CTD	2/24/02 16:32	56.00	6.50
59	**40**	1	CTD	2/24/02 23:07	56.00	5.00
60	**39**	1	CTD	2/25/02 4:32	56.00	3.50
61	**38**	1	CTD	2/25/02 9:42	2.00	56.00
62	**33**	1	CTD	2/25/02 19:06	55.00	0.50
63	**34**	1	CTD	2/25/02 22:41	55.00	-0.50
64	**27**	1	CTD	2/26/02 3:32	54.40	0.50
65	**13**	1	CTD	2/26/02 13:14	53.80	0.50
66	**26**	1	CTD	2/26/02 18:57	54.40	1.50
67	**25**	1	CTD	2/26/02 23:29	54.40	2.75

68	**31**	1	CTD	2/27/02 4:25	55.00	3.50
69	**30**	1	CTD	2/27/02 21:36	55.00	5.00
70	**29**	1	CTD	2/28/02 2:43	55.00	6.50
71	**28**	1	CTD	2/28/02 6:39	55.00	7.50
72	**20**	1	CTD	2/28/02 10:50	54.40	8.10
73	**21**	1	CTD	2/28/02 14:02	54.40	7.50
74	**19**	1	CTD	2/28/02 17:42	53.98	7.50
75	**18**	1	CTD	2/28/02 22:55	53.83	6.50
76	**22**	1	CTD	3/1/02 2:36	54.40	6.49
77	**23**	1	CTD	3/1/02 7:32	54.40	5.25
78	**17**	1	CTD	3/1/02 11:17	53.80	5.25
79	**24**	1	CTD	3/1/02 18:14	54.40	4.00
80	**15**	1	CTD	3/2/02 0:09	53.80	2.73
81	**14**	1	CTD	3/2/02 4:37	53.80	1.50
82	**12**	1	CTD	3/2/02 8:08	53.20	1.50
83	**11**	1	CTD	3/2/02 11:47	53.20	2.50
84	**10**	1	CTD	3/2/02 15:37	53.20	3.50
85	**9**	1	CTD	3/2/02 19:17	53.20	4.50
86	**8**	1	CTD	3/3/02 1:22	52.60	4.09
87	**7**	1	CTD	3/3/02 3:55	52.60	3.50
88	**6**	1	CTD	3/3/02 8:03	52.60	2.50
89	**5**	1	CTD	3/3/02 12:15	51.99	2.50
90	**2**	1	CTD	3/3/02 16:16	51.50	2.00
91	**1**	1	CTD	3/3/02 20:21	51.03	1.50
92	**1A**	1	CTD	3/3/02 23:19	50.67	1.00
93	**1B**	1	CTD	3/4/02 1:56	50.50	0.50
94	**1C**	1	CTD	3/4/02 4:05	50.50	0.00
95	**1D**	1	CTD	3/4/02 6:05	50.33	-0.50
96	**1E**	1	CTD	3/4/02 7:54	50.25	-1.00
97	**3**	1	CTD	3/5/02 2:50	51.50	3.00
98	**4**	1	CTD	3/5/02 6:30	52.00	3.50

9.4. CANOBA IV

Station No.	Station label	Cast No.	Cast type	Begin station	Position (°N)	Position (°E)
1	**9**	1	CTD	5/6/02 12:50	53.20	4.50
1	**9**	2	CTD	5/6/02 13:05	53.20	4.50
2	**10**	1	CTD	5/6/02 17:05	53.20	3.50
3	**26**	1	CTD	5/7/02 4:57	54.40	1.50
4	**27**	1	CTD	5/7/02 8:35	54.40	0.50
5	**34**	1	CTD	5/7/02 13:58	55.00	-0.50
6	**35**	1	CTD	5/7/02 20:43	56.00	-1.50
7	**50**	1	CTD	5/8/02 3:08	57.00	-1.50
8	**55**	1	CTD	5/8/02 9:15	58.00	-1.50
9	**54**	1	CTD	5/8/02 12:34	58.00	-2.50
10	**75**	1	CTD	5/8/02 19:32	59.00	-1.50
11	**76**	1	CTD	5/9/02 0:16	59.50	-2.50
12	**77**	1	CTD	5/9/02 3:35	60.00	-2.50
13	**78**	1	CTD	5/9/02 6:15	60.00	-1.70
14	**79**	1	CTD	5/9/02 11:28	60.00	-0.50
15	**92**	1	CTD	5/9/02 18:06	61.00	-0.50
16	**91**	1	CTD	5/9/02 21:24	61.00	0.50
17	**90**	1	CTD	5/10/02 0:51	61.00	1.50
18	**89**	1	CTD	5/10/02 4:06	61.00	2.50
19	**88**	1	CTD	5/10/02 7:33	61.01	3.54
20	**87**	1	CTD	5/10/02 11:13	61.00	4.00
21	**86**	1	CTD	5/10/02 13:55	61.00	4.30
22	**85**	1	CTD	5/10/02 20:55	60.00	4.50
23	**84**	1	CTD	5/10/02 23:09	60.00	4.00
24	**83**	1	CTD	5/11/02 1:58	60.00	3.50
25	**82**	1	CTD	5/11/02 6:05	60.00	2.50
26	**81**	1	CTD	5/11/02 9:34	60.00	1.50
27	**80**	1	CTD	5/11/02 13:06	60.00	0.50
28	**74**	1	CTD	5/11/02 21:05	59.00	-0.50
29	**73**	1	CTD	5/12/02 0:33	59.00	0.50
30	**72**	1	CTD	5/12/02 4:07	59.00	1.50
31	**71**	1	CTD	5/12/02 7:18	59.00	2.50
32	**70**	1	CTD	5/12/02 11:12	59.00	3.50
33	**69**	1	CTD	5/12/02 13:31	59.00	4.00

34	**68**	1	CTD	5/12/02 16:31	59.00	4.70
36	**67**	1	CTD	5/13/02 1:32	58.00	6.50
37	**61**	1	CTD	5/13/02 8:30	58.00	8.50
38	**66**	1	CTD	5/13/02 12:18	58.15	8.50
39	**65**	1	CTD	5/13/02 16:46	58.50	9.50
40	**64**	1	CTD	5/13/02 20:37	58.50	10.14
41	**63**	1	CTD	5/14/02 0:20	58.00	10.40
42	**62**	1	CTD	5/14/02 3:27	58.00	9.50
43	**53**	1	CTD	5/14/02 8:20	57.50	8.50
44	**52**	1	CTD	5/14/02 11:52	57.50	7.50
45	**51**	1	CTD	5/14/02 17:39	57.50	6.00
46	**60**	1	CTD	5/14/02 21:11	58.00	5.50
47	**59**	1	CTD	5/15/02 1:37	58.00	4.25
48	**58**	1	CTD	5/15/02 7:16	58.00	2.75
49	**57**	1	CTD	5/15/02 14:10	58.00	1.00
50	**56**	1	CTD	5/15/02 19:19	58.00	-0.50
51	**49**	1	CTD	5/16/02 6:01	57.00	-0.50
52	**48**	1	CTD	5/16/02 11:12	57.00	0.88
53	**47**	1	CTD	5/16/02 16:30	57.00	2.25
54	**46**	1	CTD	5/16/02 21:27	57.00	3.75
55	**45**	1	CTD	5/16/02 23:03	57.00	4.21
56	**44**	1	CTD	5/17/02 7:02	57.00	6.50
57	**43**	1	CTD	5/17/02 10:32	57.00	7.50
58	**42**	1	CTD	5/17/02 16:33	56.00	7.50
59	**41**	1	CTD	5/17/02 19:56	56.00	6.50
60	**40**	1	CTD	5/18/02 1:10	56.00	5.00
61	**39**	1	CTD	5/18/02 6:16	56.00	3.50
62	**38**	1	CTD	5/18/02 11:27	56.00	2.00
63	**37**	1	CTD	5/18/02 16:30	56.00	0.50
64	**36**	1	CTD	5/18/02 20:07	56.00	-0.50
65	**33**	1	CTD	5/19/02 2:44	55.07	0.42
66	**32**	1	CTD	5/19/02 8:40	55.00	2.00
67	**31**	1	CTD	5/19/02 13:38	55.00	3.50
67	**31**	2	CTD	5/19/02 14:06	55.00	3.50
68	**30**	1	CTD	5/19/02 19:19	55.00	5.00
69	**29**	1	CTD	5/20/02 0:38	55.00	6.50
70	**28**	1	CTD	5/20/02 4:06	55.00	7.50
71	**20**	1	CTD	5/20/02 8:48	54.40	8.10
72	**21**	1	CTD	5/20/02 11:09	54.40	7.50
73	**19**	1	CTD	5/20/02 14:25	53.97	7.50
74	**18**	1	CTD	5/20/02 18:10	53.83	6.50
75	**22**	1	CTD	5/20/02 21:42	54.40	6.50
76	**23**	1	CTD	5/21/02 2:13	54.40	5.25
77	**17**	1	CTD	5/21/02 6:14	53.80	5.25
78	**16**	1	CTD	5/21/02 11:12	53.80	4.00
79	**24**	1	CTD	5/21/02 15:00	54.40	4.00
80	**25**	1	CTD	5/21/02 19:31	54.40	2.75
81	**15**	1	CTD	5/21/02 23:46	53.80	2.75
82	**26***	2	CTD	5/22/02 5:33	54.40	1.50
83	**13**	1	CTD	5/22/02 11:12	53.80	0.50
84	**14**	1	CTD	5/22/02 15:01	53.80	1.50
85	**12**	1	CTD	5/22/02 19:19	53.20	1.50
86	**11**	1	CTD	5/23/02 0:03	53.20	2.50
87	**10***	1	CTD	5/23/02 3:49	53.20	3.50
88	**9***	1	CTD	5/23/02 7:28	53.20	4.50
89	**8**	1	CTD	5/23/02 12:04	52.60	4.10
90	**7**	1	CTD	5/23/02 14:45	52.60	3.51
91	**6**	1	CTD	5/23/02 18:48	52.60	2.50
92	**5**	1	CTD	5/23/02 22:46	52.00	2.50
92	**5**	2	CTD	5/23/02 23:11	52.01	2.51
93	**4**	1	CTD	5/24/02 3:11	51.98	3.50
94	**3**	1	CTD	5/24/02 6:58	51.50	3.00
95	**2**	1	CTD	5/24/02 13:03	51.50	2.00
96	**1**	1	CTD	5/24/02 18:06	51.00	1.45
97	**1A**	1	CTD	5/24/02 23:28	50.67	1.00
98	**1B**	1	CTD	5/25/02 2:32	50.50	0.50
99	**1C**	1	CTD	5/25/02 5:33	50.50	0.01
100	**1D**	1	CTD	5/25/02 10:13	50.33	-0.50
101	**1E**	1	CTD	5/25/02 12:31	50.25	-1.00

* = repeated sampling of the station

10. Week reports

10.1. CANOBA I

First week report:

After a pleasant and short stay in Peterhead, Scotland, the scientific crew entered Pelagia on 17.8.2001 and used the day to set-up most of the systems. Highlight of the preparations was the receipt of the recovered CTD-probe, which did not show any obvious damage. When leaving Peterhead on Saturday all systems were ready and the North Sea welcomed us with sunny and calm weather, which however should change significantly during the next days. Under this first calm conditions the CTD was tested and finally the CANOBA program started north of Peterhead. During the first few stations the working schedule was settled and we made good progress in sampling stations. However, rather soon the North Sea showed us its rougher face during the most northern transect causing well-known adaptation problems for the scientific crew for approximately one day.

Part of the scientific crew used the opportunity to spend some time in Scotland with hiking. Menno Keij and Renske deJonge (RUG) visited the Isle of Skye and the west-Scottish Highlands, whereas Nicole Lohrmann (AWI) followed the Whiskey-trail to come to Peterhead. Melanie Behrens (AWI) took a stop-over in London. Altogether are now busy with sampling the water for organic carbon, nitrogen and phosphorus determination. As the third AWI member Corinna Harms came to Peterhead, she is now running the oxygen measurements. The remaining crew members travelled directly to Peterhead, whereof Karel Bakker, Jan Hegeman, Heidi Pirker, Thomas Reinthaler, and Helmuth Thomas (all NIOZ) travelled by boat via Ijmuiden and Newcastle. On board, Karel is running the nutrient-lab, Jan is sampling for primary production, Chlorophyll a and Alkalinity. Heidi and Thomas are rather focussing on smaller members of the biological community, bacteria, and their activity in the water column. In contrast, Katja Peijnenberg (UvA) is exploiting this cruise to do research on genetic interactions between different zooplankton species in the North Sea and the adjacent North Atlantic Ocean. The French CO2-team Yann Bozec and Claire Treignier (both NIOZ) are now spending their time with measuring the CO2 concentrations of several tenth of samples per day. The CTD group consists of Jan Derksen (NIOZ) and Thomas Bauer (Univ. Heilbronn) both confirming that the recovered and first choice CTD is still working properly.

As a first impression of the online CO2 measurements might be mentioned that the northern North Sea has been strongly undersaturated during our cruise and the undersaturation appears to increase from north to south. This means, that the North Sea acts as a sink for atmospheric CO2 during this time of the year. This feature is similar to the North Atlantic Ocean in the same latitudes, however the North Sea reveals a stronger undersaturation and thus uptake of CO2 per area unit.
The first week of the CANOBA 1 cruise should be seen as successfully, since we could sample a significant number of our planned stations, which - last but not least - has been made possible by the very good co-operation of the Pelagia crew.

With best regards, Helmuth Thomas Onboard RV Pelagia, 24.8.01

Second week report:
During the second week of the first CANOBA cruise we left the Skagerrak area into the central North Sea. Because everybody now has adapted to the working schedules onboard Pelagia, our days have become regular, but rather less spectacular. Also during the second week we have made good progress in the program, since the co-operation with crew enables a pleasant and efficient working atmosphere. The only few highlights were some dolphins and birds, most notably Jan van Gent, and a great view of the Norwegian south coast in surprisingly sunny weather. The overall good weather conditions with only some hours stronger wind supported our work during the second week. During the 10th day we were approaching the Scottish coast again and were able to see Peterhead again from only a few miles distance.
The main work on board is focussed on gaining either filter or water samples for organic carbon, nitrogen and phosphorus compounds, which means an extended filtration procedure after sampling. Thus, no data can be reported yet. The determination of dissolved organic nitrogen and phosphorus, which had been setup recently at NIOZ, shows a good performance on board. One of the results for example is, that often the dissolved organic nitrogen compounds exceed the 10*10-6 mol l^-1 level, whereas the inorganic counterparts nitrate and nitrite are (almost) exhausted. The strong undersaturation of CO2, which has been observed already during the first week, apparently characterizes the northern and central North Sea during this summer situation. The saturation level changes dramatically when approaching the Dogger Bank and entering the southern part of the central North Sea. In this shallower part of the North Sea the surface waters are saturated or even oversaturated with respect to

CO2. The southern part of the central North Sea thus acts as a source, whereas the deeper, northern part acts as a sink for atmospheric CO2, respectively. A detailed evaluation of this interesting feature will look for the control mechanisms and moreover will provide the quantification of the net CO2 uptake or release.

With best regards from all, Helmuth Thomas, Onboard RV Pelagia, 2.9.01

10.2. CANOBA 2

First week report:

We had finished setting up the equipment on 6th of November and had enjoyed a nice and quite lunch just outside the NIOZ harbour onboard Pelagia, before the North Sea welcomed us with stormy weather. For our first stations we headed toward the English hoping to get some shelter and more quite seas, since CTD work was not possible. Upon arrival in the next morning we indeed started our program, however had to stop again very soon after only a few stations due to the increasing winds.

After this first storm and the adaptation period of most of the scientific crew we finally restarted our program with approximately two days delay. We started sampling the central North Sea in the Dogger Bank area, where we found a well mixed water column due to the (previously experienced) autumn storms. The following days the weather was still rough, but nevertheless we made continuous progress while sampling the sections from 55-57degrees North. With relatively good weather forecasts we entered the Skagerrak area, which is for us the busiest place, since the stations are the deepest and the densest ones of the program. More or less as a surprise a severe storm with wind forces between 10 and 11 rose in only a very few hours, which caused serious trouble in the Scandinavian countries. For us, its impacts were slightly more positive, since we tried to get some kind of rest before sampling the Skagerrak area one day later. With success we managed to leave this place again heading northward along the Norwegian coast, which even appeared in part in nice weather. After crossing the North Sea on our most northern section at 61 degrees north we are now passing the Shetland Islands.

A very first look on the underway data, which are continuously recorded in the surface waters, show a CO2 supersaturation of the southern part of the central North Sea, whereas the waters in the northern appear to be close to saturation, rather supersaturated than undersaturated. Even at the most northern section the North Sea reveals a slight supersaturation of CO2 in the surface waters. Having in mind the

strong undersaturation in the north and the supersaturation in the south, which we observed during summer, the current picture appears to be significant different, since the northern part has lost is undersaturation and the south appears to be closer to saturation than during summer. However, still we have to do more than 50% of our stations, and these views should be seen as very preliminary.

The scientific crew consists of a interesting mixture of European nationalities: our colleagues from the University of Liege in Belgium, Laura-Sophie Schiettekatte and Alberto Borges are actually from France and Portugal, respectively. Susann Grobe, Nicole Lohrmann, Christian Schulte, Stefan Spohr are from the AWI in Bremerhaven. The NIOZ members are Evaline van Werlee, Sander Asjes, Yann Bozec and Helmuth Thomas. Together with the ship's crew we can represent 6 nations from two continents. The Belgian group is covering the oxygen and carbonate system measurements, whereas the AWI people are filtering water samples in order to count for the organic part of our carbon and nutrient cycles study. Evaline is running the nutrient analyzer and Sander the CTD, whereas Yann and me also cover CO2 system measurements.

Despite the rather stormy we could make good progress with our program during the first part and this is last but not least due to the very good co-operation of the crew, which provides even under difficult conditions an effective working atmosphere.

With best regards from all, Helmuth Thomas 18.11.01, onboard RV Pelagia.

Second week report:

After we had sampled the central North Sea and the Skagerrak area during the first period of our cruise, we headed northward for our most northern sections, where the North Sea is open to the North Atlantic Ocean. Surprisingly, we had calm weather here and a nice view on the Shetland Islands. Within the next four or five days we sampled the three northern sections with up to 5 stations per day. Just before finishing our last westward line at 59 degrees north the wind increased again helped us to go eastward again along 58 degrees north, our last line in the northern part. We experienced our next storm at the end of this line at 58 degrees North, but since we had to go back to the southern North Sea, it did not affect our work too much expect for loosing some time due to a reduced speed. However, we had really uncomfortable 24 hours and we were kept busy with (re-)fixing our equipment in order to avoid serious damage. More or less in time, the wind speed decreased when we arrived in

the southern North Sea. Here again we had surprisingly calm weather when sampling the German Bight.

Strongly supported by the Pelagia crew and very good food, the good weather allowed us to achieve a major progress with our program, even in the most northern area, where storms occur rather frequently during this time of the year. The atmosphere onboard thus is, although very busy and productive, pleasant and we are looking forward to finish the program soon in the most southern part of the North Sea.

With best regards from all, Helmuth Thomas 26.11.01, onboard RV Pelagia.

10.3. CANOBA III

First week report:

At the beginning of the third CANOBA cruise the North Sea welcomed us (almost as usual) with stormy weather and southwesterly wind directions. We decided go northward and thus made the wind help us. On out way to the English coast we took the first stations in the Dogger Bank area, which was just possible because of both the weather and personal conditions during this early state of the cruise. However after the first day most of us have been adapted to the sea and we sampled all stations at the English and Scottish coast on our way north. Under slightly better weather conditions we passed the Orkney Islands and Shetland Islands. Between these two island groups we experienced “real” ocean feeling in the Atlantic Ocean with longer and higher, but also more regular waves. After passing the Shetland Islands during the night we started with the three most northern sections, of which we were most concerned, since those are connected to the open Atlantic Ocean. Fortunately, we found not calm, but still acceptable weather conditions enabling us to sample the 61degree north line in eastward direction without serious problems. We encountered a bit more wind on our way back westward along 60 degrees north. The next section along 59 degrees north brought us to our most busy area in the Skagerrak characterized by both the deepest and the densest stations. Similar to the November cruise we enjoyed the beautiful Norwegian coast under sunny, but cold and wintry conditions. At our first station in the Skagerrak the air temperature dropped below 0 degrees C and we had even snow – for one of our participants, Augustina Tena from Spain, for the first time ever. The work, in the Skagerrak area has been characterized by these wintry conditions and we just left this area accompanied by a strong easterly snowstorm as part of the low-pressure system, which also affected the NIOZ course on Navicula, however down

there, from westerly direction. For us the easterly wind was –although very strong - not entirely unfortunate, since we left the Skagerrak heading westward to the 58 degrees north line. This means we still could make progress in steaming and sampling, although under difficult conditions.

The CANOBA III team consists of 12 people from the usual three institutes: the Alfred-Wegener-Institute for Polar and Sea Research, Bremerhaven, Germany, the University of Liege, Liege, Belgium and the NIOZ. The AWI group, Susann Grobe, Bodo Blume, Kai Mueller and Soeren Truemper are busy with taking samples for the analysis of dissolved and particulate organic carbon, nitrogen and phosphorus compounds, whereof the dissolved organic nitrogen and phosphorus is measured directly here on board. The group from Liege, Simon Claus, Laure-Sophie Schiettecatte and Augustina Tena are measuring dissolved oxygen, alkalinity and pH. The NIOZ team covers the remaining parameters: Jan Derksen runs the CTD and Karel Bakker the nutrients and the above DON/P analysis. Ellen Boelens, Yann Bozec and Helmuth Thomas still measure dissolved inorganic carbon (CO2) and the partial pressure of CO2 (pCO2).

A very first view on the pCO2 data, which have been measured continuously on board, shows us that the pCO2 is more or less equilibrated between atmosphere and surface waters. The strong autumn and winter storms have both caused a deepening of the mixed layer importing CO2 from the deeper waters to the surface layer and caused also the equilibration with the atmosphere. In the northern section, where we found a slight CO2 under-saturation in November this means, CO2 is added to the surface layer from both the atmosphere and the deeper waters. For the southern section, which was still over-saturated with respect to CO2 in November, this means, (further) CO2 has been released to the atmosphere. Which of both characteristics, the CO2 source in the south or the CO2 sink in the north finally will dominate the overall CO2 balance, is still the open and challenging question of the CANOBA program.

All the work we have done here during our first week on RV Pelagia has been made possible by the very good and helpful co-operation by the Pelagia crew, which we highly appreciate.

With best regards from all, Helmuth Thomas, RV Pelagia, 20.02.2002.

Second week report:

During the first part of our third CANOBA cruise we had covered the northern North Sea and the Skagerrak area. Here, we had been in a rather lucky situation (and location), since the strong low-pressure systems had been south of us. However, during our second week the central part of the North was to be sampled and this meant we had to go south. Thus, the entire week was characterized by really bad weather with very strong winds allowing us only a few hours time to work under difficult conditions. We sampled the next two sections at 57 and 56 degrees North, before we headed toward the British coast at 55 degree North. After we had sampled three stations the weather forecast predicted a very strong storm for our area – west of the Dogger Bank- and we decided to seek shelter directly under the coast. Here, we waited for the storm with a mean wind speed of Beaufort 10. Under the coast the sea-state was much better the above the Dogger Bank, but we encountered the rough seas above the Dogger Bank, when we tried to continue our program in easterly direction, when the storm had calmed down. After a very few stations we again had to stop the program, before we proceeded to the Danish coast and later the German bight. Under those difficult conditions our progress during the second week was rather limited, but now the weather has been improving significantly and also the forecast sounds promising.

During this period, which was both boring and exhausting, the atmosphere on board Pelagia still remained pleasant. Consequently, the only high lights of those windy days were the excellent meals served by our cook even under the above stormy conditions.

With best regards from all, Helmuth Thomas On board RV Pelagia.

10.4. CANOBA IV

First week report:

In contrast to the previous cruises we left Texel on Monday, 6th of May 2002 under good and calm weather conditions. We decided go northward in order to first sample the stations near the British coast on our way to the most northern section. Due to the calm conditions we only had minor problems with adapting to the sea and thus could start to work just from the beginning. Also the equipment was working fine after the first hours. We thus started the program with the stations close to Texel. We then approached the English coast and sampled all stations at the English and Scottish

coast on our way north. With slightly more wind we passed the Orkney Islands and Shetland Islands. Just between two stations close to the Orkney Islands we could listen to the UEFA cup final, which finally was won by the hosting nation. After a certain, temporary imbalance the German participants recovered quickly and the CANOBA program could be continued without any delay close to the Shetlands. This time, we passed the green and rocky Shetland Islands during daytime and started with the three most northern sections, of which we were most concerned, since those are connected to the open Atlantic Ocean. Fortunately, we encountered again acceptable weather conditions enabling us to sample the sections from 61 degrees N to 59degrees N without serious problems. The section along 59 degrees north brought us to our most busy area in the Skagerrak characterized by both the deepest and the densest stations. Similar to the previous cruises we enjoyed the beautiful Norwegian coast under sunny weather. We could sample the Skagerrak area within the next 36 hours and are now leaving to the section on 58 degrees N, of which stations are less dense allowing us to recover a bit from the efforts in the Skagerrak.

The CANOBA IV team consists of 13 people from the usual three institutes: the Alfred-Wegener-Institute for Polar and Sea Research, Bremerhaven, Germany, the University of Liege, Liege, Belgium and the NIOZ. The AWI group, Carmen Hartmann, Nicole Lohrmann, Steffen Behringer and Sebastian Scherding are busy with taking samples for the analysis of dissolved and particulate organic carbon, nitrogen and phosphorus compounds, whereof the dissolved organic nitrogen and phosphorus is measured directly here on board. The group from Liege, Simon Claus, Laure-Sophie Schiettecatte and Nolwenn Richard are measuring dissolved oxygen, alkalinity and pH. The NIOZ team covers the remaining parameters: Sander Asjes runs the CTD, Jan Hegeman samples for primary production and Chlorophyll a and Jan van Ooijen performs the nutrients measurements and the above DON/P analysis. Ellen Boelens, Helmuth Thomas and Philipp Mueller (AWI) still measure dissolved inorganic carbon (CO2) and the partial pressure of CO2 (pCO2).

A first view on the pCO2 data, which have been measured continuously on board, shows us that the surface waters are again undersaturated with respect to CO2 in the northern area. The values measured in the water are approximately 100ppm lower than the atmospheric ones which means that this area is currently a rather strong CO2 sink. The decrease of the pCO2 values compared to the winter situation most probably is caused by the onset of primary production during spring. Phytoplankton uses CO2

and nutrients to grow thereby decreasing the CO2 concentrations in the water. In agreement with this, not only in the water filters of the engine room but also on the filtersamples taken for the later Chlorophyll a and POC determinations large quantities of planktonic material were found. Since we started the DON/DOP analysis during the first cruise, we could made substantial improvement on this measurement during the last cruises and now are able to perform it almost as a standard determination in close co-operation between the AWI filtration group and Jan van Ooijen.

All the work we have done here during our first week on RV Pelagia has been made possible by the very good and helpful co-operation by the Pelagia crew, which we highly appreciate.

With best regards from all, Helmuth Thomas, RV Pelagia, 15.05.2002.

Second week report:

After leaving the Skagerrak area we continued our program in the central North Sea heading toward the Scottish coast along 58 degrees N. The weather conditions remained most of the time good expect for some ours with stronger wind, which however did not cause problems for our sampling. We thus made good progress and finished the central part of the North Sea ahead schedule. We then started to sample the German Bight and the southern part, where we still encountered acceptable weather conditions.

As we already observed in the northern part of the North Sea, the surface waters of the central part are still undersaturated with respect to CO2, which means that they act as a sink for CO2. To our surprise this undersaturation has been also observed in the southern part and the German Bight, where we had found strong supersaturation during the first (summer) cruise. Apparently, in spring the biological activity has been strong enough to effectively reduce the CO2 concentrations in the surface waters and the low remineralsation rates of the freshly produced organic are yet to balance the CO2 drawdown. Moreover, we observed for almost all stations in the central and southern part a thermal stratification of the water column, which supports temporarily the CO2 drawdown in the surface waters, since the above remineralisation of organic mater is likely to occur below the thermocline, i.e. not in the surface waters. If strong remineralisation occurred already in the surface waters (e.g. because of the absence of stratification), then the remineralisation processes possibly balanced the CO2

drawdown by primary production. This means the net CO2 drawdown was small or negligible. Considering our observations during summer, this CO2 drawdown in the central and southern area indeed could be temporary, since in summer we observed a mixed water column with high CO2 concentrations. One could therefore argue, that high primary production combined with low organic matter remineralisation and the stratification indeed allow a short term CO2 uptake in the southern region. Later in spring and in summer the CO2 is then released to the atmosphere again, when the stratification has disappeared and the remineralisation of organic matter has increased. In contrast, the deeper waters of the northern parts enable CO2 drawdown in longer time scales, since the strong stratification and of course the greater water depths enables export of organic matter from the surface layer. We are now heading toward the English Channel where we found a mixed water column and still with respect to CO2 undersaturated surface water. This means in spring almost the entire North Sea is undersaturated and thus acts as sink for atmospheric CO2.

We are grateful to the co-operative Pelagia crew enabling effective work in a pleasant atmosphere during our last CANOBA cruise.

Helmuth Thomas, RV Pelagia, 23.05.2002