

SUMMERTIME OVERPRODUCTION OF CARBON IN THE NORTH SEA

Yann Bozec, Helmuth Thomas, Laure-Sophie Schiettecatte, Alberto V. Borges, Khalid Elkalay & Hein J.W. de Baar*

The North Sea has been proven to act as a highly efficient continental shelf pump for the absorption of CO₂ from the atmosphere. Also, in the summer, the Net Community Production based on the carbon budget, exceeds almost threefold the carbon production derived via the Redfield ratio C:N:P=106:16:1 from budgeting of nutrient nitrogen. This confirms some previous indications of carbon overproduction in other coastal seas, thus showing that the common practice of deriving carbon productivity from nutrient budgets seriously underestimates the high productivity of coastal seas.

For carbon, a completely new field database was established. The North Sea was successfully covered during four seasons by an adapted 1° by 1° grid corresponding to 97 stations for each season/cruise. At each station the total Dissolved Inorganic Carbon (DIC) was accurately measured at up to 12 depths. Moreover while in transit between these stations some ~22,000 data points per cruise were collected of the partial pressure of CO₂ in surface seawater (pCO₂) versus air. During late summer, the bottom topography of the North Sea has a strong impact on the distributions of DIC and pCO₂. The surface distributions of these two parameters showed a clear boundary located around 54°N. South of this boundary the DIC and pCO₂ ranged from 2070 to 2130 μmol kg⁻¹ and 290 to 490 ppm, respectively, whereas in the northern North Sea, values ranged between 1970 to 2070 μmol kg⁻¹ and 190 to 350 ppm, respectively. The vertical profiles measured in the two different areas showed that the vertical mixing regime of the water column was the major factor determining the surface distribu-

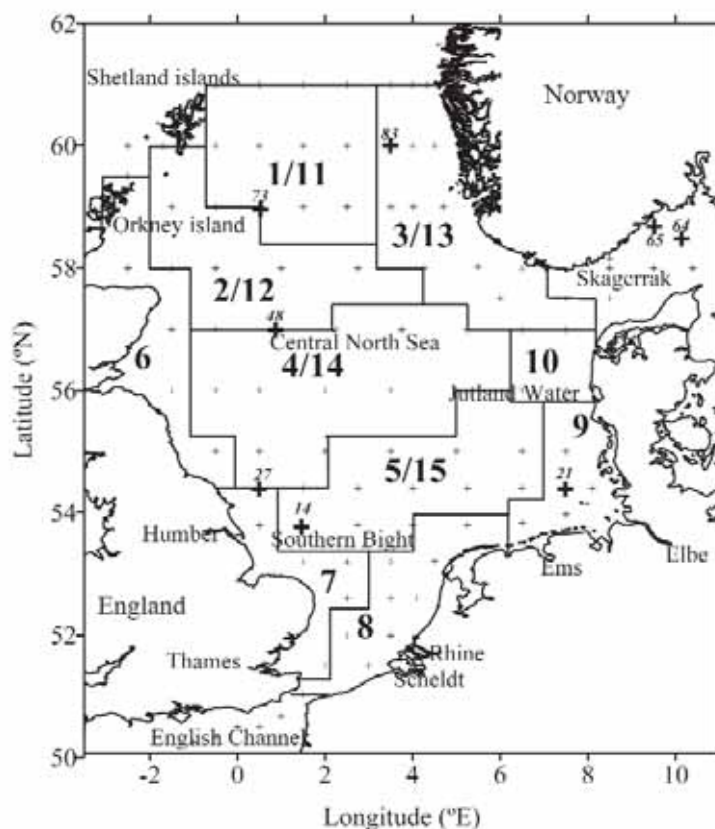


Fig. 1. Map of the study area and the International Commission for the Exploration of the Seas (ICES) boxes. Boxes 1, 2, 3, 4, and 5 represent the first 30 meters of the water column, whereas boxes 11, 12, 13, 14, and 15 are below the boxes 1-5 representing the bottom layer of the water column. The other boxes are one-layer boxes and represent the whole water column. Crosses represent the stations sampled during the four cruises.

tions. The entirely mixed water column of the shallow southern North Sea was heterotrophic (carbon release by respiration exceeding carbon fixation by photosynthesis), whereas the surface layer of the

stratified water column in the deeper northern North Sea was close to metabolic balance. During late summer, the southern North Sea acts as a source of CO₂ for the atmosphere within a range of

*corresponding author: debaar@nioz.nl

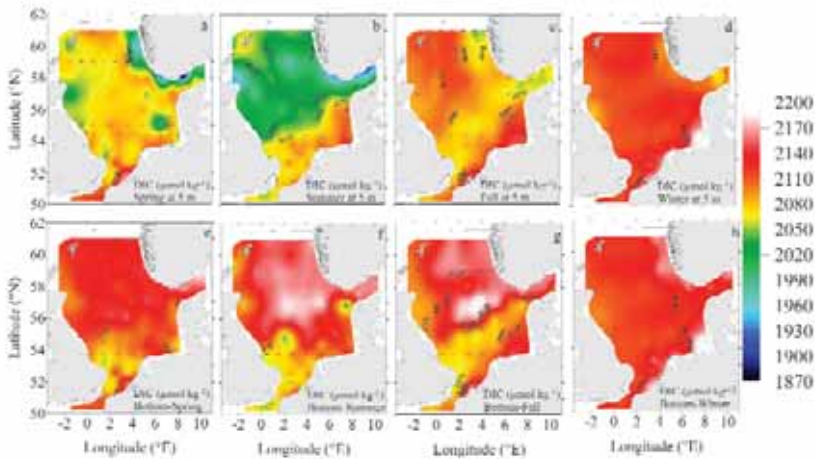


Fig. 2. Maps of DIC concentrations for the (a) spring, (b) summer, (c) fall, and (d) winter surface waters (5 m depth). Maps of DIC concentrations for the (e) spring, (f) summer, (g) fall, and (h) winter in bottom waters.

+0.8 to +1.7 mmol m⁻² day⁻¹, whereas the northern North Sea absorbs CO₂ within a range of -2.4 to -3.8 mmol m⁻² day⁻¹. The North Sea as a whole acts as a sink of atmospheric CO₂ of -1.5 to -2.2 mmol m⁻² day⁻¹ during late summer.

The annual air-sea exchange of CO₂ for the whole North Sea was obtained from the ~22,000 surface measurement of pCO₂ for each season, during the four consecutive cruises carried out during this thesis, thus constituting one of the most accurate estimates of the net annual air-sea flux of CO₂ for a coastal sea to date. As mentioned above, because of the absence of stratification during summer, the southern North Sea (south of 54°N) is an annual weak source of CO₂ for the atmosphere with a flux of 0.2 mol C m⁻² yr⁻¹. The northern North Sea (situated between 54° and 61°N) is a strong sink of CO₂ for the atmosphere with a flux of 1.7 mol C m⁻² yr⁻¹. The North Sea as a whole is a sink of CO₂ for the

atmosphere and takes up 1.4 mol C m⁻² yr⁻¹, from which approximately 93% are then transported to the deeper layer of the North Atlantic Ocean. The overall North Sea thus acts as a highly efficient continental shelf pump for the absorption of CO₂ from the atmosphere.

The seasonally resolved dataset of DIC, pCO₂ and inorganic nutri-

ents was interpolated per month, and regionally by using the 15-box scheme of the International Council for the Exploration of the Seas (ICES). The complete CO₂ system dataset allowed the first estimate of the Net Community Production based on inorganic carbon (NCP_C) in the different regions of the North Sea. An annual NCP_C of 4.3 ± 0.4 mol C m⁻² yr⁻¹ was estimated in the surface layer of the North Sea (513,000 km²), which accounts for 20-30% of the latest estimate of Global Primary Production (GPP) in the surface layer of the North Sea of 17.5 mol C m⁻² yr⁻¹. The NCP_C was almost threefold higher than the calculated NCP_N of 1.6 ± 0.2 mol C m⁻² yr⁻¹ based on the budget of nutrient nitrate. This summertime overproduction of carbon versus nitrogen is ascribed to a combination of preferential nitrogen cycling and intra-cellular mechanisms.

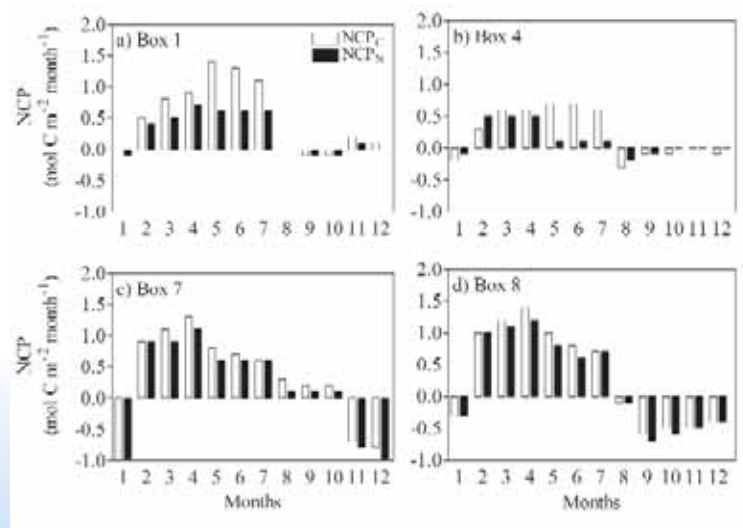


Fig. 3. Monthly net community production calculated from DIC (NCP_C) and NO_x (NCP_N) converted in C units using the Redfield ratio of 6.6 for two (a) northern and (b) central boxes as well as for (c and d) two southern boxes of the North Sea.