THE WINTER NUTRIENT STATUS OF SCOTTISH COASTAL AND OFFSHORE WATERS: 2001 – 2009

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Introduction

Nutrients such as nitrate, silicate and phosphate occur naturally and are essential for primary production. Anthropogenic discharges to our seas and oceans over the past century have resulted in nutrient enrichment of some coastal waters. Increased nutrient concentrations can lead to phytoplankton blooms and to coastal eutrophication where waters have low dissolved oxygen and can be of poor quality[1]. The time of year when samples for determination of nutrient concentrations are collected is critical as nutrient concentrations vary seasonally in a systematic manner, with concentrations being low in the spring and summer, and high in winter. The phytoplankton biomass increases in the spring due to the increase in light, temperature and water column stability. Nutrient concentrations decrease during this period as they are utilised by phytoplankton for growth. Limiting light intensity and low temperature during winter, limit phytoplankton growth and thus nutrients accumulate in the water column. Nutrient concentration can also vary systematically with depth, with higher concentrations often found in deeper water below the photic zone[2].

Over a nine year period 4,712 water samples, collected from Scottish coastal and offshore waters during January, have been analysed for nutrients (Total oxidised nitrogen [TOxN], phosphate [PO_4] ,silicate [SiO_4] and ammonia [NH_3]) with the aim of establishing regional background nutrient concentrations and contributing towards an assessment of the eutrophication status of Scottish coastal and offshore waters. The nutrient data collected from Scottish waters over this nine year period were assessed on a regional basis against assessment criteria established by OSPAR as indicators of nutrient enrichment[3]. Scottish waters were divided into 15 sea areas[4], of which 11 were investigated as part of this study: The Forth, East Scotland Coast, Moray Firth, Minches and Malin Sea, North Scotland Coast, Solway Firth and North Channel, Clyde, East Shetland, West Shetland, Forties, Herbrides and Fladen (Fig 1). Sea areas were constructed by taking into consideration; fisheries limits, Regional seas, flushing times and the 500 m depth contour.

Fig 1 Scottish Sea Areas, banded (key colour), regional , time averaged TOxN concentrations (µM) and number of samples analysed from each region.

Methods

- Surface water samples were collected from the non-toxic water supply of FRV *Scotia* IV (Fig 2) at a depth of ~ 4.5m.
- Samples collected in 2001 were analysed using the Skalar SAN+ continuous flow autoanalyser (CFA), between 2002 and 2006 samples were analysed on the Bran & Luebbe CFA AA3 and from 2007 onwards samples were analysed on the Bran & Luebbe QuAAtro autoanalyser (Fig 3).
- Temperature and salinity measurements were collected with a Sea-Bird Thermosalinograph.
- Between 2001 and 2004 samples were mainly collected close to the coastline (~ 3 nautical miles) but from 2005 onwards samples were collected every 15 minutes for the duration of the cruise and include samples from further offshore.
- Quality Control reference materials were monitored on Shewhart control charts and Quality Assurance was assured through successful participation in the nutrient programme of QUASIMEME. The methods are accredited to ISO 17025 through the United Kingdom Accreditation Service (UKAS).

Fig 3 Bran & Luebbe QuAAtro autoanalyser in containerised laboratory on board FRV *Scotia* IV

1. OSPAR, 2010, Quality status report 2010. OSPAR Commission, London 176pp
2. C. Shaw, R. Fryer, J. McKie and L. Webster, 2003. Evaluation of the sampling and analytical technique for the measurement of inorganic nutrients in sea water. FRS report No. 04/03
3. OSPAR Commission 2005. Background document on the ecological quality objectives for the greater North Sea with regards to nutrients and eutrophication effects.
4. Baxter, J.M., Boyd, I.L., Cox, M., Donald, A.E., Malcolm, S.J., Miles, H., Miller, B., Moffat, C.F., (Editors), 2011. Scotland's Marine Atlas: Information for the national marine plan. Marine Scotland, Edinburgh. pp. 191

Fig 2 FRV *Scotia* IV
Photo M Russell

Results and Discussion

- Dissolved inorganic nitrogen (DIN) is the sum of the concentration of TOxN and NH_3. In Scottish areas NH_3 contributes about 5% of the DIN. The NH_3 concentration was not determined for all the samples collected, therefore TOxN concentrations were compared to the DIN assessment levels for coastal and offshore waters.Time-averaged regional mean concentrations are shown in Fig 1.
- Percentage of sites within background levels, between background and assessment levels and greater than assessments levels for TOxN (normalised to salinity for coastal waters) are presented in Fig 4 a. Only 3, East Scotland coastal samples, out of the 4721 samples analysed exceeded the DIN assessment levels.
- Only 5% of samples exceeded background levels, most frequently in the Fladen sea area Fig 4a.
- TOxN concentrations appear to be stable with no temporal trends in any Scottish areas
- Eighty four (84) samples in 7 areas had a DIN/DIP ratio greater than the assessment ratio of 24. In all cases TOxN concentrations were below DIN background levels indicating no adverse effects to the ecosystem.
- DIN/silicate ratio was above the assessment level of 2 in a high proportion of samples from offshore sea areas (Fig 4b). High ratios were due to low silicate concentrations. DIN assessment levels were not exceeded and therefore are not a cause for concern.
- High DIN/silicate ratios in Scottish offshore waters is not unusual because of the low silicate concentrations, and therefore the assessment level may not be appropriate for these regions.

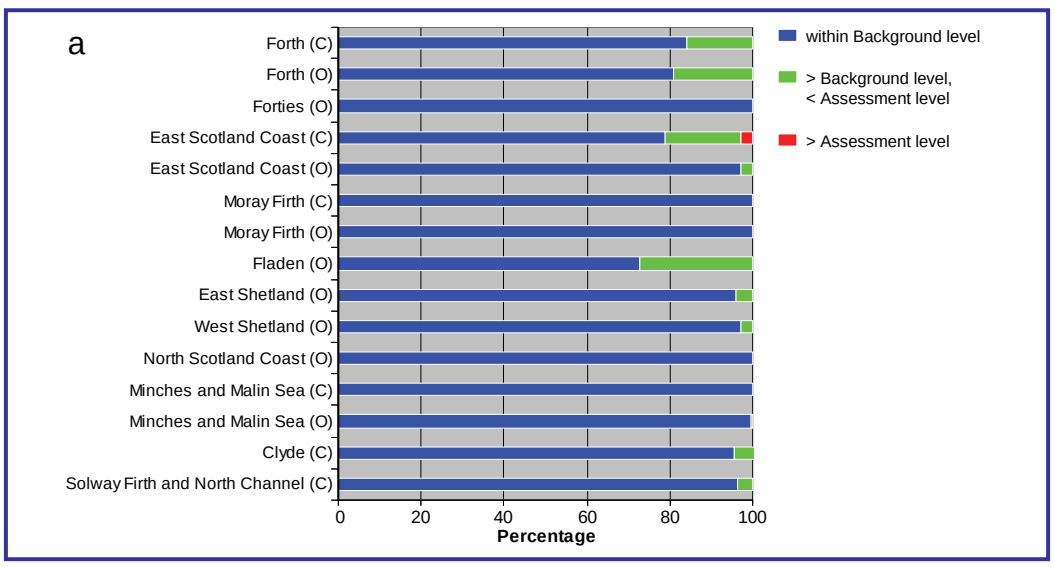

Fig 4 Percentage of sites within background levels, between background and assessment levels and above assessment levels for (a) TOxN (normalised to salinity for coastal waters) and (b) DIN/silicate. Where (C) is coastal and (O) is offshore waters.

Conclusions

- **There was no evidence of nutrient enrichment in Scottish coastal or offshore waters**
- **Nutrient concentrations appeared to be stable over a nine year period with no significant changes in nutrient concentrations.**
- **High DIN/silicate ratios in Scottish offshore waters are not unusual because of low silicate concentrations**

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