DY029 Cruise Report

RRS *Discovery*

1st April - 30th April 2015

PS: Alex Poulton

National Oceanography Centre (Southampton)

Contents:

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Key to institutes: NOC, National Oceanography Centre; NMF, National Marine Facilities; PML, Plymouth Marine Laborarotory; Aberdeen, University of Aberdeen; Southampton, University of Southampton; Liverpool, University of Liverpool; UEA, University of East Anglia; SAMS, Scottish Association of Marine Sciences; Plymouth, University of Plymouth; Edinburgh, University of Edinburgh; Essex, University of Essex.

Scientific background

Cruise DY029 was the spring cruise of the NERC/Defra-funded Shelf Sea Biogeochemistry research programme. The overall goals of this work are to determine the magnitude of carbon that the NW European shelf exports to the deep ocean, and how the shelf biogeochemistry sustains this export. Both pelagic and benthic work is associated with this research programme, through a series of cruises through 2014 and 2015. A second component to this work involves the role of the shelf in supplying the micronutrient iron to the open ocean.

DY029 was the second of the pelagic cruises of the SSB programme, sampling the spring bloom in the Celtic Sea in April 2015. The main objectives of the cruise were:

1. To make times-series process measurements at the Central Celtic Sea (CCS) site to examine the development of the spring bloom;
2. To make a number of observations at other sites across the Celtic Sea in order to put the spring bloom development at CCS into a wider context;
3. To maintain the moorings at the Central Celtic Sea site through their recovery and redeployment (including a ADCP chain, temperature chain and bedframe);
4. Deploy, and where appropriate recover, a series of glider (including long-term and short-term OMG, a Slocum with nitrate sensor, and other Seagliders and Slocums) ;
5. Deploy and recover a Wirewalker mooring at CCS;
6. Make iron and radium measurements along three inshore-offshore transects (WP3 of the SSB programme).

The cruise was hugely successful and sampled pre-bloom, peak bloom and post bloom conditions in the central Celtic Sea. Process stations were performed repeatedly in the central Celtic Sea (CCS), and to a lesser extent at the shelf edge station (CS2). Work at these stations typically comprised CTDs for water sample collection and autotrophic and bacterial rate measurements; use of Marine Snow Catchers (MSC) and Stand-Alone-Pumps (SAPS) for collection of suspended and sinking particles; and WP2 zooplankton net hauls for biomass, species composition, grazing rates and respiration rates. Two CTD transects were also sampled for standing stocks (dissolved and particulate), one between the shelf edge station (CS2) and the central Celtic Sea (CCS) site (O-transect) and one between the Celtic Deep (Site A) and the CCS (J-transect). Three cross-slope transects, each consisting of 7 stations between water depths of 2500 m and 200 m, were carried out to measure iron chemistry and radium. An array of moorings in the central Celtic Sea were recovered and redeployed with two deployments of a separate Wirewalker mooring across the two legs of the cruise. A total of 10 gliders were deployed/recovered, including two Micro-Structure gliders (one at CCS, one at CS2), and one equipped with a nitrate sensor.

Figure 1. DY029 sampling sites (prepared by A Poulton)

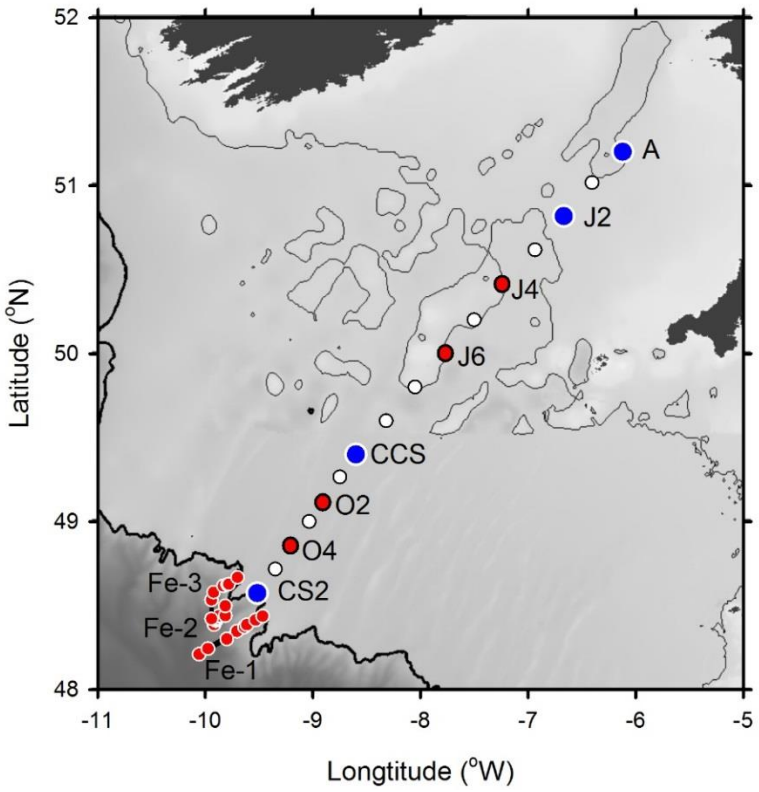


Figure 2. Map of CTD cast locations (prepared by C Williams)

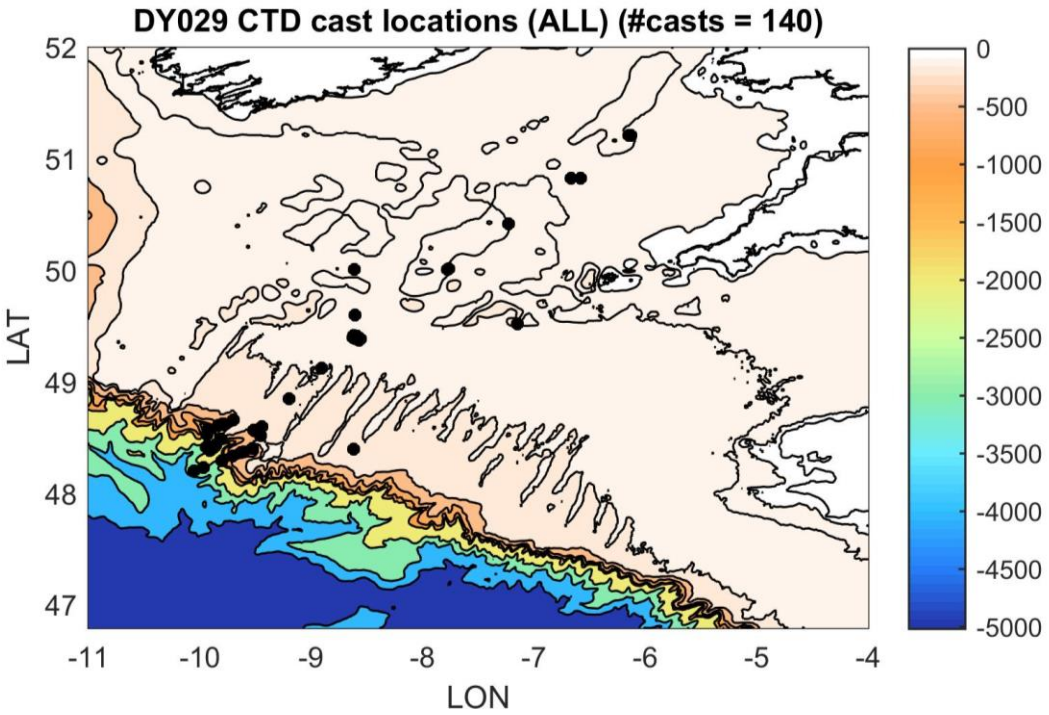


Table 1. Station positions

Note: positions are nominal. Please refer to logs of individual events.

Station ID	Latitude N	Longitude W	Depth	Comments
CCS	49° 24'	8° 36'	150 m	**Main process / mooring site**
CS2	48° 34.26'	9° 30.58'	203 m	**Shelf edge process station**
O1	49° 16.0'	8° 45.0'	Not sampled	**Transect between CCS and CS2**
O2	49° 07.0'	8° 54.3'	157 m	"
O3	49° 00.0'	9° 02.7'	Not sampled	"
O4	48° 51.2'	9° 12.0'	166 m	"
O5	48° 43.1'	9° 21.1'	Not sampled	"
Site A	51° 12.8'	6° 7.8'	111 m	**Benthic work package site A**
J1	51° 01.5'	6° 23.75'	Not sampled	**Transect between site A and CCS**
J2	50° 49.7'	6° 40.0'	103 m	"
J3	50° 37.5'	6° 56.5'	Not sampled	"
J4	50° 25.2'	7° 13.7'	100 m	"
J5	50° 12.7'	7° 30.0'	Not sampled	"
J6	50° 00.8'	7° 46.6'	118 m	"
J7	49° 48.5'	8° 03.0'	Not sampled	"
J8	49o 36.3'	8° 19.8'	Not sampled	"
Fe01	48° 12.35'	10° 3.24'	2422 m	**Iron transect 1**
Fe02	48° 14.37'	9° 57.92'	2001 m	"
Fe03	48° 20.45'	9° 42.25'	1480 m	"
Fe15	48° 18.0'	9° 48.0'	1480 m	(extra station along transect)
Fe04	48° 22.21'	9° 37.71'	934 m	"
Fe05	48° 22.69'	9° 36.49'	727 m	"
Fe06	48° 24.53'	9° 31.56'	469 m	"
Fe07	48° 25.71'	9° 28.03'	Not sampled	"
Fe08	48° 23.11'	9° 55.06'	2597 m	**Iron transect 2**
Fe09	48° 23.97'	9° 54.06'	1954 m	"
Fe10	48° 24.61'	9° 53.37'	1555 m	"
Fe11	48° 25.33'	9° 52.72'	922 m	"
Fe12	48° 25.77'	9° 52.26'	705 m	"
Fe13	48° 26.24'	9° 51.78'	485 m	"
Fe14	48° 29.49'	9° 48.51'	250 m	"
Fe16	48° 25.246'	9° 56.491'	2398 m	**Iron transect 3**
Fe17	48° 32.0'	9° 56.0'	2034 m	"
Fe18	48° 34.671'	9° 55.36'	1510 m	"
Fe19	48° 37.0'	9° 50.0'	1076 m	"
Fe20	48° 37.516'	9° 47.62'	759 m	"
Fe21	48° 37.595'	9° 46.98'	511 m	"
Fe22	48° 40.0'	9° 42.0'	280 m	"

Table 2. DY029 Day-to-day summary:

Date	Location	Activities
1	Transit	Sail from Southampton (1200)
2	Transit	Stopped for CTD test dips in transit
3	Transit CCS	AM - Recover glider in transit to CCS; PM - Arrive CCS; Attempt recovery of NOCL bedframe (failed); conditions prevents recovery of other CCS moorings; Afternoon CTDs; Evening zooplankton nets
4	CCS	AM - Predawn CTD; Glider deployment (2); mooring recovery; PM - Midday and afternoon CTDs; Evening zooplankton nets
5	CCS	AM – Glider deployment/recovery (1); morning CTDs PM – Wire-walker ballast test and deployment; Afternoon CTDs; Marine Snow Catcher (1); Afternoon and evening zooplankton nets
6	CCS Iron II transect	AM – Predawn CTD; TM fish deployed; Transit to iron transect II PM – Start sampling along iron transect II; Radium and Iron CTDs (TMF CTD developed electrical fault and needed 24 hrs for re-termination)
7	Iron II transect	AM – Radium CTDs PM – Radium CTDs; Late evening Iron CTD
8	Iron II transect	AM – Iron CTDs PM – Radium and Iron CTDs; Late evening zooplankton nets
9	Iron II transect CS2	AM – Radium and Iron CTDs; Glider deployment (2) PM –Transit to CS2; Evening nets and CTD
10	CS2 Transit to CCS	AM – Predawn and morning CTDs PM – CTD sampling along line O towards CCS; Evening nets at CCS
11	CCS	AM – Predawn CTD; Redeployment of the moorings PM – Midday CTD; Glider deployment (1); Wire-walker recovery; Evening CTDs and nets
12	CCS Transit	AM – Iron CTD; SAPS PM – Marine Snow Catchers (8); Afternoon nets and transit to Falmouth
13	Falmouth Site A	AM – Boat transfer; transit to Site A (Celtic Deep) PM – Late night CTDs at Site A
14	Transit to CCS	AM – CTD sampling along line J towards CCS PM – CTD sampling along line J towards CCS
15	CCS (Peak Chl)	AM – Predawn CTD; Wire-walker redeployment; Morning CTD PM – Midday CTD; Zooplankton nets and CTD
16	CCS	AM – Morning CTD; Zooplankton nets PM – Marine Snow Catchers (8) and SAPS; Evening zooplankton nets; TM fish deployed and transit to CS2
17	CS2 / Iron III transect	AM – Glider deployment (1) at CS2; Morning CTD; Radium and Iron CTDs PM – Radium and Iron CTDs
18	Iron III transect	AM - Radium and Iron CTDs PM - Radium and Iron CTDs; Evening zooplankton nets
19	Iron III transect	AM - Radium and Iron CTDs PM – Radium and Iron transects; transit to CCS overnight
20	CCS	AM – Predawn and Morning CTDs PM – Midday CTDs, Zooplankton nets and CTD; Evening CTD and nets
21	CCS	AM – Morning CTD and zooplankton nets PM – Iron CTD; Marine Snow Catchers (6); SAPS; transit to Fe I transect
22	Iron I transect	AM – Iron CTDs PM – Iron and midday CTDs; Evening zooplankton nets
23	Iron I transect	AM – Morning CTD; Iron CTDs

		PM – Iron and midday CTDs; transit to CS2
24	CS2	AM – Predawn and morning CTDs; recover gliders (2); SAPS PM – Marine Snow Catchers (6); Radium and Iron CTDs; transit to CCS
25	CCS	AM – Predawn and morning CTDs; recover gliders (2); recover Wire-walker PM – Midday CTD; Marine Snow Catchers (6); Zooplankton nets and CTD
26	CCS / transit to Site A	AM – Radium and Iron CTDs; bad weather at CCS PM – Transit to Site A (Celtic Deep)
27	Site A / transit to CCS	AM – Predawn, Radium and Iron CTDs (Site A); CTD sampling along J transect (Coccolithophore bloom at J2) PM – CTD sampling along J transect to CCS
28	CCS	AM – Zooplankton nets, Iron and Morning CTD at CCS; leave CCS for Southampton
29	Transit	AM – Transit to Southampton PM – Arrive Southampton (1700)
30	Southampton	AM – Demobilisation of DY029

Table 3. DY029 Cruise narrative:

Date	Time (GMT)	Time (ships)	Activity/event	Site
1st	0930	1030	Lifeboat drill	
	1100	1200	Sailed from Southampton	
	1400	1500	Science meeting	
2nd	1654	1754	Stopped for CTD test dips	
	1713	1813	**Event 001**: Test dip with Steel CTD	
	1836	1936	**Event 002**: Test dip with Titanium CTD	
	1925	2025	Off station	
3rd	0510	0610	Stopped for glider recovery	
	0640	0740	**Event 003**: Glider recovery (419)	
	0700	0800	Off station for CCS	
	1200	1300	On station CCS	
	1240	1340	**Event 004:** Attempt to recover NOCL bedframe, failed.	CCS
	1430	1530	**Event 005:** Radium CTD (Steel)	
	1538	1638	**Event 006:** Iron CTD (Titanium)	
	1646	1746	**Event 007:** Radium CTD (Steel)	
	1800	1900	**Event 008:** Zooplankton nets (2)	
4th	0205	0305	**Event 009**: First predawn CTD (Steel)	CCS
	0528	0628	Repositioned for glider deployment	
	0601	0701	**Event 010**: Glider (423) deployment	
	0629	0729	**Event 011**: Glider (SG534) deployment	
	0709	0809	**Event 012**: Post-glider deployment CTD (Steel)	
	0914	1014	**Event 013**: Recovery of ADCP mooring string	
	1028	1128	**Event 014**: Recovery of temperature chain mooring	
	1249	1349	**Event 015**: Midday CTD (Steel)	
	1511	1611	**Event 016**: Zooplankton CTD (Steel) for grazing expts.	
	1610	1710	**Events 017-020**: Zooplankton nets	
	1735	1835	Nets finished	
5th	0017	0117	**Events 021-026**: Zooplankton nets	CCS
	0137	0237	Zooplankton nets finished	
	0518	0618	Repositioned for glider deployment	
	0612	0712	**Event 027**: Glider deployed	
	0642	0742	**Events 028-029**: Glider deployed & recovered	
	0755	0855	**Event 030**: Radium CTD (Steel) inc. PvE	
	0934	1034	**Event 031a**: Guard buoy recovery	
	1248	1348	**Event 031**: Wirewalker ballast testing	
	1335	1435	**Event 032**: Wirewalker deployment	
	1454	1554	**Event 033**: Midday CTD (Steel)	
	1620	1720	**Events 034-039**: Zooplankton nets	
	1841	1941	**Event 040**: Iron CTD (Steel)	
	2014	2114	**Event 041**: SAPS	
	2216	2316	**Event 042**: Marine snow catcher 1 (70 m)	
	2358	0058	**Events 043-046**: Zooplankton nets	
6th	0052	0152	Zooplankton nets finished	CCS
	0214	0314	**Event 047**: Pre-dawn CTD (Steel)	
	0500	0600	**Event 048**: TM fish deployed	
	0601	0701	Off station for Fe08	
	1345	1445	On station Fe08	
	1408	1508	**Event 049**: Radium CTD (Steel)	Fe08
	1514	1614	**Event 050**: Iron CTD (Titanium)	
	1830	1930	**Event 051**: Radium CTD (Steel)	
	2100	2200	**Event 052**: Radium CTD (Steel)	
	2325	0025	**Event 053**: Radium CTD (Steel)	
7th	0132	0232	**Event 054**: Radium CTD (Steel)	
	0515	0615	**Events 055-057**: Zooplankton nets	
	0735	0835	Off station for Fe09	

	0757	0857	On station Fe09	
	0855	0957	**Event 058**: Radium CTD (Steel) inc. PvE	Fe09
	1217	1317	**Event 059**: Radium CTD (Steel)	
	1440	1540	**Event 060**: Radium CTD (Steel)	
	1639	1739	**Event 061**: Radium CTD (Steel)	
	1724	1824	Off station for Fe10	
	1800	1900	On station Fe10	
	1816	1916	**Event 062**: Radium CTD (Steel)	Fe10
	2033	2133	**Event 063**: Radium CTD (Steel)	
	2211	2311	**Event 064**: Iron CTD (Titanium)	
8th	0054	0154	Off station for Fe08	
	0154	0254	On station Fe08	
	0408	0508	**Event 065**: Iron CTD (Titanium)	Fe08
	0524	0624	**Event 066**: Iron CTD (Titanium)	
	0813	0913	Off station for Fe09	
	0833	0933	On station Fe09	
	1050	1150	**Event 067**: Iron CTD (Titanium)	Fe09
	1303	1403	Off station for Fe11	
	1328	1428	On station Fe11	
	1358	1458	**Event 068**: Radium CTD (Steel)	Fe11
	1600	1700	**Event 069**: Iron CTD (Titanium)	
	1739	1839	**Event 070**: Radium CTD (Steel)	
	2008	2108	**Events 071-075**: Zooplankton nets	
9th	0026	0126	Zooplankton nets finished	
	0036	0136	Off station for Fe12	
	0049	0149	On station Fe12	
	0212	0312	**Event 076**: Radium CTD (Steel)	Fe12
	0337	0437	**Event 077**: Iron CTD (Titanium)	
	0509	0609	**Event 078**: Radium CTD (Steel)	
	0530	0630	Off station for Fe13	
	0600	0700	On station Fe13	
	0723	0823	**Event 079**: Iron CTD (Titanium)	Fe13
	0850	0950	**Event 080**: Glider deployed	
	0925	1025	**Event 081**: Glider deployed	
	0959	1059	**Event 082**: Radium CTD (Steel) inc. PvE	
	1140	1240	**Event 083**: Radium CTD (Steel)	
	1250	1350	**Event 084**: Radium CTD (Steel)	
	1301	1401	Off station for Fe14	
	1335	1435	On station Fe14	
	1401	1501	**Event 085**: Iron CTD (Titanium)	Fe14
	1536	1636	Off station for CS2	
	1624	1724	On station CS2	
	1730	1830	**Events 086-089**: Zooplankton nets	CS2
	1806	1906	**Event 090**: Zooplankton CTD (Steel) for grazing expts.	
	1905	2005	**Events 091-097**: Zooplankton nets	
10th	0207	0307	**Event 098**: Pre-dawn CTD (Steel)	CS2
	0707	0807	**Event 099**: Morning CTD (Steel) for PvE	
	0748	0848	Off station for O4	
	1010	1110	On station O4	
	1016	1116	**Event 100**: Radium CTD (Steel)	O4
	1113	1213	**Event 101**: Iron CTD (Titanium)	
	1206	1306	**Event 102**: Radium CTD (Steel)	
	1340	1440	Off station for O2	
	1452	1552	On station O2	
	1459	1559	**Event 103**: Radium CTD (Steel)	O2
	1545	1645	**Event 104**: Iron CTD (Titanium)	
	1639	1739	**Event 105**: Radium CTD (Steel)	
	1755	1855	Off station for CCS	
	2005	2105	On station CCS	
	2234	2334	**Events 106-110**: Zooplankton nets	CCS

	2342	0042	Zooplankton nets finished	
11th	0210	0310	**Event 111**: Pre-dawn CTD (Steel)	CCS
	0710	0810	**Event 112**: Deployment of ADCP string mooring	
	0957	1057	**Event 113**: Deployment of temperature chain	
	1053	1153	**Event 114**: Deployment of ADCP bedframe	
	1128	1228	**Event 115**: Morning CTD (Steel) for PvE	
	1223	1323	**Event 116a**: Glider deployment	
	1319	1419	**Event 116**: Recovery of Wire-walker	
	1515	1615	**Events 117-120**: Zooplankton nets	
	1710	1810	**Event 121**: Zooplankton CTD (Steel) for grazing expts.	
	2108	2208	**Events 122-130**: Zooplankton nets	
	2236	2336	Zooplankton nets finished	
12th	0547	0647	**Event 131**: Iron CTD (Titanium)	CCS
	0945	1045	**Event 132**: SAPS	
	1150	1250	**Events 133-137**: Marine snow catcher 1 (10 m)	
	1529	1629	**Events 138-141**: Marine snow catcher 1 (70 m)	
	1456	1556	**Event 142**: Zooplankton nets	
	1459	1559	Zooplankton nets finish, leave CCS for Falmouth	
13th	0930	1030	Boat transfer in Falmouth Bay Sail to site A (Celtic Deep)	
	2110	2210	On station Site A (Celtic Sea)	
	2115	2215	**Event 143**: Evening CTD (Steel)	Site A
	2203	2303	**Event 144**: Iron CTD (Titanium)	
	2251	2351	**Event 145**: Radium CTD (Steel)	
14th	2322	0022	Off station for J2	
	0240	0340	On station J2	
	0304	0404	**Event 146**: Radium CTD (Steel)	J2
	0357	0457	**Event 147**: Iron CTD (Titanium) inc. Production	
	0508	0608	**Event 148**: Morning CTD (Steel) for PvE	
	0610	0710	****Events 150-151**: Zooplankton nets **	
	0635	0735	Off station for J4	
	1006	1106	On station J4	
	1015	1115	**Event 149**: Midday CTD (Steel)	J4
	1107	1207	**Event 152**: Iron CTD (Titanium)	
	1128	1228	Off station for J6	
	1506	1606	On station J6	
	1508	1608	**Event 153**: Afternoon CTD (Steel)	J6
	1739	1839	**Event 154**: Iron CTD (Titanium)	
	1819	1919	**Event 155**: Radium CTD (Steel)	
	1842	1942	Off station for CCS	
15th	0141	0241	On station CCS	CCS
	0202	0302	**Event 156**: Pre-dawn CTD (Steel)	
	0716	0816	**Event 157**: Wirewalker deployment	
	0822	0922	**Event 158**: Morning CTD (Steel) for PvE	
	1212	1312	**Event 159**: Midday CTD (Steel)	
	1409	1509	**Events 160-163**: Zooplankton nets	
	1523	1623	**Event 164**: Zooplankton CTD (Steel) for grazing expts.	
	2034	2134	**Events 165-172**: Zooplankton nets	
16th	0801	0901	**Event 173**: Morning CTD (Steel) for PvE	CCS
	1106	1206	**Events 174-178**: Zooplankton nets	
	1241	1341	**Event 179**: Midday CTD (Steel)	
	1327	1427	**Event 180**: Iron CTD (Titanium)	
	1430	1530	**Events 181-185**: Marine Snow Catchers (10 m)	
	1611	1711	**Event 186**: SAPS	
	1748	1848	**Event 187-191**: Marine Snow Catchers (70 m)	
	2000	2100	**Events 192-196**: Zooplankton nets	
	2235	2335	**Event 197**: TM fish deployed	
	2250	2350	Off station for CS2	
17th	0530	0630	On station CS2	CS2
	0626	0726	**Event 198**: Glider deployment (OMG #423)	

	0659	0759	**Event 199**: Morning CTD for PvE	
	0748	0848	Off station for Fe01	Fe01
	1105	1205	On station Fe01	
	1122	1222	**Event 200**: Radium CTD (Steel)	
	1334	1434	**Event 201**: Iron CTD (Titanium)	
	1744	1844	**Event 202**: Radium CTD (Steel)	
	1926	2026	**Event 203**: Radium CTD (Steel)	
	2005	2105	Off station for Fe02	Fe02
	2050	2150	On station Fe02	
	2230	2330	**Event 204**: Radium CTD (Steel)	
18th	0051	0151	**Event 205**: Iron CTD (Titanium)	Fe02
	0431	0531	**Event 206**: Radium CTD (Steel)	
	0621	0721	**Event 207**: Radium CTD (Steel)	
	0715	0815	Off station for Fe15	
	0812	0912	On station Fe15	
	0846	0946	**Event 208**: Radium CTD (Steel) inc. PvE	Fe15
	1045	1145	**Event 209**: Iron CTD (Titanium)	
	1241	1341	**Event 210**: Radium CTD (Steel)	
	1330	1430	Off station for Fe03	
	1406	1506	On station Fe03	
	1442	1542	**Event 211**: Radium CTD (Steel)	Fe03
	1618	1718	**Event 212**: Iron CTD (Titanium)	
	1804	1904	**Event 213**: Radium CTD (Steel)	
	1850	1950	Off station for Fe04	
	1950	2050	On station Fe04	
	2011	2111	**Events 214-215**: Zooplankton nets (respiration expt.)	Fe04
			Downtime for Iron and Radium groups	
19th	0610	0710	**Event 216**: Iron CTD (Titanium)	Fe04
	0754	0854	**Event 217**: Radium CTD (Steel)	
	0929	1029	**Event 218**: Radium CTD (Steel) inc. PvE	
	1010	1110	Off station for Fe05	
	1030	1130	On station Fe05	Fe05
	1055	1155	**Event 219**: Iron CTD (Titanium)	
	1206	1306	**Event 220**: Radium CTD (Steel)	
	1329	1429	**Event 221**: Radium CTD (Steel)	
	1355	1455	Off station for Fe06	
	1427	1527	On station Fe06	
	1445	1545	**Event 222**: Iron CTD (Titanium)	Fe06
	1556	1656	**Event 223**: Radium CTD (Steel)	
	1631	1731	Off station for CCS	
20th	0150	0250	On station CCS	CCS
	0214	0314	**Event 224**: Pre-dawn CTD (Steel)	
	0802	0902	**Event 225**: Morning CTD (Steel) [misfired]	
	0900	1000	**Event 226**: Morning CTD (Steel) for PvE	
	1158	1258	**Event 227**: Midday CTD (Steel)	
	1500	1600	**Events 228-231**: Zooplankton nets	
	1540	1640	**Event 232**: Zooplankton CTD (Steel) for grazing expts.	
	1859	1959	**Event 233**: Evening CTD (Steel) for 24 hr NCP expt.	
	2040	2140	**Events 234-240**: Zooplankton nets	
21st	0806	0906	**Event 241**: Morning CTD (Steel) for PvE	CCS
	1208	1330	**Events 242-245**: Zooplankton nets	
	1230	1330	**Event 246**: Midday CTD (Steel)	
	1322	1422	**Event 247**: Iron CTD (Titanium)	
	1426	1526	**Events 248-252**: Marine Snow Catchers (10 m)	
	1530	1630	**Event 253-254**: SAPS (inc. redeployment of 15 m pump)	
	1821	1921	**Events 255-259**: Marine Snow Catchers (70 m)	
	2000	2100	**Events 260-264**: Zooplankton nets	
	2135	2235	Move off for Fe16	
22nd	0610	0710	On station Fe16	
	0600	0700	**Event 265**: Iron CTD (Titanium), 2500 m	Fe16

	0848	0948	Move off for Fe17	
	0952	1052	On station Fe17	
	1012	1112	**Event 266**: Midday CTD (Steel)	Fe17
	1238	1338	**Event 267**: Iron CTD (Titanium), 2000 m	
	1420	1520	Move off for Fe18	
	1515	1615	Muster drill	
	1545	1645	On station Fe18	
	1744	1844	**Event 268**: Iron CTD (Titanium), 1500 m	Fe18
	1918	2018	Move off for Fe19	
	2000	2100	On station Fe19	
	2110	2210	**Events 269-270**: Zooplankton nets	Fe19
23rd	0754	0854	**Event 271**: Morning CTD (Steel) for PvE	Fe19
	0900	1000	**Event 272**: Iron CTD (Titanium), 1000 m	
	1020	1120	Move off for Fe20	
	1043	1143	On station Fe20	
	1205	1305	**Event 273**: Midday CTD (Steel)	Fe20
	1312	1412	**Event 274**: Iron CTD (Titanium), 734 m	
	1439	1539	Off station for Fe21	
	1450	1550	On station Fe21	
	1738	1838	**Event 275**: Iron CTD (Titanium), 512 m	Fe21
	1807	1907	Off station for Fe22	
	1915	2015	On station Fe22	
	2016	2116	**Event 276**: Iron CTD (Titanium), 283 m	Fe22
	2105	2205	Off station for CS2	
	2222	2322	On station CS2	
24th	0206	0306	**Event 277**: Predawn CTD (Steel)	CS2
	0530	0630	**Event 278**: Pre-recovery calibration CTD (Titanium)	
	0730	0830	**Event 279**: Recover gliders OMG3	
	0841	0941	**Event 280**: Morning CTD (Steel)	
	0954	1054	**Event 281**: Recover glider SG533	
	1103	1203	**Events 282:** SAPS	
	1241	1341	**Events 283-284**: Marine Snow Catchers (80 and 10 m)	
	1322	1422	**Event 285**: Midday CTD (Steel)	
	1415	1515	**Events 286-289**: Zooplankton nets	
	1522	1622	**Event 290**: Radium CTD (Steel)	
	1608	1708	**Event 291**: Iron CTD (Titanium)	
	1713	1813	**Event 292**: Radium CTD (Steel)	
	1725	1825	Move off station of CCS	
25th	2340	0040	On station CCS	CCS
	0200	0300	**Event 293**: Morning CTD (Steel) for PvE	
	0430	0530	**Event 294**: Pre-recovery calibration CTD (Titanium)	
	0459	0559	**Event 295**: Pre-recovery calibration dip (Titanium)	
	0624	0724	**Event 296**: Glider recovery OMG3	
	0658	0758	**Event 297**: Glider recovery SG534	
	0833	0933	**Event 298**: Wire-walker recovery	
	1002	1102	**Event 299**: Morning CTD (Steel) for PvE	
	1040	1140	**Event 300**: SAPS	
	1202	1302	**Event 301**: Midday CTD (Steel)	
	1317	1417	**Events 302-304**: Marine Snow Catchers (10 m)	
	1407	1507	**Events 305-309**: Zooplankton nets	
	1526	1626	**Events 310-312**: Marine Snow Catchers (70 m)	
	1622	1722	**Event 313**: Zooplankton CTD (Steel)	
	2112	2212	**Events 314-321**: Zooplankton nets	
26th	0506	0606	**Event 322**: Radium CTD (Steel)	CCS
	0550	0650	**Event 323**: Iron CTD (Steel)	
	06460	0746	**Event 324**: Radium CTD (Steel)	
	0710	0810	Move off for Site A	
27th	0035	0135	On station Site A	
	0104	0204	**Event 325**: Radium CTD (Steel)	Site A
	0210	0310	**Event 326**: Iron CTD (Titanium)	

	0301	0401	**Event 327**: Pre-dawn CTD (Steel)	
	0328	0428	Move off for J2	
	0642	0742	On station J2	
	0653	0753	**Event 328**: Morning CTD (Steel)	J2
	0903	0803	**Event 329**: Iron CTD (Titanium)	
	1045	0945	Move off for J4	
	1213	1313	On station J4	
	1221	1321	**Event 330**: Midday CTD (Steel)	J4
	1313	1413	**Event 331**: Iron CTD (Titanium)	
	1335	1435	Move off for J6	
	1658	1758	On station J6	
	1711	1811	**Event 332**: Evening CTD (Steel)	J6
	1800	1900	**Event 333**: Iron CTD (Titanium), aborted	
	1925	1825	**Event 334**: Iron CTD (Titanium)	
	1945	1845	Move off for CCS	
28th	0005	0105	On station CCS	
	0012	0112	**Events 335-338**: Zooplankton nets	CCS
	0700	0800	**Event 339**: Iron CTD (Titanium)	
	0745	0845	**Event 340**: Trace metal fish recovered	
	0821	0921	**Event 341**: Morning CTD	
	0851	0951	Move off for Southampton	
	1600	1700	Science meeting	
	1900	2000	RPC	
29th		1700	Arrive Southampton	
30th			Demobilisation complete	

2. Dissolved inorganic carbon and total alkalinity

Alex Poulton, Sue Hartman & Caroline Kimivae (National Oceanography Centre - Southampton)

Overview

Dissolved inorganic carbon (DIC) and total alkalinity (TA) discrete samples were collected by Alex Poulton and Kyle Mayers (cruise participants) on behalf of Sue Hartman and Caroline Kimivae at the National Oceanography Centre (NOC). Samples were collected from CTD casts (n = 165 from Stainless Steel CTD frame; n = 29 from Trace-metal free (Titanium) CTD frame) as part of WP1 in order to characterise the water column of the study area. Six depths across the water column were collected at all sampling sites. Further samples were collected daily (~midday) from the non-toxic underway water supply in order to calibrate the pCO_2 sensor (PML, Vas Kitidis) on-board the RRS Discovery (n = 27).

Methods

Samples were collected in 250 mL glass stoppered bottles. Water samples were withdrawn from CTD niskin bottles and non-toxic underway supply using silicone tubing. Tubing was inserted into the base of the bottle, rinsed twice and slowly (over) filled from the bottom to the top to avoid and remove air bubbles. Samples were poisoned by removal of 2.5 mL volume and addition of 50 µL of a saturated mercuric chloride solution. Samples were then stored in the dark at room temperature for later analysis back at NOC.

Table 4. Discrete DIC/TA samples from CTD casts:

Date	Time (GMT)	Event	Station	CTD cast number	Niskins	Sample ID
04/04/15	0205	009	CCS	CTD_006_SS	3, 8, 13, 24	NERC-NOC-1020, NERC-NOC-1029, NERC-NOC-1016, NERC-NOC-A1017
04/04/15	1248	015	CCS	CTD_008_SS	3, 7, 9, 13, 17, 21	NERC-NOC-1033, NERC-NOC-1015, NERC-NOC-1012, NERC-NOC-1027, NERC-NOC-1031, A015-1
05/04/15	1454	033	CCS	CTD_011_SS	4, 7, 9, 11, 17, 21	NERC-NOC-1025, NERC-NOC-1040, NERC-NOC-1010, NERC-NOC-1005, NERC-NOC-1021, NERC-NOC-1036
06/04/15	0220	047	CCS	CTD_013_SS	2, 8, 13, 16, 20, 24	NERC-NOC-1062A, NERC-NOC-1060A, NERC-NOC-1073A, NERC-NOC-1078A, NERC-NOC-1063A, NERC-NOC-1067A
08/04/15	2210	064	Fe10	CTD_025_TT	9T, 1T, 6T, 13T, 16T, 22 T	NERC-NOC-344, NERC-NOC-330, NERC-NOC-895, NERC-NOC-337, NERC-NOC-340, NERC-NOC-335
08/04/15	0525	066	Fe08	CTD_027_TT	8T, 14T, 3T, 1T, 23T	NERC-NOC-42, NERC-NOC-20, NERC-NOC-332, NERC-NOC-341, NERC-NOC-331
10/04/15	0207	099	CS2	CTD_042_SS	6, 9, 12, 15, 18, 23	NERC-NOC-1068A, NERC-NOC-1064A, NERC-NOC-1138A, NERC-NOC-1076A, NERC-NOC-1070A, NERC-NOC-1065A
10/04/15	1300	102	O4	CTD_045_SS	2, 10, 12, 15, 22, 23	UoS-NOC-2368, UoS-NOC-2373, UoS-NOC-2378 UoS-NOC-2383, UoS-NOC-2367, UoS-NOC-2372
10/04/15	1500	103	O2	CTD_048_SS	9, 11, 13, 20, 23	UoS-NOC-2382, UoS-NOC-2366, UoS-NOC-2371 UoS-NOC-2376, UoS-NOC-2381
11/04/15	0210	111	CCS	CTD_049_SS	7, 10, 13, 15, 17, 21	UoS-NOC-2365, UoS-NOC-2370, UoS-NOC-2375 UoS-NOC-2380, UoS-NOC-2364, UoS-NOC-2369
13/04/15	2100	143	A	CTD_053_SS	5, 8, 10, 15, 17, 23	UoS-NOC-2308, UoS-NOC-2313, UoS-NOC-2318 UoS-NOC-2323, UoS-NOC-2307, UoS-NOC-2312
14/04/15	0508	148	J2	CTD_058_SS	3, 10, 11, 16, 19, 23	UoS-NOC-2317, UoS-NOC-2322, UoS-NOC-2306 UoS-NOC-2311, UoS-NOC-2316, UoS-NOC-2321
14/04/15	1015	151	J4	CTD_059_SS	3, 9, 12, 13, 18, 20	UoS-NOC-2304, UoS-NOC-2310, UoS-NOC-2315 UoS-NOC-2320, UoS-NOC-2303, UoS-NOC-2309
14/04/15	1500	153	J6	CTD_061_SS	4, 8, 12, 15, 18, 23	NERC-NOC-1066A, NERC-NOC-1072A, UoS-NOC-2319 UoS-NOC-2314, UoS-NOC-2324, UoS-NOC-2329
15/04/15	0202	156	CCS	CTD_064_SS	7, 9, 10, 13, 15, 24	UoS-NOC-2340, UoS-NOC-2335, UoS-NOC-2330 UoS-NOC-2325, UoS-NOC-2341, UoS-NOC-2336
16/04/15	1200	179	CCS	CTD_069_SS	5, 10, 11, 13, 17, 21	UoS-NOC-2348, UoS-NOC-2353, UoS-NOC-2358 UoS-NOC-2363, UoS-NOC-2347, UoS-NOC-2352
17/04/15	0700	199	CS2	CTD_071_SS	8, 10, 12, 15, 18, 20	UoS-NOC-2357, UoS-NOC-2362, UoS-NOC-2361 UoS-NOC-2356, UoS-NOC-2351, UoS-NOC-2346

18/04/15	1200	209	Fe15	CTD_081_TT	21T, 13T, 10T, 1T, 24T, 17T	UoS-NOC-2345, UoS-NOC-2350, UoS-NOC-2355 UoS-NOC-2360, UoS-NOC-2344, UoS-NOC-2349
20/04/15	0214	224	CCS	CTD_094_SS	17, 15, 13, 10, 8, 7	UoS-NOC-2415, UoS-NOC-2405, UoS-NOC-2421 UoS-NOC-2416, UoS-NOC-2411, UoS-NOC-2406
20/04/15	1158	227	CCS	CTD_097_SS	6, 8, 11, 13, 17, 24	UoS-NOC-2420, UoS-NOC-2403, UoS-NOC-2409 UoS-NOC-2414, UoS-NOC-2419, UoS-NOC-2402
21/04/15	1300	246	CCS	CTD_101_SS	8, 10, 14, 16, 18, 22	UoS-NOC-2408, UoS-NOC-2413, UoS-NOC-2401 UoS-NOC-2407, UoS-NOC-2412, UoS-NOC-2417
22/04/15	1015	266	Fe17	CTD_104_SS	8T, 10T, 13T, 16T, 19T, 22T	UoS-NOC-2422, UoS-NOC-2423, UoS-NOC-2424 UoS-NOC-2425, UoS-NOC-2426, UoS-NOC-2427
22/04/15	1205	273	Fe20	CTD_109_SS	5T, 8T, 11T, 14T, 17T, 21T	UoS-NOC-2428, UoS-NOC-2429, UoS-NOC-2430 UoS-NOC-2431, UoS-NOC-2432, UoS-NOC-2433
24/04/15	0300	277	CS2	CTD_113_SS	5, 8, 13, 15, 19, 24	UoS-NOC-2434, UoS-NOC-2435, UoS-NOC-2436 UoS-NOC-2437, UoS-NOC-2438, UoS-NOC-2439
24/04/15	1304	285	CS2	CTD_116_SS	3, 5, 7, 10, 13, 19	UoS-NOC-2386, UoS-NOC-2284A, UoS-NOC-2397 UoS-NOC-2392, UoS-NOC-2387, UoS-NOC-2095A
25/04/15	0200	293	CCS	CTD_120_SS	8, 10, 12, 15, 17, 24	UoS-NOC-2393, UoS-NOC-2388, UoS-NOC-2090A UoS-NOC-2399, UoS-NOC-2394, UoS-NOC-2389
25/04/15	1200	301	CCS	CTD_124_SS	4, 9, 12, 15, 18, 24	UoS-NOC-2441, UoS-NOC-2384, UoS-NOC-2400 UoS-NOC-2395, UoS-NOC-2390, UoS-NOC-2385
26/04/15	0646	324	CCS	CTD_128_SS	4, 5, 7, 11, 15, 20	NERC-NOC-710A, NERC-NOC-711A, NERC-NOC-712A NERC-NOC-713A, NERC-NOC-714A, NERC-NOC-715A
27/04/15	0300	327	A	CTD_131_SS	7, 8, 10, 13, 17, 24	UoS-NOC-2015A, UoS-NOC-2039A, UoS-NOC-2051A UoS-NOC-2053A, UoS-NOC-2267A, UoS-NOC-2268A
27/04/15	0803	329	J2	CTD_133_SS	3, 8, 12, 17, 20	UoS-NOC-2269A, UoS-NOC-2270A, UoS-NOC-2271A UoS-NOC-2272A, UoS-NOC-2273A
27/04/15	1200	330	J4	CTD_134_SS	4, 8, 13, 15, 19, 24	UoS-NOC-2274A, UoS-NOC-2275A, UoS-NOC-2276A UoS-NOC-2277A, UoS-NOC-2278A, UoS-NOC-2279A
27/04/15	1704	332	J6	CTD_136_SS	3, 8, 11, 16, 19, 22	UoS-NOC-2280A, UoS-NOC-2281A, UoS-NOC-2282A NERC-NOC-719A, NERC-NOC-720A, NERC-NOC-721A
28/04/15	0815	341	CCS	CTD_140_SS	5, 9, 11, 15, 18, 22	NERC-NOC-723A, NERC-NOC-724A, NERC-NOC-725A NERC-NOC-726A, NERC-NOC-728A, NERC-NOC-896A

Table 5. Discrete DIC/TA samples from the UW system:

Bottle ID	Sample no.	Date	Time (GMT)	Latitude	Longitude
NERC-NOC-1000	1	02/04/15	1105	49 43.69 N	5 51.24 W
NERC-NOC-1018	2	03/04/15	1524	49 24.00 N	8 36.00 W
NERC-NOC-1023	3	04/04/15	1120	49 23.69 N	8 36.75 W
NERC-NOC-1002	4	05/04/15	1354	49 24.28 N	8 35.97W
NERC-NOC-1074	5	06/04/15	1215	48 41.28 N	9 31.19 W
NERC-NOC-1079	6	07/04/15	1200	48 23.97 N	9 54.08 W
NERC-NOC-1071	7	08/04/15	1205	48 23.97 N	9 54.07 W
NERC-NOC-1075A	8	09/04/15	1245	48 29.49 N	9 48.53 W
NERC-NOC-1163A	9	10/04/15	1333	48 58.03 N	9 04.73 W
NERC-NOC-1077A	10	11/04/15	1204	49 23.62 N	8 35.98 W
UoS-NOC-2374	11	12/04/15	1223	49 24.83 N	8 35.36 W
UoS-NOC-2379	12	13/04/15	1202	49 55.18 N	5 29.26 W
UoS-NOC-2339	13	14/04/15	1355	50 07.71 N	7 37.17 W
UoS-NOC-2343	14	15/04/15	1325	49 23.54 N	8 35.60 W
UoS-NOC-2334	15	16/04/15	1217	49 23.94 N	8 36.51 W
UoS-NOC-2338	16	17/04/15	1210	48 12.29 N	10 3.23 W
UoS-NOC-2354	17	18/04/15	1240	48 17.99 N	9 48.02 W
UoS-NOC-2359	18	19/04/15	1210	48 22.68 N	9 36.51 W
UoS-NOC-2333	19	20/04/15	1255	48 24.05 N	8 37.46 W
UoS-NOC-2328	20	21/04/15	1210	49 24.06 N	8 37.40 W
UoS-NOC-2396	21	22/04/15	1422	48 32.05 N	9 56.15 W
UoS-NOC-2391	22	23/04/15	1202	48 37.51 N	9 47.63 W
UoS-NOC-2398	23	24/04/15	1416	48 34.14 N	9 30.55 W
UoS-NOC-2418	24	25/04/15	1257	49 24.56 N	8 35.48 W
NERC-NOC-716A	25	26/04/15	1209	49 52.86 N	7 55.49 W
NERC-NOC-718A	26	27/04/15	1210	50 25.22 N	7 13.60 W
NERC-NOC-905A	27	28/04/15	1204	49 30.54 N	7 44.97 W

3. Underway navigation, sea surface hydrography & meteorology

DY029 NMFSS Ship Systems Computing Cruise Report

Cruise Overview

Shelf Seas Project 1st – 30th April 2015 Celtic Sea	

All times given in this report are in UT.

Technician

Jon Seddon (Science Systems Tech) (nocs_nmfss_shipsys@noc.ac.uk)

Ship scientific computing systems

Data was logged by the Techsas data acquisition system into NetCDF files. The format of the NetCDF files is given in the file Discovery_netcdf_description.docx. The instruments logged are given in DY029_Ship_fitted_information_sheet_DY.docx. Data was additionally logged into the RVS Level-C format, which is described in the NetCDF document.

Summary data was generated using the Near Real Time (NRT) software written for returning data to BODC. The summary data was produced from the NetCDF files logged by Techsas. The true wind speed and direction were calculated by the NRT software. The raw PAR and TIR light sensor voltages were included in the data as were the transmissometer and fluorimeter voltages. The calibration factors for these light and sea surface sensors were taken from the calibration sheets for these instruments and then included in the NRT meta data. The calibration factors were then applied to the data. Therefore for these six instruments two values are included: the uncalibrated voltages and scientific units. Two sets of summary data are included, one at one hour intervals and the other at one minute intervals. The latitude and longitude are spot values at that time stamp. All other values have been averaged over one minute or hour. The time stamp is the time at the start of the averaging period. If a data value is not available or valid at a time period then the data has been replaced by a fill value of 99999.0.

Position and attitude

All GPS and attitude measurement systems were run throughout the cruise. The Seapath system is the vessel's primary GPS system, outputting the position of the ship's common reference point in the gravity meter room. The POSMV is the GPS that is repeated around the vessel and sent out to other

systems. In Techsas and Level-C only attitude data from the POSMV was logged. A Techsas data logging module for the iXSea PHINS and Seapath 330 is under development.

The Techsas module logging ship's gyro data crashed on several occasions causing a gap in the ship's gyro data in the NetCDF and Level-C files. The dates and times of these gaps are given in Table . The cause of the crash is unknown; there are no error messages left in the Techsas log or in the gyro module's debug log. It doesn't crash frequently enough to be able to reproduce the bug. The heading is also logged by the POSMV heading module and also by a separate gyro module and there are no gaps in this POSMV heading data.

Table 6. Date and times of the gaps in the ship's gyro data

Date	Times
Tuesday 7th April	02:58 to 07:41
Tuesday 7th April	08:32 to 08:46
Thursday 9th April	11:58 to 12:40
Wednesday 15th April	03:10 to 06:59
Tuesday 21st April	15:58 to 16:26
Thursday 23rd April	10:45 to 12:06
Friday 24th April	04:40 to 07:04

Meteorology and Sea Surface monitoring package

The Surfmet system was run throughout the cruise. Please see the separate BODC information sheet DY029_Surfmet_sensor_information_sheet.docx for details of the sensors used and the calibrations that need to be applied. The calibration sheets are included in the directory Ship_Systems\Met\SURFMET\calibrations. The non-toxic water supply was active from 16:10 on 1st April until 11:00 on 29th April.

There was air trapped in the underway water sampling system from 16:56 on 1st April until 06:51 on 2nd April and so the salinity/conductivity, housing temperature, fluorimeter and transmissometer data for this period should be ignored.

From 6th until 10th April and again on 12th April there were birds resting on the meteorological platform. There are numerous dips in the TIR and PAR light sensor data on these days when the birds were covering one or more of the light sensors.

The underway water sampling system was off from 05:30 until 07:20 on the approach to Falmouth for the mid-cruise boat transfer on Monday April 13th. The under-way system was turned back on at this point but was stopped again shortly afterwards to clean the fluorimeter and transmissometer. It took a while to clear air from the system after the cleaning, but the data became stable again at 10:44.

On Thursday 16th April at 12:16 the SBE38 remote temperature jumped by about 0.2°C and became noisy. It was believed that something was caught on the SBE38 probe in the non-toxic supply. At 14:58 the non-toxic supply was shut off to all instruments. The SBE38 was removed and cleaned but was damaged during this process and was outputting values of around 2000°C when the non-toxic supply was restarted. The non-toxic supply was then stopped and the SBE38 was swapped for the spare. The non-toxic supply was restored to all instruments at 15:20.

At 07:02 on Monday 20th April the temperature sensor in the SBE45 TSG increased in noise, probably due to something becoming stuck on the temperature probe. Several attempts were unsuccessfully made to clean and back flush the SBE45. Eventually the spare SBE45 was fitted but despite having been calibrated at the manufacturer, it was found to have a faulty conductivity sensor. The original SBE45 had to be reinstalled at 19:46 on the same day. The data from all of the underway water sampling instruments should be treated with caution during this period.

By the time the SBE45 was reinstalled on 20th April some of the contamination had been cleared from the sensor The typical peak-to-peak noise in a SBE45's temperature sensor is 8.0×10^{-4} °C. In the water conditions at the start of the cruise the SBE45 had a typical peak-to-peak noise of 8.0×10^{-3} °C. After being reinstalled the peak-to-peak noise was around 1.7×10^{-2} °C. The conductivity was not affected, but the calculated salinity is. The noise is of a much higher frequency than the temperature data. A simple 9-point moving average filter was applied to the housing temperature data and the salinity recalculated for one day. Figure shows the raw salinity and the salinity calculated from the filtered temperature data for 21st April. The filter was not optimised and nine points was chosen to show that the noise from the temperature sensor can be removed from the calculated salinity. A moving average filter was chosen for its each of implementation. It has a poor suppression of higher frequencies. A discrete time low-pass filter has a much improved suppression of higher frequencies and could be used to recover the underlying temperatures and hence salinities from this noisy data.

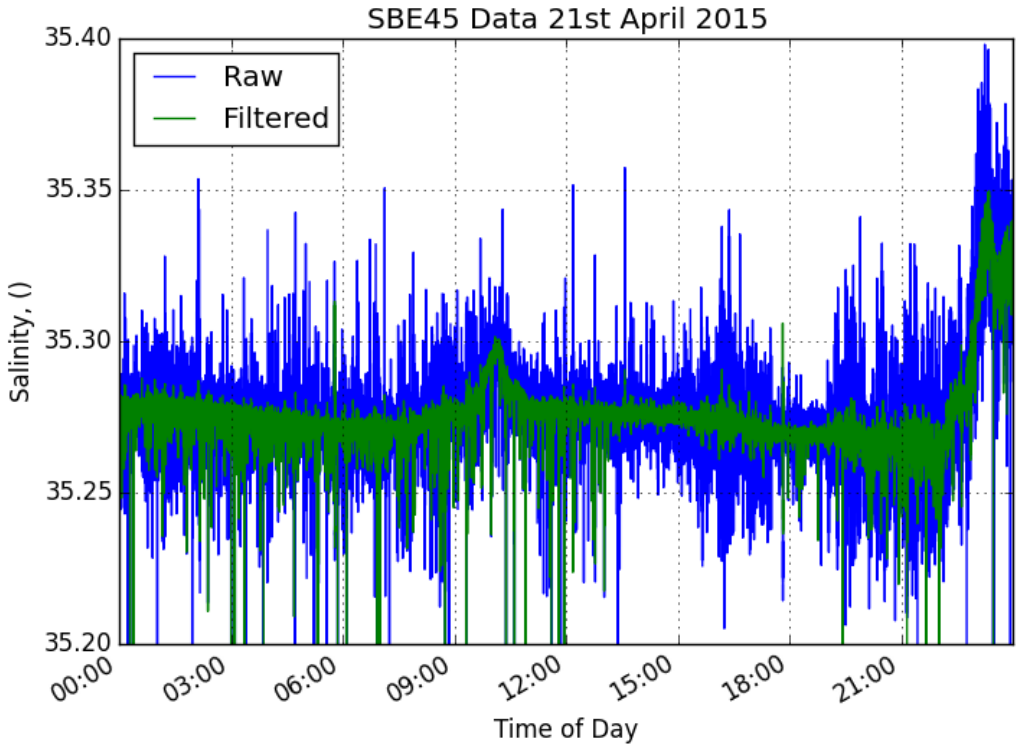


Figure 3. Raw and 9 point moving average filtered salinity data

There was a drop in flow rate to the underway water sampling system between 07:55 and 08:33 on Thursday 23rd April and again between 22:22 on Thursday 23rd and 07:09 on Friday 24th April. The underway water sampling data should be treated with caution between these times.

The fluorimeter and transmissometer recorded values of 999.999 between 15:01 and 15:20 on Friday 24th April due to a bug in the Surfmet software that cannot be found.

There were several spikes in all channels of the data on several occasions on 24th to 25th April. Surfmet was stopped and rebooted between 15:41 and 15:45 on Saturday 25th April to see if this fixed the problem.

Kongsberg EA640 10 & 12 kHZ single beam echo sounder

The EA640 single beam echo sounder was run throughout the cruise. The 10kHz transducer was used for the whole of the cruise. The EA640 was used with a constant sound velocity of 1500 ms^{-1} throughout the water column to allow it to be corrected for sound velocity in post processing. As well as depths being logged to the Techsas and Level-C data loggers, files were saved as .BMP images and in raw Kongsberg format. The EA640 was initially synchronised to the K-Sync synchronisation system until 6th April. At 13:18 on this day the K-Sync stopped the EA640 pinging because its ping rate did not match the EM122's. The EA640 was then set to ping freely. Its 10 kHz channel was found

to be relatively free of interference from the EM122 and so it was left unsynchronised for the rest of the cruise.

The EA640 was stopped between 13:40 and 14:11 on Friday 10th April and again between 09:03 and 10:10 on Wednesday 15th April. On these occasions new software was being installed and tested to attempt to fix the problems with the 12 kHz channel of the EA640. Unfortunately the new software did not cure the problems and so the 10 kHz channel was used throughout the cruise.

Kongsberg EM122 and EM710 Multi-beam echo sounders

Either the EM122 deep water multi-beam system or the EM710 shallow water system was run throughout the cruise. The EM710 was run from the start of the cruise. On 6th April it was noticed that its outer beams were very noisy. The EM122 was then additionally started and run throughout the rest of the cruise, producing cleaner data than the EM710.

During fault finding on the EM710 it was found that the transmit transducer had its orientation entered incorrectly in the SIS software's Installation Parameters. It was falsely set to a starboard orientation. At 13:26 on Friday 10th April the Transmit orientation was correctly set to port. This did not improve the quality of the data from the EM710 and discussions with Kongsberg continued. The effect of the incorrect orientation in the EM710 data is not known. The problem was not apparent in the very clean data from the start of the cruise. The data should be examined in a processing package such as Caris and compared with the EM122 data.

The Sound Velocity Profiles section of this report describes the sound velocity profiles used in both multi-beam systems.

Sound Velocity Profiles

The sound velocity profiles used in the EM710 and EM122 multi-beam systems are shown in Table . While compiling this report it was noted that the profile recorded by the Valeport Midas SVP serial number 22356 (calibration sheet with the Valeport data on the data disk) had invalid times and depths that went to 256 m when the water depth was only 145 m. If the bathymetry data recorded between 17:28 on 6th April and 18:27 on 7th April is being used in any way it should be reprocessed in a package such as Caris with a valid sound velocity profile derived from CTD data. After a service the Valeport was successfully deployed measuring two profiles at the end of the cruise.

75 kHz and 150 kHz hull mounted ADCP systems

Both the 75 kHz and 150 kHz ADCP systems were run during the cruise. The raw data files and configurations are included on the data disk. They were set-up by Jo Hopkins from NOC Liverpool. They were run synchronised to the K-Sync system except for occasional periods in deeper water off the shelf when the 150 kHz system refused to run with the K-Sync and was left free running. The 75

kHz system was always synchronised to the K-Sync. When the EM710 multi-beam system was running the 75 kHz ADCP and EM710 were allowed to ping on alternate periods to prevent them from interfering with each other. When the EM710 was not running then the 75 kHz was set to ping on every period.

The systems were left in bottom tracking mode even when working in deeper water off the shelf When the ADCP data was processed pings were being rejected from these periods when bottom tracking was enabled. Bottom tracking was disabled for the third period off the shelf between 17:36 on 21st April and 08:58 on 24th April. The reason for this rejection of data in the processing was not ascertained during the cruise. Data was continuously recorded during these periods in deep water and so all of the data should be in the .ENR, .N1R and .N2R raw data files. An attempt was made to reprocess the deep water data in VMDAS but there was no option to reprocess with bottom tracking disabled. The .VMO configuration files were compared from a period when bottom tracking was enabled against a period when it was disabled to see if editing this would allow the data to be reprocessed. No differences were found between these .VMO files apart from the deployment number and the name of the configuration file.

The ADCPs were looked after by Charlotte Williams from NOC Liverpool and her report should be consulted for the logsheets that were kept of the ADCP operation.

Gravity Meter

No gravity meter was installed on the vessel for the cruise. The NetCDF and Level-C gravity files are empty streams.

WAMOS Wave Radar

The WAMOS wave radar was run throughout the cruise. All data was logged and is included on the data disk, but a summary of its output is given in the PARA*.ems files.

CTD, LADCP, Salinometer and Moorings

The CTD and lowered ADCP data is included in the specific_equipment/CTD/ directory on the data disk.

The data from the ADCP moorings downloaded by NOC Southampton staff is in specific_equipment/MOORINGS/.

The data from the wire walker and the t-chain mooring downloaded by NOC Liverpool staff is in third_party/NOCL_moorings/ on the data disk.

For these data items please see the separate cruise reports written by the staff looking after each of these items of equipment.

Table 7. Sound velocity profiles used in the multi-beam systems

Position	Time at Bottom	NMF CTD Cast No.	Processed File	Time Applied to SIS
Unknown	Unknown	-	Unknown from previous cruise	From start
49° 31.61' N 007° 08.94' W	02/04/2015 17:27	001	CTD_Derived/20150402_DY029_CTD001_sorted.asvp	03/04/2015 10:10
49° 23.87' N 008° 36.24' W	04/04/2015 12:55	008	SVP_Probe/22356/20150406/20150406_Fe08_sorted_thinned.asvp	06/04/2015 17:28
48° 23.97' N 009° 54.08' W	07/04/2015 12:56	020	CTD_Derived/20150407_DY029_CTD020_sorted_thinned.asvp	07/04/2015 18:27
49° 24.58' N 008° 35.16' W	15/04/2015 02:09	064	CTD_Derived/20150415_DY029_CTD064_sorted_thinned.asvp	15/04/2015 08:16
49° 24.07' N 008° 37.29' W	21/04/2015 13:27	102	CTD_Derived/ 20150421_DY029_CTD102_sorted_thinned.asvp	21/04/2015 15:37
49° 24.50' N 008° 35.23' W	25/04/2015 16:27	125	SVP_Probe/22356/20150425/20150425_DY029_CTD125_sorted_thinned.asvp	25/04/2015 20:47
50° 25.20' N 007° 13.66' W	27/04/2015 12:26	134	SVP_Probe/22356/20150427/20150427_DY029_CTD134_sorted_thinned.asvp	27/04/2015 13:44

4. CTD processing

Charlotte Williams (National Oceanography Centre - Liverpool)

This report documents the sequential processing carried out on CTD profiles from cruise DY029, including bin averaging, despiking and calibrations. A total of 140 CTD casts (leg 1: 1-52, leg 2: 53-140) with the stainless steel (94) and titanium (46) CTDs were completed. See technical reports for sensor serial numbers and channels. The cruise was split into two halves, 1 and 2. Casts 1-52 were conducted on leg 1. Casts 53-140 on leg 2.

The secondary salinity sensor displayed problems from CTD017SS and was changed before CTD020SS and used onwards.

CTD076SS suffered communication failure halfway through and was split into to 2 raw files:

CTD076SS – Niskins 1 -7 fired

CTD076SSA – Niskin bottles 8 – 19, 23 – 24 fired, but are labelled as Niskins 1-14 in the raw data files provided by NMF. In the processed data files these have been corrected (.ROS, .BTL. CNV).

*Note that data for Niskins 20, 21, 22 are missing from the raw data file as they were not recorded for unknown reason.

A number of CTD casts had technical issues, these are listed here:

CTD015T (aborted); CTD019SS (aborted); CTD055SS (bottomed); CTD095SS (aborted)

Raw data files:

The following raw data files were generated for both stainless steel and titanium:

DY029_001.bl (a record of bottle firing locations)

DY029_001.hdr (header file)

DY029_001.hex (raw data file)

DY029_001.con (configuration file)

Where _001 is the CTD cast number (not STNNBR)

SBE Data Processing steps

The following processing routines were run in the SBEDataProcessing software (Seasave Version 7.23.2):

1. **DatCnv:** A conversion routine to read in the raw CTD data file (.hex) containing data in engineering units output by the CTD hardware. Calibrations as appropriate through the instrument configuration file (.CON) are applied.

Data Setup options were set to the following:

Process scans to end of file: yes
Scans to skip: 0
Output format: ascii
Convert data from: upcast & downcast
Create file types: both bottle and data
Source of scan range data: bottle log .BL file
Scan range offset: -2.5 seconds
Scan range duration: 5 seconds for
Merge separate header file: No

Apply oxygen hysteresis correction: yes (2 second window)

Apply oxygen Tau correction: yes

Selected output variables:

- Time [seconds]
- Pressure [db]
- Temperature [ITS-90, °C] and Temperature 2 [ITS-90, °C], referring to primary and secondary sensors)
- Conductivity and Conductivity 2 [S/m]
- Salinity and salinity 2 [PSU, PSS-78]
- Oxygen raw, SBE 43 [V]
- Oxygen, SBE 43 [µmol/l]
- Beam attenuation [1/m]
- Fluorescence [µg/l]
- PAR/irradiance, downwelling [W m^2]
- Turbidity [m^{-1} sr^{-1}]
- Altimeter [m]
- Voltage channel 2: Downwelling Irradiance sensor (DWIRR)
- Voltage channel 3: Upwelling Irradiance sensor (UWIRR)
- Voltage channel 4: Altimeter
- Voltage channel 5: Light scattering Wetlabs BBRTD
- Voltage channel 6: Transmissometer

- Voltage channel 7: Fluorometer

2. **Bottle Summary** was run to create a .BTL file containing the average, standard deviation, min and max values at bottle firings. .ROS files were placed in the same directory as the .bl files during this routine to ensure that bottle rosette position was captured in the .btl file.

The output was saved to DY029_XXX.btl for each CTD cast, and a summary excel spreadsheet of the bottle data was created as the cruise progressed as an uncalibrated reference.

3. **Wild Edit:** Removal of pressure spikes

   Standard deviations for pass 1: 2
   Standard deviations for pass 2: 20
   Scans per black: 100
   Keep data within this distance of the mean: 0
   Exclude scans marked as bad: yes

4. **Filter:** Run on the pressure channel to smooth out high frequency data

   Low pass filter time B: 0.15 seconds

5. **AlignCTD:** Based on examination of different casts **a 2.5 second** advance was chosen for alignment of the oxygen sensor. This alignment is a function of the temperature and the state of the oxygen sensor membrane. The colder (deeper) the water the greater the advance needed. The above alignments were chosen as a compromise between results in deep (cold) and shallow (warmer) waters.

The deck unit was set to advance both the primary and secondary conductivity channels by + 1.75 scans (equivalent to 0.073 seconds at 24 Hz), no further adjustment was applied.

6. **CellTM:** Removes the effect of thermal inertia on the conductivity cells. Alpha = 0.03 (thermal anomaly amplitude) and 1/beta = 7 (thermal anomaly time constant) for both cells.

Output of steps 1-6 above saved in DY029_001.cnv (24 Hz resolution)

7. **Derive:** Variables selected are

Oxygen SBE43 [µmol/l]

Oxygen Tau correction: yes (2 second window)

Output saved to DY029_001_derive.cnv (24 Hz resolution)

8. **BinAverage:** Average into 2Hz (0.5 seconds),

   Exclude bad scans: yes

   Scans to skip over: 0

   Casts to process: Up and down

9. **Strip:** Remove salinity and oxygen channels from the 2 Hz file that were originally created by DatCnv, but then later regenerated by Derive.

   Output saved to DY029_001_derive_2Hz.cnv

Matlab processing steps

The following processing steps were performed in MATLAB:

(1) Create a .mat file of meta data extracted from the cruise Event Log with the following variables:

CRUISECODE e.g. DY029
STNNBR (as per BODC data management guidance for the Shelf Sea Biogeochemistry programme)
DATE and TIME of the cast at the START of the profile
LAT and LON when the CTD was at the bottom of the profile
DEPTH (nominal water depth in metres from echo sounder)
CAST (CTD cast number, e.g. 001)
File created: DY029_metadata.mat

(2) Extract data from 2Hz averaged files (e.g. DY029_001_derive_2Hz.cnv), merge with metadata and save into a matlab structure for each cast. Each file (e.g. DY029_001_derive_2Hz.mat) contains the following un-calibrated channels.

CTD001 =

CRUISE: 'DY029'

CAST: 1

STNNBR: 1

DATE: '02/04/2015'

TIME: '17:13'

LAT: 49.5268
LON: -7.149
DEPTH: 127 [m]
CTDtime: [3658x1 double] [seconds]
CTDpres: [3658x1 double] [db]
CTDtemp1: [3658x1 double] [°C]
CTDtemp2: [3658x1 double] [°C]
CTDcond1: [3658x1 double] [S/m]
CTDcond2: [3658x1 double] [S/m]
CTDoxy_raw: [3658x1 double] [V]
CTDatt: [3658x1 double] [1/m]
CTDfluor: [3658x1 double] [µg/l]
CTDpar: [3658x1 double] [Wm^2]
CTDturb: [3658x1 double] [m^{-1} Sr^{-1}]
CTDalt: [3658x1 double] [m]
CTDpar_dn_raw: [3658x1 double] [V]
CTDpar_up_raw: [3658x1 double] [V]
CTDalt_raw: [3658x1 double] [V]
CTDturb_raw: [3658x1 double] [V]
CTDatt_raw: [3658x1 double] [V]
CTDfluor_raw: [3658x1 double] [V]
CTDsal1: [3658x1 double] [PSU]
CTDsal2: [3658x1 double] [PSU]
CTDoxy_umoll: [3658x1 double] [µmol/l]
CTDflag: [3658x1 double]

(3) Extract data from 24Hz files (e.g. DY029_CTD001_derive.cnv), merge with metadata and save into a matlab structure for each cast. Each file (e.g. DY029_001_derive.mat) contains the following un-calibrated channels.

CTD001 =
CRUISE: 'DY029'
CAST: 1
STNNBR: 1
DATE: '02/04/2015'
TIME: '17:13'
LAT: 49.5268
LON: -7.149
DEPTH: 127 [m]

CTDtime: [43896x1 double]	[seconds]
CTDpres: [43896x1 double]	[db]
CTDtemp1: [43896x1 double]	[°C]
CTDtemp2: [43896x1 double]	[°C]
CTDcond1: [43896x1 double]	[S/m]
CTDcond2: [43896x1 double]	[S/m]
CTDsal1_1: [43896x1 double]	[PSU]
CTDsal2_1: [43896x1 double]	[PSU]
CTDoxy_raw: [43896x1 double]	[V]
CTD_oxy_umoll_1: [43896x1 double]	[µmol/l]
CTDatt: [43896x1 double]	[1/m]
CTDfluor: [43896x1 double]	[µg/l]
CTDpar: [43896x1 double]	[Wm^2]
CTDturb: [43896x1 double]	[m^{-1} Sr^{-1}]
CTDalt: [43896x1 double]	[m]
CTDpar_dn_raw: [43896x1 double]	[V]
CTDpar_up_raw: [43896x1 double]	[V]
CTDalt_raw: [43896x1 double]	[V]
CTDturb_raw: [43896x1 double]	[V]
CTDatt_raw: [43896x1 double]	[V]
CTDfluor_raw: [43896x1 double]	[V]
CTDsal1: [43896x1 double]	[PSU]
CTDsal2: [43896x1 double]	[PSU]
CTDoxy_umoll: [43896x1 double]	[µmol/l]
CTDflag: [43896x1 double]	

Note that '_1' for the first instances of oxygen in this file are variables before re-derivation in the SeaBird Processing routines.

As observed in an earlier cruise (DY018, DY026), inspection of the turbidity channel (CTDturb) and comparison to the original raw voltage (CTDturb_raw) revealed a potential bug in the SeaBird DatCnv conversion module. As previously discussed with SeaBird, the converted ECO-BB output was being reported to a fixed precision. This is demonstrated below (left) where the raw voltage channel (blue) is compared to the SeaBird DatCnv output (green). Direct conversion using the scale factor (SF) and dark counts (DC) supplied in the manufacturer's calibration appears to rectify this problem (right plot). We therefore replace the original turbidity channel in the .cnv files with a corrected version using:

CTDturb = CTDturb_raw .* SF - (SF x DC);

Where the scale factor (SF) for this sensor = 0.002365

and the dark count (DC) = 0.061000

By applying this correcting to the raw turbidity sensor output we appear to retrieve the original resolution (Fig. 2b).

Two CTD casts had erroneous turbidity voltage outputs and thus turbidity was not calculated from the raw voltage either. These were CTD009 (event 56) and CTD034 (event 162).

(4) Manual identification of the surface soak (the time taken while waiting for pumps to turn on) and the end of the downcast using the 2Hz files. Times to crop were saved to DY029_stainless_castcrop_times.mat and DY029_titanium_castcrop_times.mat

CAST: [14x6 char]
STNNBR: [14x1 double]
CTDstart: [14x1 double] [seconds]
CTDstop: [14x1 double] [seconds]

This was then used to crop both the 2Hz and 24Hz files and output (i.e. just the downcast recordings) saved to DY029_CTD001_derive_2Hz_cropped.mat and DY029_CTD001_derive_cropped.mat respectively.

(5) De-spiking of downcast 24 Hz data. The salinity, conductivity, temperature, oxygen, attenuation, turbidity and fluorescence channels were all de-spiked. The worst spikes were identified using an automated routine (similar to WildEdit) where the data was scanned twice and points falling outside a threshold of *nstd* x standard deviations from the mean within a set window size were removed (turned into NaNs).

Table 8. Window size (#scans) and number of standard deviations from the mean (nstd) used for each channel.

Channel	Pass 1 window	Pass 1 nstd	Pass 2 window	Pass 2 nstd
Temperature, conductivity, fluorescence	100	3	200	3
Salinity, turbidity	200	2	200	3
Oxygen	100	2	200	3

Auto-despiking saved to DY029_CTD001_derived_cropped_autospike.mat

Manual de-spiking was then performed to remove larger sections of bad data or any remaining isolated spikes in each channel.

Large ‘spikes’ were regularly observed in the CT sensors lasting a few seconds, predominantly in the thermocline. This is a persistent problem in shallow water with strong property gradients (e.g. see for example DY018, D352, D376, DY026); particularly where a large CTD package carrying large volume

bottles is used. The spikes coincide with a decrease in the decent rate of the CTD package and are therefore likely associated with inefficient flushing of water around the sensors. It is caused by the pitch and roll of the boat, so is accentuated in rough weather. As the decent rate of the CTD package slows on the downcast 'old' water (from above and therefore typically warmer) is pushed back passed the sensors. As the decent rate increases again 'new' water is flushed past the sensors. A similar problem can occur if the veer rate on the CTD winch varies.

The largest and most significant warm anomalies identified in the primary CT sensors were removed from all variables (incl. turbidity, oxygen, chlorophyll and attenuation since these sensors would also be sampling 'old' water during these periods). This was at times up to 5 m of the profile. However, in many cases oxygen, chlorophyll, turbidity and attenuation profiles that had valued nulled from selected spikes were revisited and identified manually. This is because misalignment of sensors to the CT sensors on the CTD package can be up to 1m and therefore automatically omitting data based on CT spikes can potentially be incorrect. Anomalies identified in the secondary sensors were only removed from the secondary temperature, salinity and conductivity channels. The impact of smaller scale anomalies that were not removed is mostly minimised during the averaging processes, but care should be taken when interpreting smaller scale features, particularly through the thermocline. The casts are more than good enough for looking at large scale trends and anomalies but should probably not be used for Thorpe scale analysis and interpretation of fine scale structures. To achieve this in a shelf sea environment free fall profiling techniques are more suitable.

Individual, isolated spikes within each channel were only removed (NaN'd) from that particular variable.

Output saved to DY029_CTD001_derived_cropped_autospike_manualspike.mat

Additional channels added into this file:

Vectors of 0's and 1's indicating data that has been NaN'd (= 1). Outputs depend on channels loaded and viewed so each column may have variable meaning and is saved for processing archive purposes only.

INSERT

(6) Average 24Hz (cropped and de-spiked data) into 1 db. Linear interpolation used when no data available for averaging.

Files for each cast were created: DY029_001_1db_dn.mat

(7) Application of calibrations to salinity, chlorophyll and oxygen in 1db downcasts. Calibrated files saved to DY029_001_1db_dn_calib.mat.

Sigma theta (σ_θ) (relative to 0 pressure) is also calculated at this stage using the matlab function sw_pden-1000 from the SEAWATER toolkit.

INSERT

The calibrations were also applied to the 24 Hz data (cropped and de-spiked) and output to .mat files DY029_001_derive_cropped_autospike_manualspike_calib.mat containing the same variables as above.

(8) Application of salinity, chlorophyll and oxygen calibrations to bottle firing data. A new file, DY029_stainless_btl_calib.mat/ DY029_titanium_btl_calib.mat, with variables CTDsal1_cal, CTDsal2_cal, CTDoxy_umoll_cal and CTDfluor_cal was created.

Calibrations

Salinity

A total of 263 salinity samples from the stainless and titanium CTDs were taken and used for calibration.

There was a primary and secondary sensor on both the stainless and titanium CTD. The secondary sensor (Sal2) on the stainless steel CTD frame showed problems on CTD018SS, after investigation the sensor was changed ready for CTD020SS. The Sal2 readings from CTD017SS and CTD018SS were clear outliers (see below) when performing calibration and thus have been removed when calculating the calibration for Sal2. There are two separate calibrations applied to Sal2, pre CTD020ss and post CTD020SS to account for the changing of the sensor.

STAINLESS CTD

143 stainless bottle salinities were taken.

Using all samples the mean and standard deviation of residuals from the stainless primary and secondary sensors were:

Mean difference between BOTsal and SAL1 = 0.0026811 (std = 0.0050375)
Mean difference between BOTsal and SAL2 (up to CTD019SS)= -2.7486 (std = 7.3602)
Mean difference between BOTsal and SAL2(after CTD019SS) = -0.92063 (std = 4.4306)

After removal of outliers where the difference between Autosal and CTD values was greater than 1standard deviations the mean ± standard deviations for the stainless primary and secondary sensors was reduced to:

(After removal of outliers (+/- 2 stds))
Mean difference between BOTsal and SAL1 = 0.0022377 (std = 0.0023854)
Mean difference between BOTsal and SAL2(up to CTD019SS) = 0.0029619 (std = 0.0076094)
Mean difference between BOTsal and SAL2(after CTD019SS) = 0.0029635 (std = 0.0049118)
After calibrations applied to both stainless sensors:
Mean difference between BOTsal and SAL1 = -6.848e-15 (std = 0.0023332)
Mean difference between BOTsal and SAL2(up to CTD019SS) = 4.737e-15 (std = 0.0075398)
Mean difference between BOTsal and SAL2 (after CTD019SS) = 1.0269e-14 (std = 0.0048638)

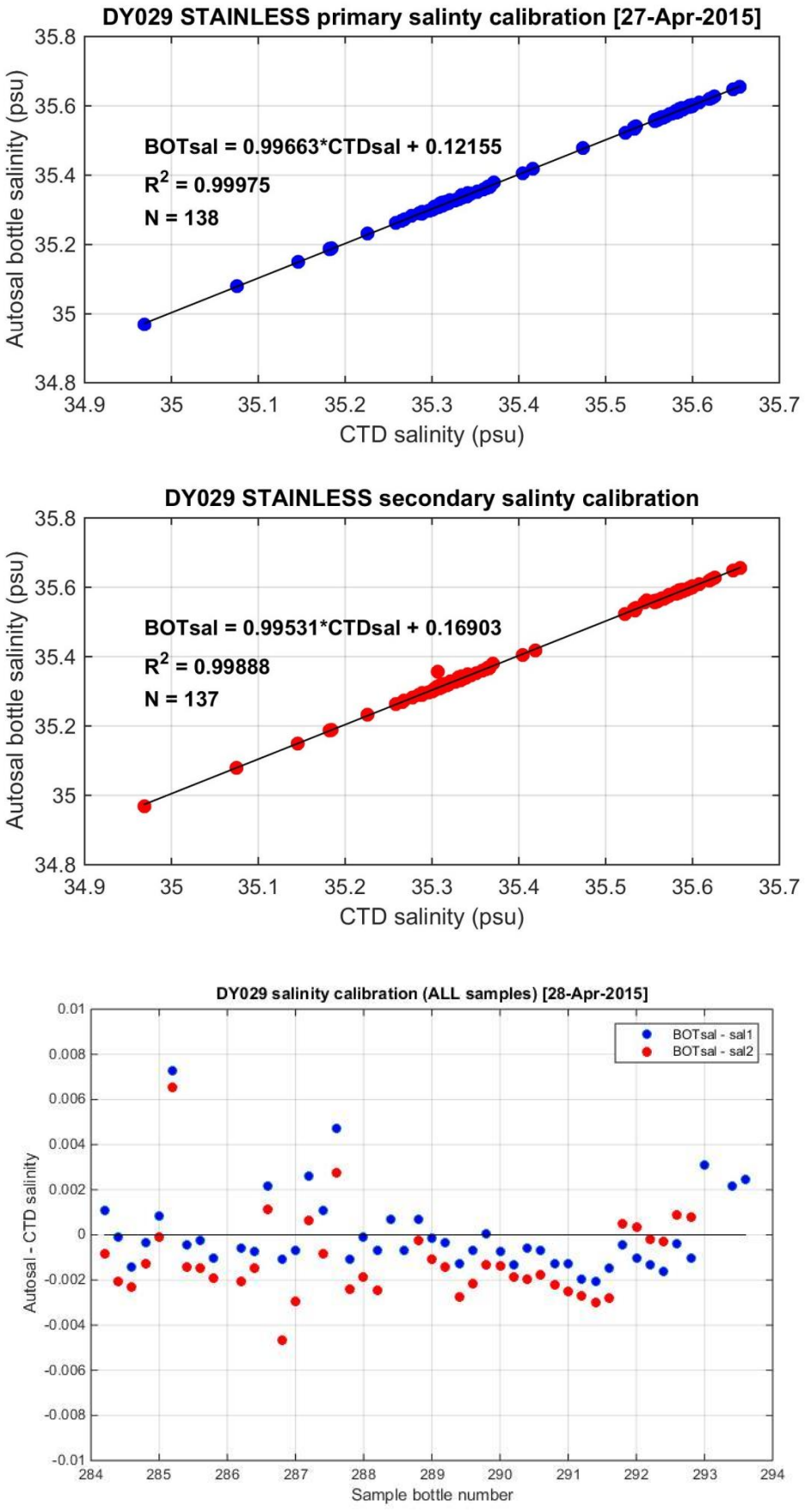


Figure 4. Salinity calibration for the Stainless Steel CTD.

TITANIUM CTD

120 titanium bottle salinities were taken.

Using all samples the mean and standard deviation of residuals from the titanium primary and secondary sensors were:

Mean difference between BOTsal and SAL1 = 0.0027692 (std = 0.012453)
Mean difference between BOTsal and SAL2 = 0.0030375 (std = 0.012359)
After removal of outliers (+/- 2 stds):
Mean difference between BOTsal and SAL1 = 0.0039915 (std = 0.0043402)
Mean difference between BOTsal and SAL2 = 0.0042542 (std = 0.0042027)

After calibrations:

Mean difference between BOTsal and SAL1 = 5.6603e-15 (std = 0.0043254)
Mean difference between BOTsal and SAL2 = -1.8245e-14 (std = 0.0041968)

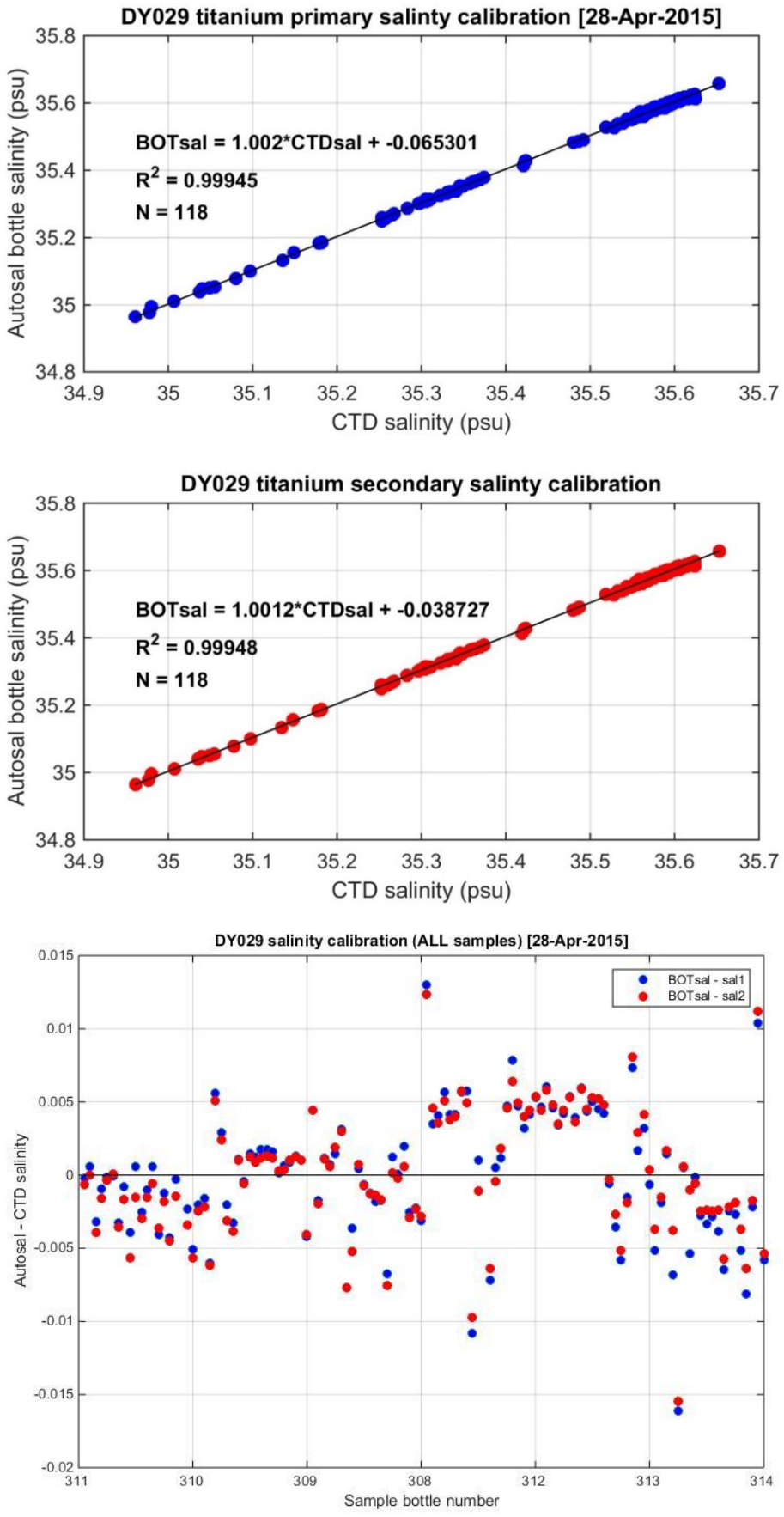


Figure 5. Salinity calibration for the Titanium CTD.

Chlorophyll fluorescence

There were 223 discrete chlorophyll samples taken from the stainless and the titanium CTD.

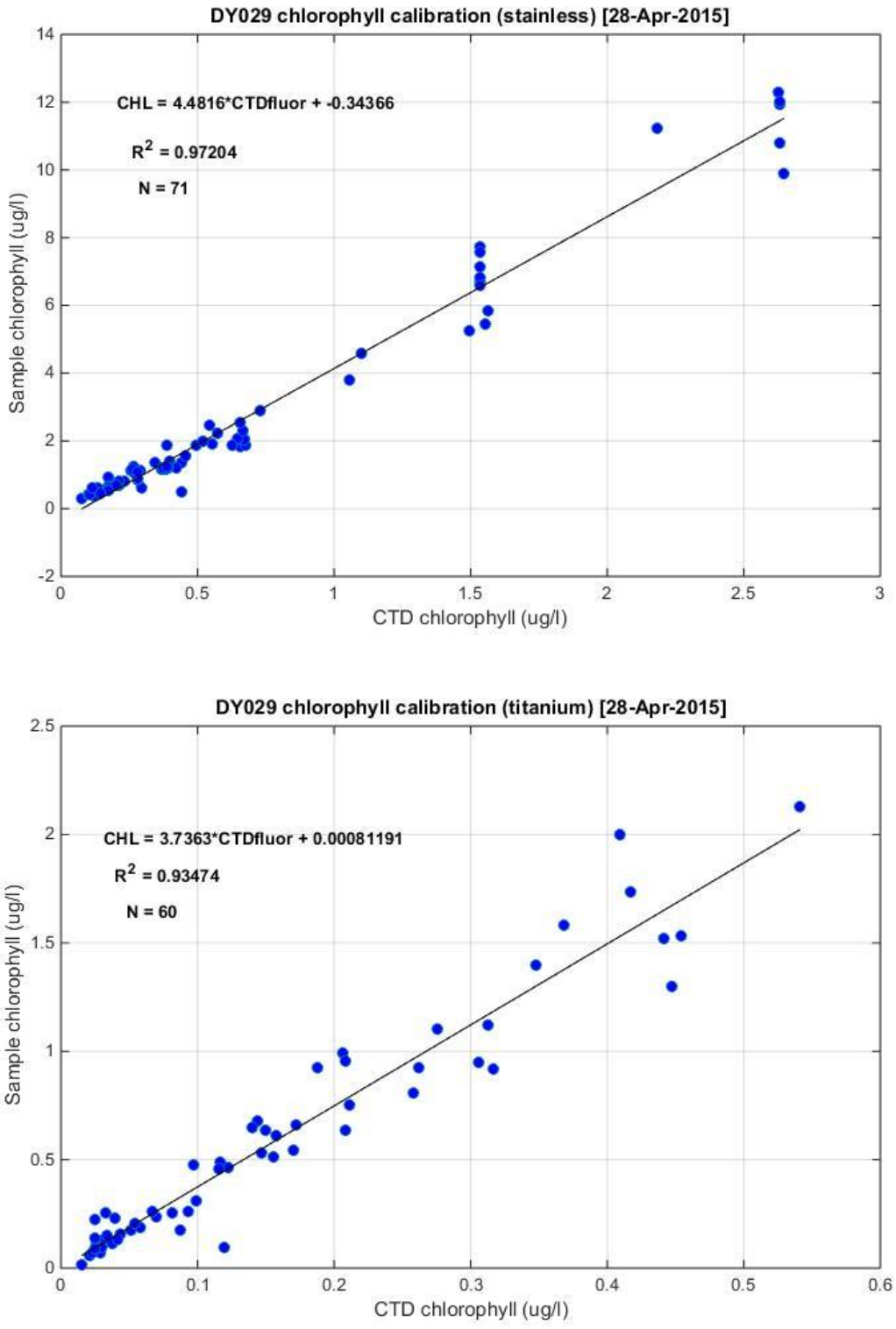


Figure 6. Fluorescence calibrations for both the Stainless Steel and Titanium CTDs

Oxygen

There were 186 discrete samples taken from the stainless and the titanium CTD for oxygen analysis using the Winkler method. The calibrations that have been applied to the data are as follows:

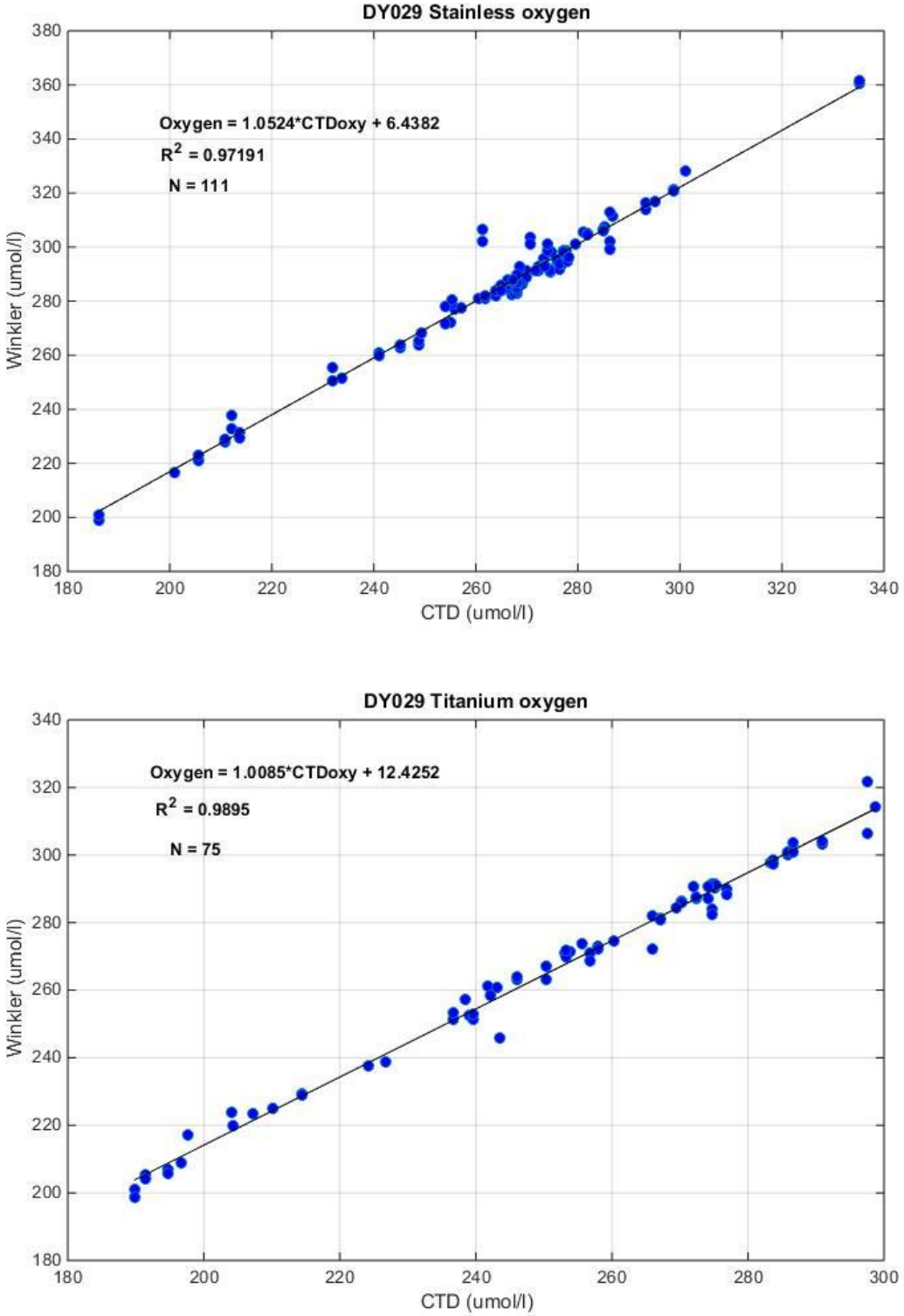


Figure 7. Oxygen calibration for the Stainless Steel and Titanium CTDs

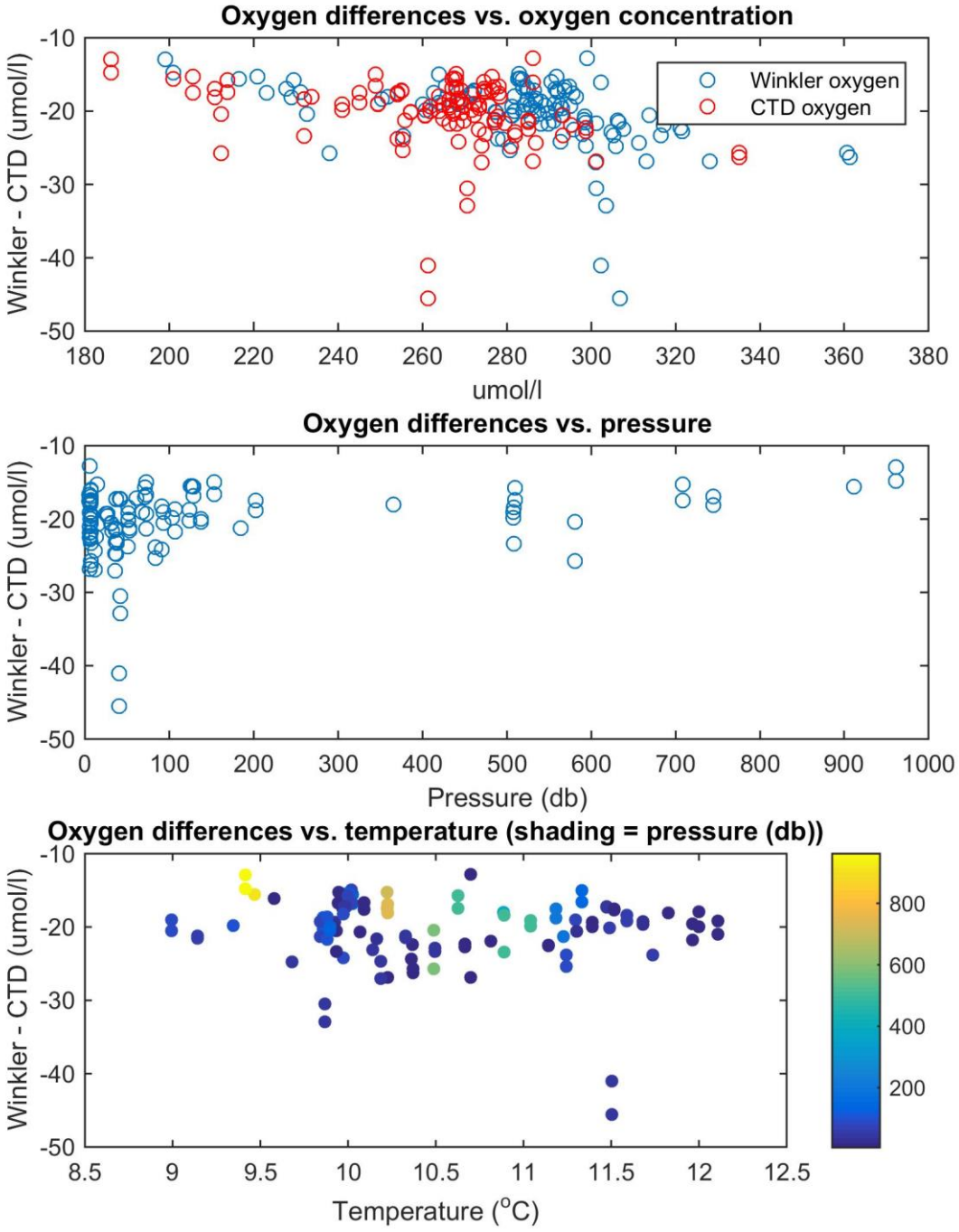


Figure 8. Anomoly analysis for the oxygen calibration for the Stainless Steel and Titanium CTDs

5. Vessel Mounted ADCP (VMADCP)

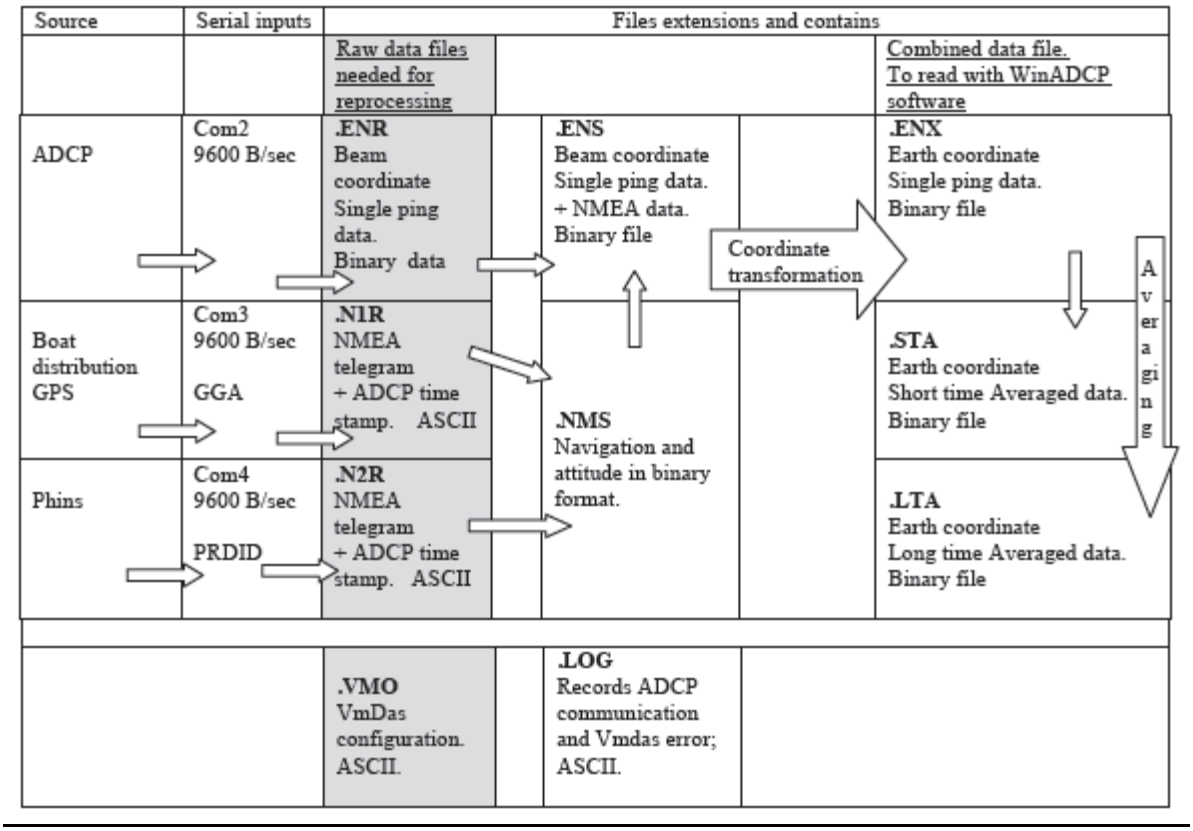
Charlotte Williams (National Oceanography Centre - Liverpool)

The RRS Discovery is fitted with RD Instruments 75 kHz and 150 kHz Ocean Surveyor ADCPs. The following table, taken from the Dock Side and Sea Acceptance Test report (June 3-5, 2013), details the serial numbers, computer operating systems and software versions installed.

SYSTEM / SHIP INFORMATION		
Vessel Length	99.70 m	
Vessel Weight		
System Frequency	**150 Khz**	**75 kHz**
XDCR Serial Number	SN 648108	SN 640594
Chassis Serial Number	SN 28550	SN 28548
Cable Length	20+30 m	20+30 m
ADCP Electronics Rack or Table mounted	Rack	Rack
Transducer Mounting Angle (Bow, 45 starboard …)	-45	-45°
Transducer Mounting Type (Acoustic Window, Flush, Keel, Gondola …)	Hull + windows	Hull + windows
PC System type		
Operating System	Windows 7 64 bits	Windows 7 64 bits
Computer Ram	6 GB	6 GB
Comports available on Computer	COM2, COM 3, COM 4, COM5	COM2, COM 3, COM 4, COM5
Network Card	Yes	Yes
Hard Drive Space		230 GB
RDI Programs Installed	VMDAS 1.46, BBTalk 3.08, WinADCP 1.14	VMDAS 1.46, BBTalk 3.08, WinADCP 1.14

The instruments are mounted 6.6 m below the ships waterline and beam 3 (Y-axis) is rotated -45° (anti-clockwise) relative to the ships centreline. A nominal rotation of -45° (misalignment angle) is therefore necessary to remove the ships velocity from the data. Fine tuning of this misalignment is performed in the Matlab post-processing routines.

The VmDas computer setup and file structure recorded by each OS ADCP was as shown in the schematic below.



There are two navigation (NAV) feeds into the VMDas software. NMEA1 stream is from the Applainix PosMV GPS and contains navigation (heading) information. This is written to the .N1R files. NMEA2 stream is from the IXSEA PHINS and contains both navigation (heading) and attitude (pitch and roll) information.

N1R contents (from PosMV)

$INZDA : Date and time information

$INGGA : Time, position and fix related to the GPS receiver (PosMV)

$INVTG : Track made good and Ground speed (relative to the ground)

$INRMC : Date, time, position speed and tracks made good, magnetic variation

$GPGST : GPS pseudorange noise statistics

$PADCP : Time stamp from the VmDas software every time the ADCP pings

N2R contents (from PHINS)

$PRDID : Ships heading, pitch and roll from PHINS

$PADCP : Time stamp from the VmDas software every time the ADCP pings

The Matlab post processing uses the $PRDID string in the .N2R files and the binary .ENX file from VMDAS that contains single ping, bin mapped, earth coordinate data (transformed within the software using the heading and tilt sources specified).

DY029 OS150 setup

The OS150 was reset every 24 hours apart from when we were in deep water and a different config file (see 3 below) was used or we experienced problems with K-sync, in which case we would leave the ADCP for slightly longer (~48 hours) and then reset.

A number of OS150 command files provided by Jo Hopkins (NOC) and user options were used during DY029:

1) Alongside K-sync with bottom tracking (primary choice)
2) 'Free running' (without K-sync) with bottom tracking (when 1) was failing)
3) Alongside K-sync with no bottom tracking (in deep water)

The main ADCP user options selected were as follows:

Number of bins: 96
Bin Size: 4 m
Blanking distance: 4 m
Transducer depth: 6.6 m
Processing mode: low resolution (long range, narrow band)
Bottom track: on (range 800 m)
Ensemble time: as fast as possible
Max file size: 10 mb
NMEA Ship Position (GGA) Source: NMEA1
NMEA Ship Speed (VTG) Source: NMEA1
Transform: Heading/tilt source: PRDID; NMEA2
Custom NMEA from C:\\RDI\VmDas
ADCP misalignment correction: -45 degrees
All data screening unchecked
Do NOT set a backup location

Corresponding to the command files listed above, these options are saved to respectively:

1) DY029 OS150 Narrowband and Bottom track with sync (primary choice and only not used if there was a problem).
2) DY029 OS150 Narrowband and Bottom track NO sync
3) DY029 OS150 Narrowband and NO Bottom track with sync

DY029 OS75 setup

The OS75 was reset every 24 hours apart from when we were in deep water and a different config file (see 3 below) was used or we experienced problems with K-sync, in which case we would leave the ADCP for slightly longer (~48 hours) and then reset.

A number of OS75 command files provided by Jo Hopkins (NOC) and user options were used during DY029:

1) Alongside K-sync with bottom tracking (primary choice)
2) 'Free running' (without K-sync) with bottom tracking (when 1) was failing)
3) Alongside K-sync with no bottom tracking (in deep water)

The main ADCP user options selected were as follows:

Number of bins: 60
Bin Size: 16 m
Blanking distance: 8 m
Transducer depth: 6.6 m
Processing mode: low resolution (long range, narrow band)
Bottom track: on (range 1200 m)
Ensemble time: as fast as possible
Max file size: 10 mb
NMEA Ship Position (GGA) Source: NMEA1
NMEA Ship Speed (VTG) Source: NMEA1
Transform: Heading/tilt source: PRDID; NMEA2
Custom NMEA from C:\\RDI\VmDas
ADCP misalignment correction: -45 degrees
All data screening unchecked
Do NOT set a backup location

Corresponding to the command files listed above, these options are saved to respectively:

1) DY029 OS75 Narrowband and Bottom track with sync (primary choice and only not used if there was a problem).
2) DY029 OS75 Narrowband and Bottom track NO sync
3) DY029 OS75 Narrowband and NO Bottom track with sync

Post-processing in Matlab

A suite of Matlab routines was used to perform data screening and transformation into absolute velocities in Earth coordinates. The routines were first obtained from IfM Kiel by Mark Inall and adapted for use on the RRS James Clark Ross by Deb Shoosmith in 2005. Since then numerous bug fixes and refinements have been added by various users, the most recent by Jo Hopkins on DY018. In short the following processing takes place:

1. RDI binary file with extension ENX (single-ping ADCP ship referenced data from VMDAS) and extension N2R (ascii NMEA output from PHINS saved by VMDAS) read into MATLAB environment. NB: The N2R file consists of ADCP single ping time stamps ($PADCP string) and pitch, roll and heading information ($PRDID string).

2. Ensembles with no ADCP data removed
3. Ensembles with bad or missing PHINS heading data identified and adjusted GYRO heading substituted
4. Attitude information time-merged with single ping data
5. Heading data used to rotate single ping ADCP velocities from vessel centreline reference to True North reference
6. Transducer mis-alignment error corrected for (derived from the mis-alignment determination)
7. Ship velocity derived from PHINS positional information
8. Further data screening performed:
   -Max heading change between pings (10 degrees per ping)
   -Max ship velocity change between pings (>2ms^{-1}pingrate^{-1})
   -Error velocity greater than twice Stdev of error velocities of single ping profile
9. All data averaged into 300-second super-ensembles
10. Determine absolute water velocities from either bottom track derived ship velocity or PHINS GPS derived ship velocity, dependent on depth.

The final post processing output is saved to OS150_DY02900x_000000_zz_abs.mat where "*zz"* is the number of the last file in the concatenation. Two structures are saved in this .mat file.

Data to be banked by BODC are contained within the structure OS75_abs (n.b. both 150 kHz and 75 kHz data are saved in structures called 'OS75' but it does contain the correct information). Underlined variables are those to be banked.

OS75_abs =

ref: [1x1 struct]
vel: [96x2x3094 double] : Absolute velocity in m/s (zonal, meridional)
nav: [1x1 struct]
depth: [96x3094 double] : bin depths (m) of velocity profiles

OS75_abs.nav =

txy1: [3x3094 double] : array of time (Julian day), longitude and latitude
txy2: [3x3094 double]

Output

It was not possible to create one long concatenated file for the entire cruise due to changes in configurations and file sizes. The following 5 min average data files have therefore been created.

Check with Jo, as I have calculated misalignment quite frequently.

OS150

TO COME

OS75

TO COME

Plots of absolute velocity in processed files

WILL NEED TO BE UPDATED IN FINAL CRUISE REPORT

Problems encountered

1. *Gaps in data where bottom tracking failed in deep water*

During DY029 a number of transects off the shelf edge were carried out and water depth exceeded 2000m. Both ADCPs appeared to have problems when K-sync and bottom tracking when performing the daily reset in deep waters. Initially, we used config file 2) which did not use K-Sync as a solution, as we believed this to be the issue. This appeared to work OK but on inspection of the files without K-Sync showed noisy data and/or gaps. We found that having bottom tracking on when in deep water caused this problem and therefore used a config file which did not use bottom tracking but used K-sync. This appeared to rectify the problem.

The gaps in the data appeared to be introduced in the transformation to .LTA and .STA files, where the VMDAS processing software has used bottom tracking navigation. On closer inspection of the raw .ENR files it became apparent that raw data exists for the apparent ‘gaps’, however the VMDAS software does not allow reprocessing with a new config file (with no bottom tracking). Attempts to retrieve this data will be made before the final data files are distributed.

Table 9. Log of files opened and closed during the cruise - DY029 OS75 VMADCP

DATE	TIME (GMT)	FILENAME	OPEN /CLOSED	COMMENTS (e.g. setup file, problems etc)
30/03/15	12:57	OS075_DY029_001	O	TESTING – SET UP FILE: DY029_OS75_narrow_no_sync
	13:02	"	C	"
	13:02	OS075_DY029_002	O	Testing
	13:05	"	C	Testing at Southampton Port
	13:08	OS075_DY029_003	O	Testing set up with K sync config file
	13:12	"	C	"
01/04/15	13:15	OS075_DY029_004	O	Start collecting data as leaving Southampton with K-SYNC config file
	21:44	"	C	
	21:45	OS075_DY029_005	O	With bottom track sync
03/04/15	09:23	"	C	Near CCS mooring
	09:25	OS075_DY029_006	O	Daily reset near CCS mooring.
04/04/15	05:27	"	C	Daily reset: Moved from CCS for glider deployment
	05:29	OS075_DY029_007	O	"
05/04/15	06:30	"	C	Daily reset
	06:32	OS075_DY029_008	O	Daily reset
06/04/15	07:32	"	C	"
	07:34	OS075_DY029_009	O	"
07/04/15	08:13	"	C	
07/04/15	08:14	OS075_DY029_010 OS075_DY029_011	O,C,O	Daily reset steaming to iron transect, problems working with K sync in deep water
	08:17	OS075_DY029_011	C	"
	08:17	OS075_DY029_012	O	"
08/04/15	07:03	"	C	Daily reset
	07:04	OS075_DY029_013	O	"
	16:34	"	C	K-SYNC issues
	16:34	OS075_DY029_014	O/C	"
	16:38	OS075_DY029_015	O	"
09/04/15	07:27	"	C	Daily reset – now running with K-SYNC
	07:30	OS075_DY029_016	O	"
10/04/15	08:45	"	C	"
	08:46	OS075_DY029_017	O	"
11/04/15	10:02	"	C	"
	10:03	OS075_DY029_018	O	"
13/04/15	07:53	"	C	"
	07:53	OS075_DY029_019	O	"
14/04/15	17:54	"	C	"
14/04/15	17:55	OS075_DY029_020	O	Daily reset
16/04/15	07:44	"	C	"
	07:48	OS075_DY029_021	O	Daily reset, leave until finished iron transect as appears to have problems working with K-SYNC in deep water
19/04/15	14:21	"	C	Reset
	14:22	OS075_DY029_022	O	Reset
21/04/15	07:47	"	C	Reset
	07:48	OS075_DY029_023	O/C	Errors resetting
	07:49	OS075_DY029_024	O	
	17:36	"	C	Resetting so can use config with no bottom tracking on route to Fe transect
	17:39	OS075_DY029_025	O	"
23/04/15	08:43	"	C	Reset with no bottom tracking
	08:45	OS075_DY029_026	O	"
24/04/15	08:58	"	C	Reset and turn on bottom tracking and K-Sync at CS2

DATE	TIME (GMT)	FILENAME	OPEN /CLOSED	COMMENTS (e.g. setup file, problems etc)
	08:59	OS075_DY029_027	O	"
25/04/15	09:08	"	C	Turned off for mooring acoustic work
	10:40	OS075_DY029_028	O	Turned on again
26/04/15	11:16	"	C	Reset
	11:18	OS075_DY029_029	O	Reset

Table 10. Log of files opened and closed during the cruise - DY029 OS150 VMADCP

DATE	TIME (GMT)	FILENAME	OPEN /CLOSED	COMMENTS (e.g. setup file, problems etc)
30/03/15	13:17	OS150_DY029_001	O	Narrowband bottom track sync
	13:19	"	C	Testing in dock
01/04/15	13:12	OS150_DY029_002	O	Start cruise collecting data with K-SYNC, leaving dock
	21:45	"	C	
	21:46	OS150_DY029_003	O	With K-SYNC, transit to CCS mooring
02/04/15	17:16	"	C	Problems, need to resey
	17:20	OS150_DY029_004	O	Was closed have restarted and looks like working with K-SYNC OK
03/04/15	09:18	"	C	Daily reset
	09:22	OS150_DY029_005	O	Daily reset for CCS mooring
04/04/15	05:32	"	C	Moved from CCS for glider deployment
	05:33	OS150_DY029_006	O	"
05/04/15	07:54	"	C	Daily reset
	07:55	OS150_DY029_007	O	"
06/04/15	07:29	"	C	"
	07:30	OS150_DY029_008	O	"
07/04/15	08:13	"	C	"
	08:14	OS150_DY029_009	O	"
08/04/15	07:08	OS150_DY029_009	C	Daily reset @ iron transect off shelf
	07:10	OS150_DY029_010	O	"
	07:11	"	C	Problems working with K-SYNC
	07:13	OS150_DY029_011	O	"
	07:15	"	C	" Still failing
	07:18	OS150_DY029_012	O	"
	07:20	"	C	
	07:22	OS150_DY029_013	O	Try with no K-SYNC, works
09/04/15	07:25	"	C	Daily reset,
	07:26	OS150_DY029_014	O	" with K-SYNC now
10/04/15	08:43	"	C	"
	08:44	OS150_DY029_015	O	"
11/04/15	10:05	"	C	"
		OS150_DY029_016	O	"
13/04/15	07:49	"	C	"
	07:50	OS150_DY029_017	O	" @ port call
	07:51	"	C	Mistake
	07:52	OS150_DY029_018	O	
14/04/15	17:56	OS150_DY029_018	C	Daily reset
	17:57	OS150_DY029_019	O	"
16/04/15	07:42	"	C	"
	07:44	OS150_DY029_020	O	"
17/04/15	14:53	"	C	"
	14:54	OS150_DY029_021	O	Daily reset at CS2, on transit to iron transect – issues

	14:55	“	C	Problems
	14:56	OS150_DY029_022	O	“
	14:58	“	C	“
	15:00	OS150_DY029_023 OS150_DY029_024	O/C/O	“
	15:00	“	C	“
	15:03	OS150_DY029_025	O	“
	15:04	“	C	“
	15:05	OS150_DY029_026	O	WITH NO K-SYNC, leave alone for a while until we leave deep water.
19/04/15	14:23	“	C	“
	14:24	OS150_DY029_027	O	Attempt with K-Sync, OK.
21/04/15	07:45	“	C	Reset
	07:46	OS150_DY029_028	O	“
21/04/15	17:41	OS150_DY029_028	C	Reset with no bottom tracking for the iron transect.
	17:42	OS150_DY029_029	O	“
23/04/15	08:46	“	C	Reset no bottom tracking in deep water.
	08:47	OS150_DY029_030	O	“
24/04/15	08:54	“	C	“
	08:57	OS150_DY029_031	O	Reset with bottom tracking now at CS2 and shallower.
25/04/15	09:08	“	C	Turn off for moorings acoustic work.
	10:41	OS150_DY029_032	O	Restarted.
26/04/15	11:14	“	C	“
	11:15	OS150_DY029_033	O	“

6. NMF-SS sensors & moorings cruise report

Jon Short (NMF)

CTD system configurations

1) Two CTD systems were prepared. The first water sampling arrangement was a 24-way titanium frame system (s/n SBE CTD TITA1), and the initial sensor configuration was as follows:

Sea-Bird 9plus underwater unit, s/n 09P-77801-1182 (Ti)
Sea-Bird 3P temperature sensor, s/n 03P-4593, Frequency 1 (primary)
Sea-Bird 4C conductivity sensor, s/n 04C-2164, Frequency 2 (primary)
Digiquartz temperature compensated pressure sensor, s/n 129735, Frequency 3
Sea-Bird 3P temperature sensor, s/n 03P-5494, Frequency 4 (secondary)
Sea-Bird 4C conductivity sensor, s/n 04C-4140, Frequency 5 (secondary)
Sea-Bird 5T submersible pump, s/n 05T-3085, (primary)
Sea-Bird 5T submersible pump, s/n 05T-6916, (secondary)
Sea-Bird 32 Carousel 24 position pylon, s/n 32-60380-0805
Sea-Bird 11plus deck unit, s/n 11P-34173-0676 (main)
Sea-Bird 11plus deck unit, s/n 11P-24680-0589 (back-up logging)

2) The auxiliary input initial sensor configuration was as follows:

Sea-Bird 43 dissolved oxygen sensor, s/n 43-0862 (V0)
Chelsea 2pi-PAR irradiance sensor, DWIRR, s/n 02 (V2)
Chelsea 2pi-PAR irradiance sensor, UWIRR, s/n 04 (V3)
Benthos PSA-916T altimeter, s/n 62679 (V4)
WETLabs light scattering sensor, s/n BBRTD-758R (V5)
Chelsea Alphatracka MKII transmissometer, s/n 161049 (V6)
Chelsea Aquatracka MKIII fluorometer, s/n 088244 (V7)

3) Additional instruments:

TRDI Workhorse 300kHz Sentinel LADCP, s/n 13400 Plus LADCP battery pack pressure case s/n WH009T

4) Sea-Bird 9*plus* configuration file DY029_tita_NMEA.xmlcon was used for the titanium frame CTD casts.

5) The second water sampling arrangement was a 24-way stainless steel frame system (s/n SBE CTD1), and the initial sensor configuration was as follows:

Sea-Bird 9plus underwater unit, s/n 09P-24680-0637

Sea-Bird 3P temperature sensor, s/n 03P-4712, Frequency 1 (primary)

Sea-Bird 4C conductivity sensor, s/n 04C-2858, Frequency 2 (primary)

Digiquartz temperature compensated pressure sensor, s/n 79501, Frequency 3

Sea-Bird 3P temperature sensor, s/n 03P-5660, Frequency 4 (secondary)

Sea-Bird 4C conductivity sensor, s/n 04C-3054, Frequency 5 (secondary)

Sea-Bird 4C conductivity sensor, s/n 04C-3873, Frequency 5 (secondary) Replaced above sensor from CTD cast CTD_020SS

Sea-Bird 5T submersible pump, s/n 05T-5247, (primary)

Sea-Bird 5T submersible pump, s/n 05T-6320, (secondary)

Sea-Bird 32 Carousel 24 position pylon, s/n 32-31240-0423

Sea-Bird 11plus deck unit, s/n 11P-34173-0676 (main)

Sea-Bird 11plus deck unit, s/n 11P-24680-0589 (back-up logging)

6) The auxiliary input initial sensor configuration was as follows:

Sea-Bird 43 dissolved oxygen sensor, s/n 43-2575 (V0)

WETLabs light scattering sensor, s/n BBRTD-1055 (V2)

Benthos PSA-916T altimeter, s/n 59493 (V3)

Chelsea Aquatracka MKIII fluorometer, s/n 88-2615-124 (V4)

Chelsea Alphatracka MKII transmissometer, s/n 161048 (V5)

Biospherical QCP Cosine PAR irradiance sensor, UWIRR, s/n 70510 (V6)

Biospherical QCP Cosine PAR irradiance sensor, DWIRR, s/n 70520 (V7)

7) Additional instruments:

TRDI Workhorse 300kHz Sentinel LADCP, s/n 15288 Plus LADCP battery pack pressure case s/n WH010T

8) Sea-Bird 9*plus* configuration file DY029_ss_NMEA.xmlcon was used for all stainless steel frame CTD casts upto CTD_019SS. From CTD_020SS Sea-Bird 9*plus* configuration file DY029_ss_NMEA_070415.xmlcon

Total number of casts – 46 titanium frame, 94 S/S frame.
Casts deeper than 2000 m - 6 titanium frame, 10 S/S frame.
Deepest casts – 2552 m titanium frame, 2553m S/S frame.

8. Mooring deployments & servicing

Emlyn Jones (National Oceanography Centre – Liverpool)

The table below summarises the deployment and recovery times and positions of the long-term moorings at Site 1 (also referred to as CCS and/or Candyfloss site). Further times and positions relevant to the mooring deployments and recoveries can be found in the cruise Event Logs. Details of senor serial numbers, depth etc. can be found in reports provided by Emlyn Jones, Jon Short and the NMFSS mooring team.

Table 11. Summary of long-term mooring deployment and recovery positions and dates/times

	Mooring	**Date**	**Time**	**Latitude**	**Longitude**	**Depth (m)**
Recoveries		*Recovery start time*				
Site 1 (Candyfloss)	Temperature chain	Event 14 04/04/15	11:55	49° 23.880 N	8° 36.470 W	145.8
*	In-line ADCP mooring	Event 13 04/04/15	09:47	49° 24.001 N	8° 36.234 W	146
ADCP bedframe was not recovered on this cruise due to fouled up release.	Was later recovered on DY034 using a camera and grapple system.	23/08/15	16:30	49° 23.942 N	8° 35.863 W	148
Deployments		*Recovery end time (anchor/frame dropped)*				
Site 1 (Candyfloss)	Temperature chain	Event 113 11/04/15	10:22	49° 23.980 N	8° 36.180 W	146
	In-line ADCP mooring	Event 112 11/04/15	07:45	49° 24.100 N	8° 36.060 W	147
	ADCP bedframe	Event 114 11/04/15	11:00	49° 23.844 N	8° 35.997 W	147

*In line ADCP mooring was assigned to NMF-SS who performed the servicing and data downloads.

Moorings and instrumentation (all times GMT)

Deployments

Mooring Site 1 - (49.40, -8.60) Candyfloss - NOCL Bedframe Due to us not being able to recover the Bedframe that was deployed in November 2014 the new Bedframe was deployed at new co-ordinates. **Deployed on 11/04/2015 at 11:00, GPS 49° 23.844'N, 8° 35.997'W, depth 147.5m** Standard buoyancy of 6 Trelleborg floats and a standard aluminium ballast frame with 6, 25KG lead billets attached.	
Instrument	**Details**
Seabird 16 plus RS485 + DQ pressure, pumped CTD, SN4596	The CTD clock was reset and logging was set to start at 06:00 on 01/04/15. The CTD cell was located 67cm above seabed and configured for a 300s logging interval. A horizontal mounting orientation was used.
*Flowquest 150 kHz underwater current profiler (ADCP), SN011043	The FlowQuest real time clock was reset at 12:38:00 on 29/03/15 and a delayed start was set for 06:00:00 on 01/04/15. The top of the FlowQuest sensor array was 98cm above the deck. An extra external battery case with two internal packs was connected to double the endurance of the FlowQuest to ensure that data is recorded until the next scheduled recovery of the NOCL bedframe during July 2015.
*600 kHz RDI (turbulence mode) ADCP, SN5807 fitted to a gimbal. 2G of memory was installed and the pressure sensor port was blanked.	The top of the ADCP sensor array was 98cm above the deck. Beam 2 pointed towards the FlowQuest. The instrument clock was reset to 11:44:00 on 29/03/15 and logging was set to commence at 06:00:00 on 01/01/15.
NOCL ballast jettison acoustic release 1	SN72381, RX 11.0, TX 12.0, Release B
NOCL ballast jettison acoustic release 2	SN70356, RX 10.5, TX 12.0, Release D

Figure 9. Image of the NOCL Bedframe

Mooring Site 1 (cont) - (49.40, -8.60) Candyfloss - Long term T chain 2

11/04/2015 at 10:22 at a GPS location of 49° 23.980 N, 8° 36.180 W at a nominal depth 147m.

Depth	Type	Param	SN	Details
-10	SBE 16+	RS232+ DQ pressure pumped CTD	4597	Sample Interval = 300 seconds. Sample Number= 0 Time set at 13:23:00 on 29/03/2015. Delayed start at 06::00:00 on 01/04/15
-15	RBR Solo	Temperature	76797	Logger clock set to UTC. Start logging at 06:00:00 on 01/04/2015. Logging at 300 Seconds. New Battery installed. Est duration 30/11/2053
-20	Star Oddi Starmon mini	Temperature	3587	Logger clock set to GMT. Start logging at 06:00:00 on 01/04/2015. Logging at 300 seconds. Battery energy at start 80.6%
-25	RBR Solo	Temperature	76806	Logger clock set to UTC. Start logging at 06:00:00 on 01/04/2015. Logging at 300 Seconds. New Battery installed. Est duration 30/11/2053
-30	SBE 37	RS232 + press (unpump) CTD	4998	Sample Interval = 300 seconds. Sample Number = 0 Average = 4 Time set at 12:36 on 29/03/2015. Delayed start at 06:00:00 on 01/04/15
-35	Star Oddi Starmon mini	Temperature	3584	Logger clock set to GMT. Start logging at 06:00:00 on 01/04/2015. Logging at 300 seconds. Battery energy at start 81.9%
-37	RBR Solo	Temperature	76807	Logger clock set to UTC. Start logging at 06:00:00 on 01/04/2015. Logging at 300 Seconds. New Battery installed. Est duration 30/11/2053
-40	Star Oddi Starmon mini	Temperature	3580	Logger clock set to GMT. Start logging at 06:00:00 on 01/04/2015. Logging at 300 seconds. Battery energy at start 81.9%
-42	RBR Solo	Temperature	76798	Logger clock set to UTC. Start logging at 06:00:00 on 01/04/2015. Logging at 300 Seconds. New Battery installed. Est duration 30/11/2053
-45	SBE 16+	RS232 + DQ pressure - Pumped CTD	5309	Sample Interval = 300 seconds. Sample Number = 0 Time set at 13:05:00 on 29/03/2015. Delayed start at 06::00:00 on 01/04/15
-47	Star Oddi Starmon mini	Temperature	2836	Logger clock set to GMT. Start logging at 06:00:00 on 01/04/2015. Logging at 300 seconds. Battery energy at start 73.5%
-49	SBE 37	RS232+pressure (pumped) - V2 CTD	7459	Sample Interval = 300 seconds. Sample Number = 0 Average = 4 Problem setting time. Time = 11:13:10 at 13:13:00. Delayed start at 06:00:00 on 01/04/15
-54	Star Oddi Starmon mini	Temperature	3890	Logger clock set to GMT. Start logging at 06:00:00 on 01/04/2015. Logging at 300 seconds. Battery energy at start 85.9%
-59	Star Oddi Starmon mini	Temperature	3581	Logger clock set to GMT. Start logging at 06:00:00 on 01/04/2015. Logging at 300 seconds. Battery energy at start 81.9%
-64	Star Oddi Starmon mini	Temperature	3891	Logger clock set to GMT. Start logging at 06:00:00 on 01/04/2015. Logging at 300 seconds. Battery energy at start 85.9%

-69	SBE 37	IM + No pressure CT	2010	Sample Interval = 300 seconds. Sample Number = 0 Average = 4 Time set at 13:34 on 29/03/2015. Delayed start at 06::00:00 on 01/04/15
-74	RBR Solo	Temperature	76799	Logger clock set to UTC. Start logging at 06:00:00 on 01/04/2015. Logging at 300 Seconds. New Battery installed. Est duration 30/11/2053
-79	Star Oddi Starmon mini	Temperature	3582	Logger clock set to GMT. Start logging at 06:00:00 on 01/04/2015. Logging at 300 seconds. Battery energy at start 81.9%
-89	Star Oddi Starmon mini	Temperature	3583	Logger clock set to GMT. Start logging at 06:00:00 on 01/04/2015. Logging at 300 seconds. Battery energy at start 81.9%
-99	SBE 37	RS232 CTD	5434	Sample Interval = 300 seconds. Sample Number = 0 Average = 4 Time set at 12:43:00 on 29/03/2015. Delayed start at 06::00:00 on 01/04/15
-109	RBR Solo	Temperature	76800	Logger clock set to UTC. Start logging at 06:00:00 on 01/04/2015. Logging at 300 Seconds. New Battery installed. Est duration 30/11/2053
-120	RBR Solo	Temperature	76801	Logger clock set to UTC. Start logging at 06:00:00 on 01/04/2015. Logging at 300 Seconds. New Battery installed. Est duration 30/11/2053
-129	SBE 16+	RS485 + DQ pressure pumped CTD	4738	Sample Interval = 300 seconds. Sample Number = 0 Time set at 10:06:00 on 02/04/2015. Delayed start at 10::30:00 on 02/04/15 Note different start time due to error in original setup.

Instrument Recoveries

Mooring Site 1 (cont) - (49.40, -8.60) Candyfloss - Long term T chain This mooring was deployed on during DY018 on 21/11/2014 at 10:59, the instrument logging interval was set to 300s. The mooring recovery occurred during DY029 and was completed by 11:55 on 04/04/15 at a GPS of 49° 23.881'N, 8° 33.472'W from a water column depth of 145m. The instruments were the put into a sink of salt water for logging comparisons at 15:13 on 04/04/15. Following this the instruments were subsequently removed from the sink of salt water at 17:40 on 04/04/15. Initial tests show a full data return from all of the instruments.

Depth	Type	Param	SN	Details
-10	SBE 16+	RS232+ DQ pressure pumped CTD	4848	Clock drift was GMT +25s, 39795 Samples
-15	RBR Solo	Temperature	076789	Clock drift was GMT minus 9s. Stopped logging @ 08:06 0n 06/04/15
-20	Star Oddi Starmon mini	Temperature	T3893	85% battery left. Number of measurements taken 39510
-25	RBR Solo	Temperature	076709	Clock drift was GMT minus 10s. Stopped logging @ 07:54 0n 06/04/15
-30	SBE 37	Inductive Modem (un-pumped) CTD	2506	Clock drift GMT +23s Downloaded back in the lab. IM was playing up on the ship.
-35	Star Oddi Starmon mini	Temperature	T3894	85% battery left. Number of measurements taken 39522
-37	RBR Solo	Temperature	076791	Clock drift was GMT minus 7s. Stopped logging @ 08:31 0n 06/04/15
-40	Star Oddi Starmon mini	Temperature	T3896	85% battery left. Number of measurements taken 39508
-42	RBR Solo	Temperature	076792	Clock drift was GMT minus 12s. Stopped logging @ 08:37 0n 06/04/15
-45	SBE 16+	RS232+ DQ pressure pumped CTD	5310	Clock drift was GMT +15s, 39846 Samples
-47	Star Oddi DST	Temperature	076792	Clock drift was GMT minus 12s. Stopped logging @ 08:37 0n 06/04/15
-49	SBE 37	RS232 (pumped) V2 CTD	7460	Clock drift GMT +5s 39337 Samples
-54	Star Oddi Starmon mini	Temperature	T3897	85% battery left. Number of measurements taken 39490
-59	Star Oddi Starmon mini	Temperature	T3899	85% battery left. Number of measurements taken 39514
-64	Star Oddi Starmon mini	Temperature	T3901	85% battery left. Number of measurements taken 39512
-69	SBE 37	Inductive Modem (un-pumped) CTD	2081	Clock drift GMT +23s Downloaded back in the lab. IM was playing up on the ship.
-74	RBR Solo	Temperature	076794	Clock drift was GMT minus 15s. Stopped logging @ 08:26 0n 06/04/15
-79	Star Oddi Starmon mini	Temperature	T3903	85% battery left. Number of measurements taken 39520
-89	Star Oddi Starmon mini	Temperature	T3905	86% battery left. Number of measurements taken 39506
-99	SBE 37	RS232 + press (pumped) CTD	7458	Clock drift GMT +6s 39246 Samples
-109	RBR Solo	Temperature	076795	Clock drift was GMT minus 9s. Stopped logging @ 08:16 0n 06/04/15

-120	RBR Solo	Temperature	076796	Clock drift was GMT minus 6s. Stopped logging @ 08:12 0n 06/04/15
-129	SBE 16+	RS485 + DQ pressure pumped CTD	4737	Clock drift was GMT +14s, 39824 Samples

Mooring Site 1 - (49.40, -8.60) Candyfloss - NOCL Bedframe

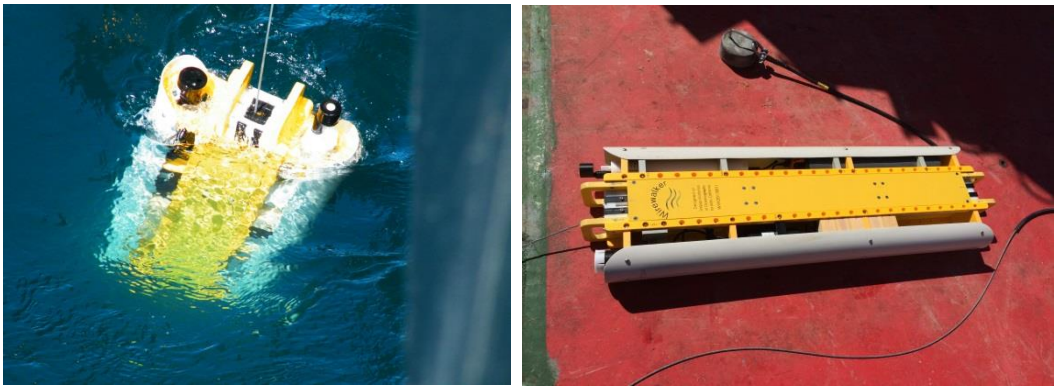
Not recovered on DY029. Several attempts were made to recover the frame without any luck. We had communications through the Benthos deck unit, and fired both acoustics. Recovered on 23/08/2014 at 16:30, GPS 49° 23.942'N, 8° 35.863'W, depth 148m The frame had been lodged on the seabed primarily due to an extended deployment from November 2014 until the first recovery attempt during April 2015. Examination in August 2015 after a recovery with a NMF/CEFAS supplied camera and grapple system showed that the frame ballast was buried in sediment and the burn wire based ballast release assembly was ceased due to suspected sediment and biofouling. The frame was recovered using a grapple system on 23rd August 2015 at approximately 16:45 during the RRS Discovery based DY034 research cruise.

Instrument	**Details**
RS485 + DQ pressure, pumped CTD, SN4736	On recovery the CTD was still running and 79772 samples had been recorded. The clock drift was GMT + 43 seconds at 08:46 on 25/08/15 after the prolonged deployment. The data set seems OK from 21/11/14 to 23/08/15.
Flowquest 150 kHz underwater Current profiler (ADCP), SN015963	The FlowQuest real time clock was reset and a delayed start was set for 12:00 on 18/11/14. The top of the FlowQuest sensor array was 97cm above the deck. An extra external battery case with two internal packs was connected to double the endurance of the FlowQuest to ensure that data is recorded until the next scheduled recovery of the NOCL bedframe during April 2015. After an extended deployment until a grapple recovery during DY034 on 23/08/15. Data was recorded from 18/11/14 to 09/08/15 and successfully downloaded.
NOCL ballast jettison acoustic release 1	SN72863, RX 13.5, TX 12.0, Release A
NOCL ballast jettison acoustic release 2	SN70358, RX 11.0, TX 12.0, Release A

Wire Walker System Deployments and Recoveries Overview

The Wirewalker is a wave-powered autonomous profiler. It uses the surface wave field to power continual vertical profiling. Internally powered and recording instrumentation attached to the Wirewalker collects a two-dimensional depth-time record. Briefly, the mooring itself includes a surface buoy, a wire suspended from the buoy, a weight at the end of the wire, and the profiler attached to the wire via a cam mechanism. A mooring diagram is included below. The wire and weight follow the surface motion of the buoy. The wave-induced motion of the water is reduced with increasing depth, and the relative motion between the wire and the water is used to propel the profiler. The cam engages the wire as it descends and releases it as it ascends, pulling the profiler downwards. At the bottom of the wire, the wirewalker hits a mechanical stop that causes the cam to remain open and the profiler free floats to the surface. At the top of the wire, the cam is reset and the wirewalker is ratcheted downwards again.

Figure 10. Images of the NOCL Wire-walkers



Two short term deployments took place during DY029:

Deployment 1

Deployed: 05/04/15 16:31, 49° 24.279 N, 8° 35.824 W

Recovered: 11/04/15 13:49, 49° 24.195, 8° 36.211 W

The WireWalker with the intended 110m long underwater profiling wire was deployed at 14:06 on 05/04/15 at a GPS location of 49° 24.279'N, 8° 35.824'W with a water depth of 147.5m. The RBR Concerto CTD measurements recorded during this deployment were retrieved successfully. I had an issue with the DH4 logger which is the logger for the Triplet. When I downloaded the data, the logger had only recorded the first 10 hours of data. I set it up as I was shown in the lab, but there was a problem with one of the parameters which was resolved for the second deployment.

Instrumentation:

- RBR Concerto Fast SN 060047 sampling at 6 Hz (Temperature, Conductivity and Pressure)
- Wetlabs Triplet SN 2550 sampling at 4 Hz (Chlorophyll-a, Phycoerythrin and CDOM fluorescence)
- DH-4 Logger SN 096

Deployment 2

Deployed: 15/04/15 11:23, 49° 24.363 N, 8° 35.987 W

Recovered: 25/04/15 09:23, 49° 24.311N, 8° 35.990 W

The WireWalker with the 110m long underwater profiling wire was deployed for a second time at 07:50 on 05/04/15 at a GPS location of 49° 24.281'N, 8° 36.035'W, with a water depth of 146m. The WireWalker was recovered at 10:00 on 25/04/15

A full RBR CTD and WetLabs triplet data return was achieved.

Instrumentation

- RBR Concerto Fast SN 060047 sampling at 6 Hz (Temperature, Conductivity and Pressure)

- Wetlabs Triplet SN 2550 sampling at 4 Hz (Chlorophyll-a, Phycoerythrin and CDOM fluorescence)
- DH-4 Logger SN 096

Ballasting Test:

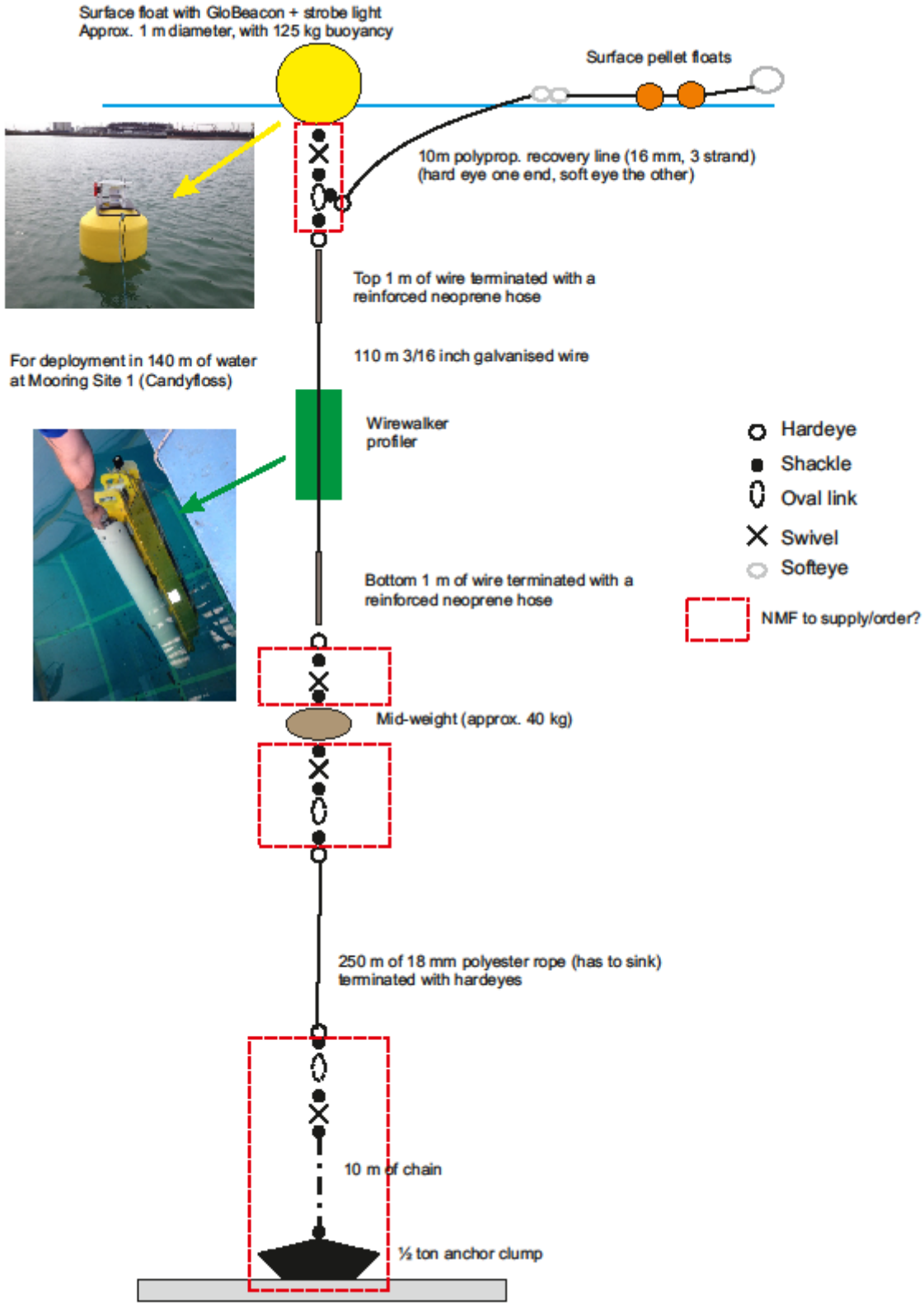
This was a wirewalker buoyancy test from the stern of RRS Discovery using a 10m long underwater profiling guide line, the subsurface 40kg weight and the surface buoy. The test occurred between 12:48 and 13:00 at a GPS location of 49° 24.300'N, 8° 36.600'W on 05/04/15, with a water depth of 148.5m. Analysis of the pressure record of the RBR CTD confirmed that the accent rate was a bit slower than the desired rate of 0.25-0.3 meters per second. I decided to add one block of buoyancy to gain a slightly faster accent rate. The triplet measurements were also retrieved successfully from this test deployment.

Calibration dip

After the second deployment of the wirewalker the RBR Concerto and the Triplet were mounted on to the CTD carousel for a calibration dip. This was event number 301 which took place on 25/04/2015 at 12:02. 48°24.568 N, 8°35.477 W

Figure 11. Wirewalker sensors strapped to the Stainless Steel CTD for calibration dip

Figure 12. WireWalker mooring diagram



8. Gliders

Sam Ward (National Marine Facilities, MARS Gliders) & Charlotte Williams (National Oceanography Centre - Liverpool)

DY029 Glider Aims and Objectives

SSB Slocum Glider Deployments:

- To deploy four 200m (shallow) Slocum gliders:
  - Unit_424 'OMG3' (Microrider) deployed for the duration of DY029
  - Unit_423 'OMG2' (Microrider) deployed at selected stations for 25 hours (one tidal cycle)
  - Unit_397 'Nelson' and Unit_400 'Drake' (D-Tag) long term deployments

- To deploy one 1000m (deep) Slocum glider:
  - Unit_437 'Boondoggle' long term deployment

Seaglider Deployments:

- To deploy two 1000m (deep) Seagliders:
  - SG534 'Denebola' with the LoC Nitrate sensor for the duration of DY029
  - SG533 'Canopus' long term deployment

Table 12. Glider Activity Tables in Chronological Order (Grey recovery, blank deployed)

TIME (GMT)	DATE	GLIDER	LATITUDE	LONGITUDE	EVENT No.	CTD CALIBRATION CAST
0740	03/04/15	Slocum (Deep 1000m) Unit_419 '49'R'	48° 53.34 N	09° 07.09 W	003	None, week into deployment when glider aborted
0601	04/04/15	Slocum (Shallow 200m) Unit_424 'OMG3'	49° 23.319 N	08° 33.512 W	010	CTD Num: 007SS Event No: 012
0627	04/04/15	Seaglider (Deep 1000m) SG534 'Denebola' (LoC)	49° 23.496 N	08° 33.270 W	010	CTD No: 007SS Event No: 012
0613	05/04/15	Slocum (Shallow 200m) Unit_397 'Nelson'	49° 23.420 N	08° 33.591 W	027	CTD No: 010SS Event No: 029
0630	05/04/15	Slocum (Shallow 200m) Unit_400 'Drake'	49° 29.263 N	08° 33.653 W	n/a	n/a
0720	05/04/15	Slocum Unit_400 'Drake'	49° 23.618 N	08° 33.752 W	n/a	n/a
0850	09/04/15	Slocum Unit_437 'Boondoggle'	48° 26.249 N	09° 51.752 W	80	CTD No: 035SS+036SS Event No: 079 + 082
0925	09/04/15	Seaglider SG533 'Canopus'	48° 26.328 N	09° 51.508 W	81	CTD No: 035SS+036SS Event No: 079 + 082
1223	11/04/15	Slocum (Shallow 200m) Unit_400 'Drake'	49° 23.589 N	08° 36.033 W	116A	CTD No: 050SS Event No: 115
06:26	17/04/15	Slocum Unit_423 'OMG2'	49° 34.29 N	09° 30.61 W	198	CTD No: 071SS Event No: 199
0730	24/04/15	Seaglider SG533 'Canopus'	48° 32.33 N	09° 24.874 W	279	CTD No: 114T Event No: 278
0945	24/04/15	Slocum Unit_423 'OMG2'	48° 36.88 N	09° 24.94 W	281	CTD No: 113SS Event No: 277
0624	25/04/15	Slocum (Shallow 200m) Unit_424 'OMG3'	49° 24.723 N	08° 32.861 W	296	CTD Num: 122T Event No: 295

TIME (GMT)	DATE	GLIDER	LATITUDE	LONGITUDE	EVENT No.	CTD CALIBRATION CAST
0658	25/04/15	Seaglider (Deep 1000m) SG534 'Denebola' (LoC)	49° 24.660 N	08° 32.970 W		CTD No: 121T Event No: 294

Table 13. Glider Sensors and Serial Numbers

'Boondoggle' Unit_437	Sensors	Serial Number
	Aanderaa Optode	Type 4831 S/N: 248 Cal Date: 30th Sep 2013
	Wet Labs Triple Puck	Type 700nm S/N: 3351 Cal Date: 19th Oct 2013
	Micron Pressure Sensor	Pressure Tx (Micron) S/N: 96609 Cal Date: 29th Jul 2013
	SeaBird CT sail	S/N: 9135 Cal Date: 26th Oct 2013
	Satlantic PAR	S/N: 431 Cal date: 18/11/2013

'Canopous' SG533	Sensors	Serial Number
	Aanderaa Optode	Optode S/N: 288 Cal date: 11th Nov 2013
	Wet Labs Triple Puck	S/N: BBFL2VMT-868 Cal date: 02nd Nov 2014
	Paine Pressure Sensor	S/N: 256784 Cal date: 03/03/2010
	SeaBird CT Sail	S/N: 0209 Cal date: 06/05/2012
	PAR Sensor	QSP2150A S/N: 50181 Cal date: 05/03/2014

'Denebola' SG534	Sensors	Serial Number
	Wet Labs Triple Puck	S/N: BBFL2VMT-791 Cal date:2nd Oct 2014
	SeaBird CT Sail	S/N: 0230 Cal date: Installed 09/02/2015 on SG534 (scaw)
	NOC LoC	1 x Nitrate sensors in a single housing with external oil bladder and no battery

'Drake' Unit_400	Sensors	Serial Number
	Aanderaa Optode	Type 4831 S/N 230 Cal Date: 8th Aug 2013?
	Wet Labs Triple Puck	Type 700nm S/N: 3288 Cal Date: 22 Aug 2013

	Micron Pressure Sensor	Pressure Tx (Micron) S/N: 94401 Cal Date: 23rd Apr 2013
	SeaBird CT Sail	S/N: 9100 Cal Date: 02nd July 2013

'Nelson' Unit_397	**Sensors**	**Serial Number**
	Aanderaa Optode	Type 4831 S/N: 197 Cal Date: 25th May 2013
	Wet Labs Triple Puck	Type 700nm S/N: 3263 Cal Date: 8th Aug 2013
	Micron Pressure Sensor	Pressure Tx (Micron) S/N: 94401 Cal Date: 16th Jan 2013
	SeaBird CT Sail	S/N: 9098 Cal Date: 28th June 2013

'OMG2' Unit_423	**Sensors**	**Serial Number**
	Aanderaa Optode:	Type 4831 S/N: 252 Cal Date: 16th Sep 2013
	Wet Labs Triple Puck	N/A Not Installed
	Micron Pressure Sensor	Pressure Tx (Micron) S/N: 96161 Cal Date: 17th June 2013
	SeaBird CT Sail	S/N: 207
		Micro Rider: S/N: 106 S1 = M1077, 0.0997, 600 Bar. Horizontal so there for will be measuring vertical. S2 = M1075, 0.0854, 600 Bar. Vertical so there for will be measuring horizontal. T1 = T839 2K0hm T2 = T698 2K0hm

'OMG3' Unit_424	**Sensors**	**Serial Number**
	Aanderaa Optode:	Type 4831 S/N: 268 Cal Date: 23rd sep 2013
	Wet Labs Triple Puck	N/A Not Installed
	Micron Pressure Sensor	Pressure Tx (Micron) S/N: 96124 Cal Date: 17th June 2013
	SeaBird CT Sail	S/N: 221
		Micro Rider: S/N: 105 S1 = M1073, 0.0729, 600 Bar. Horizontal so there for will be measuring vertical. S2 = M1074, 0.0887, 600 Bar. Vertical so there for will be measuring horizontal. T1 = T838 2K0hm T2 = T699 2K0hm

'Boondoggle' Unit_437	Sensors	Serial Number
	Aanderaa Optode	Type 4831 S/N: 248 Cal Date: 30th Sep 2013
	Wet Labs Triple Puck	Type 700nm S/N: 3351 Cal Date: 19th Oct 2013
	Micron Pressure Sensor	Pressure Tx (Micron) S/N: 96609 Cal Date: 29th Jul 2013
	SeaBird CT sail	S/N: 9135 Cal Date: 26th Oct 2013
	Satlantic PAR	S/N: 431 Cal date: 18/11/2013

'Canopous' SG533	Sensors	Serial Number
	Aanderaa Optode	Optode S/N: 288 Cal date: 11th Nov 2013
	Wet Labs Triple Puck	S/N: BBFL2VMT-868 Cal date: 02nd Nov 2014
	Paine Pressure Sensor	S/N: 256784 Cal date: 03/03/2010
	SeaBird CT Sail	S/N: 0209 Cal date: 06/05/2012
	PAR Sensor	QSP2150A S/N: 50181 Cal date: 05/03/2014

'Denebola' SG534	Sensors	Serial Number
	Wet Labs Triple Puck	S/N: BBFL2VMT-791 Cal date:2nd Oct 2014
	SeaBird CT Sail	S/N: 0230 Cal date: Installed 09/02/2015 on SG534 (scaw)
	NOC LoC	1 x Nitrate sensors in a single housing with external oil bladder and no battery

'Drake' Unit_400	Sensors	Serial Number
	Aanderaa Optode	Type 4831 S/N 230 Cal Date: 8th Aug 2013?
	Wet Labs Triple Puck	Type 700nm S/N: 3288 Cal Date: 22 Aug 2013
	Micron Pressure Sensor	Pressure Tx (Micron) S/N: 94401 Cal Date: 23rd Apr 2013
	SeaBird CT Sail	S/N: 9100 Cal Date: 02nd July 2013

'Nelson' Unit_397	Sensors	Serial Number
	Aanderaa Optode	Type 4831 S/N: 197 Cal Date: 25th May 2013
	Wet Labs Triple Puck	Type 700nm

		S/N: 3263 Cal Date: 8th Aug 2013
	Micron Pressure Sensor	Pressure Tx (Micron) S/N: 94401 Cal Date: 16th Jan 2013
	SeaBird CT Sail	S/N: 9098 Cal Date: 28th June 2013

'OMG2' Unit_423	**Sensors**	**Serial Number**
	Aanderaa Optode:	Type 4831 S/N: 252 Cal Date: 16th Sep 2013
	Wet Labs Triple Puck	N/A Not Installed
	Micron Pressure Sensor	Pressure Tx (Micron) S/N: 96161 Cal Date: 17th June 2013
	SeaBird CT Sail	S/N: 207
		Micro Rider: S/N: 106 S1 = M1077, 0.0997, 600 Bar. Horizontal so there for will be measuring vertical. S2 = M1075, 0.0854, 600 Bar. Vertical so there for will be measuring horizontal. T1 = T839 2K0hm T2 = T698 2K0hm

'OMG3' Unit_424	**Sensors**	**Serial Number**
	Aanderaa Optode:	Type 4831 S/N: 268 Cal Date: 23rd sep 2013
	Wet Labs Triple Puck	N/A Not Installed
	Micron Pressure Sensor	Pressure Tx (Micron) S/N: 96124 Cal Date: 17th June 2013
	SeaBird CT Sail	S/N: 221
		Micro Rider: S/N: 105 S1 = M1073, 0.0729, 600 Bar. Horizontal so there for will be measuring vertical. S2 = M1074, 0.0887, 600 Bar. Vertical so there for will be measuring horizontal. T1 = T838 2K0hm T2 = T699 2K0hm

9. Dissolved inorganic nutrients

Carolyn Harris (PML)

Objectives

To investigate the spatial and temporal variations of the micromolar nutrient species; Nitrate, Nitrite, Silicate, Ammonium and Phosphate during the DY026 research voyage in the Celtic Sea and Western Approaches off the West coast of the UK. Carry out nutrient analysis from zooplankton and benthic experiments where required as part of the SSB programme (Giering and Bone).

Please see individual cruise reports for these colleagues as to their individual sampling protocols.

Sampling and Analytical methodology:

Sample collection

Water samples were taken from the 24 x 10 litre Stainless Steel CTD/Rosette system (SeaBird). Clean handling techniques were employed to avoid any contamination of the samples, particularly for the ammonium samples. Gloves used were Dura-Touch to minimise nutrient contamination. Samples were kept tightly closed until just before analysis for the ammonium, this to avoid any contamination from external sources.

Sample preparation and procedure

There was minimal storage of the Underway non-toxic and CTD water column samples except for the time waiting to be analysed in the laboratory. These samples were always run at lab temperature and were not filtered. 60m ml HDPE Nalgene bottles were used for all the nutrient sampling, these were aged, acid washed and cleaned initially, and stored with a 10% acid solution between sampling. Samples were taken from the Sea-Bird CTD system on-board the RRS Discovery. The sample bottle was washed 3 times before taking final sample, and capping tightly. This was then taken immediately to the analyzer in the lab and analysis conducted as soon as possible after sampling. Nutrient free gloves (Duratouch) were used and other clean handling protocols were adopted as close to those according to the GO-SHIP protocols, (2010).

Sample Analysis

The micro-molar segmented flow auto-analyser used was the PML 5 channel (nitrate, nitrite, phosphate, silicate and ammonium) Bran and Luebbe AAIII system, using classical proven analytical techniques.

The instrument was calibrated with home produced nutrient standards and then compared regularly against Nutrient Reference Materials, from KANSO Technos, Japan. The results from this also being part of a global nutrient programme (the INSS, International Nutrient Scale System) to improve nutrient analysis data quality world-wide.

The analytical chemical methodologies used were according to Brewer and Riley (1965) for nitrate, Grasshoff (1976) for nitrite, Kirkwood (1989) for phosphate and silicate, and Mantoura and Woodward (1983) for ammonium.

References:

Brewer P.G. and Riley J.P., 1965. The automatic determination of nitrate in seawater. Deep Sea Research, 12, 765-72.

Grasshoff K., 1976. Methods of seawater analysis. Verlag Chemie, Weinheim and New York, 317pp.

Kirkwood D., 1989. Simultaneous determination of selected nutrients in seawater. ICES CM 1989/C:29.

Mantoura, R.F.C and Woodward E.M.S, 1983. Estuarine, Coastal and Shelf Science, 17, 219-224.

Table 14. CTD Samples Analysed by AAIII Micromolar analysis

Date	CTD	Site	Position	CTD bottle analysed
03/04/15	CTD_004	CCS	49^{0}23.70'N 8^{0}35.84'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,14 (depths: 135,135,135,120,120,120,90,90,65, 65,40,40, 20,20m)
04/04/15	CTD_006	CCS	49^{0}23.37'N 8^{0}35.59'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,14,15, 16,17,18,19,20,21,22,23,24 (depths:135,125,125,100,100,70,70,70,60, 60,35,35,35,23,23,18,18,12,12,8,8,5,5,5m)
04/04/15	CTD_008SS	CCS	49^{0}23.076'N 8^{0}36.241'W	Bottles:1,2,3,4,5,7,8,9,10,11,12,13,14,15,16,17,18, 19, 20,21,22,23,24 (depths:135,135,125,125,100,70,70,60,60, 35,35,25,25,20,20,15,15,10,10,5,5,5,5m)
05/05/15	CTD_011SS	CCS	49^{0}24.329'N 8^{0}35.708'W	Bottles:2,3,5,6,7,8,9,10,11,12,13,14,15,16, 17,18,19,20,21,22,23,24 (depths:135,125,100,100,70,70,60,60,40,40,25,25, 20,20,15,15,10,10,5,5,5,5m)
06/04/15	CTD_013SS	CCS	49^{0}24.306'N 8^0.35.289'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,14,15, 16,18,19,20,21,22,23,24 (depths:135,135,125,125,90,70,70,70,60,60,35,35, 35,23,23,18,12,12,8,8,5,5,5m)
06/04/15	CTD_014SS	Fe08	48^0 'N 9^{0}54.654'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,14,15, 16,17,18,19,20,21,22,23,24 (depths:240,240,200,200,180,180,150,150,120,120 ,80,80,60,60,40,40,25,25,15,15,5,5,5,5m)
07/04/15	CTD_025T	Fe 10	48^{0}24.608'N 9^{0}53.391'W	Bottles:1,2,3,4,5,6,7,8,9,11,12,13,14,15,16, 17,18,19,20,21,22,23,24 (depths:1400,1350,1300,1200,1100,1000,900,800, 700,500,450,400,400,350,300,250, 200,150,100,75,50,20,20m)
07/04/15	CTD_027T	Fe 08	48^{0}34.23.N 9.54.82'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,14,15, 16,17,18,19,20,21,22,23,24 (depths:2460,2300,2100,1900,1750,1650, 1500,1250,1000,900,800,700,650,600,500, 400,300,250,200,150,100,75,50,20m)
08/04/15	CTD_028T	067 Fe 09	48 23.972N 009 54.82W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,14,15, 16,17,18,19,20,21,22,23,24 (depths:1811,1800,1750,1500,1250,1250, 1150,950,800,800,700,600,500,400,370, 300,250,200,150,100,80,60,40,20m)
08/04/15	CTD_030	067 Fe 11	48^0 23.972N 009^{0}54.82W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,14 (depths:912,900,800,700,600,500,400,300, 200,150,100,80,40,20m)
09/04/15	CTD_033T	077 Fe 12	48^{0}25.779.N 009^{0}52.28W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12 (depths:650,550,450,400,300,200,150,100, 80,40,20,20m)
09/04/15	CTD_035T	079 Fe 13	48^{0}26.247'N 009^0.51.798 W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12 (depths:475,475,400,400,300,200,150,100,80,50,2 0,20m)
09/04/15	CTD_038T	084 Fe 14	49^{0}29.494N 009^{0}48.529 W	Bottles:1,2,3,4,5,6,7,8,9,10 (depths:243,243,200,150,100,80,50,40,20, 20m)
10/04/15	CTD_041SS	098 CS2	48^{0}34.26'N 009 30.59W	Bottles:2,4,5,6,7,8,9,11,12,13,15,16,17,18, 19,20,23,24 (depths:190,180,80,80,80,65,55,45,45,45, 29,22,22,16,16,8,5,5,5m)
10/04/15	CTD_042SS	099 CS2	48^{0}34.268'N 9^{0}30.596'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,1 8,19,20,21,22,23,24

Date	CTD	Site	Position	CTD bottle analysed
				(depths:190,190,182,140,100,100,75,60,60,50,38,38,38,25,25,25,15,15,15,5,5,5,5,5m)
10/04/15	CTD_044T	101 Fe 04	48^{0}51.207'N 09^{0}11.966'W	Bottles:2,3,4,5,6,7,8,9 (depths:150,140,110,80,60,40,25,20,20m)
10/04/15	CTD_046SS	0103 02	49^{0}7.703'N 8^{0}54.270'W	Bottles:21,22,23,24 (depths: 33,25,15,6m)
10/04/15	CTD_047T	0105 Fe 02	49^{0}07.703'N 8^{0}54.270'W	Bottles:2,3,4,5,6,7,8,9,10,11 (depths:145,130,100,80,80,60,40,25,20, 20m)
11/04/15	CTD_049SS	111 CCS	49^{0}23.87'N 8^0.34.897'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,15,16, 17,18,19,20,21,22,23,24 (depths:130,130,120,120,70,70,70,50,40,40,30,30, 30,20,15,15,10,10,5,5,5,5,5m)
12/04/15	CTD_052T	131 CCS	49^{0}24.834'N 8^{0}35.369W	Bottles:1,2,3,4,5,6,7,8,9,10,11 (depths:135,135,120,120,100,80,80,40,30, 20,20,5m)
13/04/15	CTD_053SS	143 A	51^0 .12.87'N 6^{0}7.775'W	Bottles:23,19,17,15,12,10,8,6,5,1 (depths: 90,80,70,60,50,40,30,20,10 5m)
13/04/15	CTD_054T	144 A Fe	51.12.705'N 6^{0}7.775'W	Bottles:1,2,3,4,5,6,7,8,9,10 (depths: 95,95,95,80,80,60,45,35,20,20m)
14/04/15	CTD_057T	147 J02	50^{0}49.705'N 6^{0}39.977'W	Bottles:1,2,3,4,5,6,7,8,9 (depths: 90,90,80,80,60,40,30,20,20m)
14/04/15	CTD_058SS	148 J2	50^{0}49.705'N 6^{0}39.977'W	Bottles:2,3,6,7,10,11,13,16,19,20,23 (depths: 90,80,70,60,50,45,40,30,20,10,5m)
14/04/15	CTD_059SS	151 J4	50^{0}25.212'N 7^{0}13.694'W	Bottles:2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18, 19,20,21,23,24 (depths:100,80,8065,65,52,52,52,45,45,45, 35,35,35,22,22,22,12,12,12,5,5m)
14/04/15	CTD_060T	152 Fe0J4	50^{0}25.212'N 7^{0}13.694'W	Bottles:1,2,3,4,5,6 (depths:100,80,60,40,30,20m)
14/04/15	CTD_061SS	153	50^0.795'N 7^{0}46.500'W	Bottles:1,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18, 20,21,22,23,24 (depths:105,80,80,60,60,40,40,33,33,28,28,23,23,23,15,15,1510,5,5,5,5m)
14/04/15	CTD_062T	154 J6 Fe	50^{00}0.795'N 7^0.46.500'W	Bottles 1,2,3,4,5,6,7,8,9 (depths:110,110,80,60,60,40,30,20,2095,70,50,15, 20,15,10,5m)
15/04/15	CTD_064SS	156 CCS	49^{0}24.575'N 8^{0}35.158W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,14,15, 16,18,19,20,22,23,24 (depths:135,135,125,125,70,70,70,45,45,35,25,25, 25,16,16,13,10,10,5,5,5m)
15/04/15	CTD_065SS	158 CCS	49^{0}23.539'N 8^{0}35.605'W	Bottles:2,4,5,6,7,8,9,10,11,12,13,15,16,17, 18,19,21,22,23,24 (depths:132,120,90,90,75,75,65,65,50,50, 42,33,33,22,22,14,8,8,4,4m)
16/04/15	CTD_068SS	173 CCS	49 23.511'N 08 35.601'W	Bottles:1,2,3,4,5,7,8,9,10,11,12 (depths:34,34,34,22,22,12,12,12,4,4,4m)
16/04/15	CTD_069SS	179 CCS	49 23.952 'N 08 36.565'W	Bottles:2,3,4,5,6,7,8,10,11,12,13,14,15,16, 17,18,19,20,21,22,23,24 (depths:130,130,105,105,75,75,60,60,55,45,45,35, 35,25,25,20,20,15,15,10,10,5,5m)
16/04/15	CTD_070T	180 CCS Fe	49 23.952'N 08 36.565'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13 (depths:140,140,140,100,100,100,70,70,70,40,30,20,20m)
17/04/15	CTD_071SS	199 CS2	48 34.31 'N 09 30.63'W	Bottles:14,2,3,4,7,8,9,10,11,12,13,15,16,17,18,19,20,22,23,24 (depths:185,185,150,150,100,80,80,60,60, 40,40,30,30,20,20,2010,10,5,5,5m)

Date	CTD	Site	Position	CTD bottle analysed
17/04/15	CTD_073T	201 Fe01	48 12.29'N 10 03.23'W	Bottles:1,2,3,4,6,7,8,9,10,11,12,13,14,15,16,17,18, 19,20,21,22,23,24 (depths:2470,2440,2300,2000,1500,1300, 1000,950,850,750,650,550,400,300,200, 150,100,90,70,60,40,20m)
18/04/15	CTD_077T	205 Fe02	48 14.37'N 09 57.930'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,14,15, 16,17,18,19,20,21,22,23,24 (depths:1972,1972,1800,1650,1550,1550, 1300,1100,1100,950,750,650,550,400,300, 200,150,100,90,60,60,40,20,20m)
18/04/15	CTD_081T	209 Fe 15	48 17.997'N 09 48.026'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,14,15, 16,17,18,19,20,21,22,23,24 (depths:1507,1507,1350,1100,1100,900, 850,750,700,700,600,550,550,400,350,200,200,15 0,100,65,65,45,20,20m)
18/04/15	CTD_084T	212 Fe 03	40 20.452'N 09 42.269'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,14,15, 16,17,18,19,20,21,22,23,24 (depths:1477,1477,1300,1200,1100,1100, 950,850,750,750,700,650,650,550,400, 300,200,150,150,100,60,60,40,20
19/04/15	CTD_086T	216 Fe 04	48 22.205'N 09 37.728'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,1 8,19,20,21,22,24(depths:1000,1000,1000,950,950, 950,850,750,750,650,650,650,550,400,300,200,10 0,100,100,70,70,40,20m)
19/04/15	CTD_089T	219 Fe 05	48 22.686'N 9 36.514'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,14,15, 16 (depths:741,741,650,650,650,500,450,450, 450,250,100,100,100,70,40,20m)
19/04/15	CTD_092T	222 Fe 06	48 24.532'N 9 31.580'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,14,15, 16,17 (depths:467,467,467,400,400,400,225,225, 225,225,100,100,100,70,70,70,40,20m)
20/04/15	CTD_094SS	224 CCS	49 24.030'N 8 37.139'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,14,15, 16,17,18,19,20,21,22,23,24 (depths:140,140,130,130,70,70,70,48,38,38,28,28, 28,20,20,15,15,11,11,5,5,5,5,5m)
20/04/15	CTD_097 SS	227 CCS	49 24.064'N 8 37.268 'W	Bottles:1,2,4,5,6,7,8,9,10,11,12,13,14,15,16, 17,20,22,23,24 (depths:130,130,95,70,70,55,55,47,42,42, 36,36,26,26,20,20,14,10,5,5m)
21/04/15	CTD_100 SS	241 CCS	49 24.098'N 8 37.221'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,14,15, 16,17,18,19,20,21,22,23,24 (depths:137,137,95,95,60,60,50,50,45,45, 35,35,35,30,30,25,25,20,20,20,14,14,5,5m)
21/04/15	CTD_101SS	246 CCS	49 24.012'N 8 38.060'W	Bottles:1,2,3,5,6,7,8,9,10,11,12,13,14,15,16, 17,18,19,20,21,22,23,24 (depths:132,132,105,90,90,75,75,50,50,40, 40,35,35,25,25,20,20,15,15,10,10,5,5m)
21/04/15	CTD_102T	247 CCS Fe	49 24.012'N 8 38.060'W	Bottles:1,2,3,4,5,6 (depths:140,105,70,45,35,20m)
22/04/15	CTD_103T	265 Fe 16	48 25.250'N 9 56.490'W	Bottles:1,2,4,5,6,7,8,9,10,11,12,13,14,15,16, 17,18,19,20,21,22,23,24 (depths:2400,2400,2000,2000,1750,1500, 1500,1300,1000,950,850,750,650,500,400, 300,200,150,100,70,50,35,20m)
22/04/15	CTD_104SS	266 Fe17	48 32.006'N 9 56.010'W	Bottles:2,9,11,14,19,23 (depths:504,250,100,60,25,5m)

Date	CTD	Site	Position	CTD bottle analysed
22/04/15	CTD_105T	267 Fe 17	48 32.006'N 9 56.009'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,14,15, 16,17,18,19,20,21,22,23,24 (depths:2015,2015,1850,1850,1750,1550, 1550,1350,1050,1050,900,850,750,750, 650,550,400,300,250,125,70,50,30m)
22/04/15	CTD_106T	268 Fe 18	48 34.679'N 9 55.378'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,14,15, 16,17,18,19,20,21,22,23,24 (depths:1510,1510,1450,1350,1350,1100, 1100,950,850,750,750,650,550,500,425, 400,300,200,200,100,70,50,35,20m)
23/04/15	CTD_108T	272 Fe 19	48 37.015'N 9 49.917'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,14,15, 16,17,18,19,20 (depths:1062,1062,950,950,850,750,750, 650,500,400,400,350,250,125,125,100,75, 55,55,20m)
23/04/15	CTD_109SS	273 Fe 20	48 37.015'N 9 49.917'W	Bottles:2,3,6,12,18,23 (depths:500,250,100,50,15,5m)
23/04/14	CTD_110T	274 Fe 20	48 37.515'N 9 47.628'W	Bottles:1,2,3,4,6,7,8,9,10,11,12,13,14,15,16 (depths:758,758,650,650,450,450,300,175, 125,100,100,70,50,30,20m)
23/04/15	CTD_111T	275 Fe 21	48 37.597'N 9 46.998'W	Bottles:1,2,3,4,5,6,7,10,11,12,13 (depths:503,450,400,300,200,165,100,70, 55,30,20m)
23/04/15	CTD_112T	276 Fe 22	48 40.010'N 9 42.002'W	Bottles:1,2,3,4,5,6,7,10,11,12,13 (depths:269,269,200,200,150,120,120,80, 80,50,20m)
24/04/15	CTD_113 SS	277 CS2	48 34.276'N 9 30.567'W	Bottles:1,2,3,4,6,7,8,9,10,11,12,13,14,15,16, 17,18,19,20,21,22,23,24 (depths:185,185,175,175,125,70,70,70,40, 40,30,30,30,24,24,18,18,13,13,7,7,5,5m)
24/04/15	CTD_116SS	285 CS2	48 34.266'N 9 30.581'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,14,15, 16,17,19,20,21,22,23,24 (depths:192,192,100,100,70,70,50,50,50,30, 30,30,20,20,20,15,15,10,10,10,5,5,5m)
24/04/15	CTD_118T	291 Fe CS2	48 33.987'N 9 30.555'W	Bottles:1,2,3,4,5,6,7,9,10,11,12,13,14,15,16,17 (depth:170,170,170,150,150,150,100,100, 100,70,70,70,40,30,20,20m)
25/04/15	CTD_120SS	293 CCS	49 24.090'N 8 37.172'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,14,15, 16,17,18,19,20,21,22,23,24 (depths:132,132,120,120,95,70,70,70,45,45, 35,35,35,24,24,18,18,12,12,6,6,5,5,5m)
25/04/15	CTD_124SS	301 CCS	49 24.568'N 8 35.478'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,14,15,16, 17,18,19,20,21,22,23,24(depths:133,133,90, 90,60,60,45,45,45,30,30,30,20,20,15,15,15, 10,10,10,5,5,5m)
26/04/15	CTD_127T	323 Fe CCS	49 24.490'N 8 35.237'W	Bottles:1,2,4,5,6 (depths:135,100,50,30,20m)
26/04/15	CTD_128SS	324 CCS	49 24.490'N 8 35.237'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,14,15,16, 17,18,19,20,21,22,23,24 (depths:135,135,80,80,55,55,42,42,34,34, 30,30,20,16,16,10,10,5,5,5,5,5,5m)
27/04/15	CTD_130T	326 Fe A	51 12.786'N 6 7.800'W	Bottles:I,J,K,L,M,N (depths:93,80,60,45,30,20m)
27/04/15	CTD_131SS	327 A	51 12.786'N 6 7.800'W	Bottles:2,3,4,5,6,7,8,9,10,11,12,13,14,15,16, 17,18,19,20,21,22,23,24 (depths:95,85,85,70,70,70,50,40,40,30,30,

Date	CTD	Site	Position	CTD bottle analysed
				30,20,20,15,15,10,10,5,5,5,5,5m)
27/04/15	CTD_132T	328 Fe J2	50 49.680'N 6 39.937'W	Bottles:1,2,3,4,5,6(depths:90,80,55,35,25, 20m)
27/04/15	CTD_133SS	329 J2	50 49.680'N 6 39.937'W	Bottles:2,4,5,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22(depths:90,70,40,28,28,24, 24,18,18,15,15,15,8,8,8,5,5,5,5m)
27/04/15	CTD_134SS	330 J4	50 25.197'N 7 13.657'W	Bottles:1,2,3,4,5,6,7,8,9,10,11,12,13,14,15, 16,17,18,19,20,21,22,23,24 (depths:97,97,70,70,50,50,34,34,26,26,26, 22,22,20,20,18,18,16,16,12,12,5,5,5m)
27/04/15	CTD_135T	331 Fe J4	50 25.197'N 7 13.657'W	Bottles:1,2,3,4,5,6
27/04/15	CTD_136SS	332 J6	50 0.786'N 7 46.582'W	Bottles: 2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,18,19,21,22,23,24(depths:105,85,85,65,65,45,45,37,37,32,32,28, 28,24,24,18,14,10,10,5,5m)
27/04/15	CTD_138T	333 Fe J6	50 0.786'N 7 46.582'W	Bottles:2,3,4,5,6,7 (depths:111,85,45,35,30,20m)
28/04/15	CTD_139T	338 Fe CCS	49 24.352'N 8 34.851'W	Bottles:2,3,4,5,6,7 (depths:135,100,75,50,30,20m)
28/04/15	CTD_140SS	341 CCS	49 24.352'N 8 34.851'W	Bottles:2,3,4,5,7,8,9,10,11,12,13,14,15,16, 17,18,19,20,21,22,23,24 (depths:135,135,100,100,60,60,60,46,46,46, 41,41,41,35,35,35,25,25,15,15,5,5m)

Thanks:

To the officers and engineers of RRS Discovery, the NMF technicians and crew who made things work for us and kept them working, and of course the catering team for excellent food.

10. Dissolved & particulate material

Clare Davis & Calum Preece (Liverpool)

Dissolved nutrient sampling protocols

Total dissolved phosphorus (TDP): Samples were collected from between 6 and 12 depths from the CTD and were filtered through 47 mm GF/F (combusted, Whatman, nominal pore size 0.7 µm) and stored in acid-cleaned 175 mL HDPE bottles at -20°C for later laboratory analysis to determine total dissolved phosphorus concentration.

Dissolved organic carbon (DOC) and total dissolved nitrogen (TDN): Samples were collected from between 6 and 12 depths from the CTD and were filtered through 47 mm GF/F (combusted, Whatman, nominal pore size 0.7 µm) and stored in 20 mL muffled glass vials with 20µL 50% hydrochloric acid and stored at 4°C for later laboratory analysis.

Dissolved free and total hydrolysable amino acids (DFAA, THAA): Samples were collected from between 6 and 12 depths from the CTD and were filtered through 47 mm GF/F (combusted, Whatman, nominal pore size 0.7 µm) and stored in 20 mL muffled glass vials at -20°C for later laboratory analysis.

Coloured Dissolved Organic Matter (CDOM): Samples were collected from between 6 and 12 depths from the CTD and underway system. Samples were filtered through 47 mm GF/F (combusted, Whatman, nominal pore size 0.7 µm) and then through 0.2 µm Durapore filters. Samples were kept in the dark and analysed on board using a Shimadzu UV-1650PC spectrophotometer and a Horiba Fluoromax-4 spectrofluorometer. Data will later be processed using PARAFAC by Nealy Carr (Sensors on Gliders PhD student) to determine the source and composition of CDOM.

Stable isotopes of dissolved nitrate ($\delta^{15}N$) : Samples were collected from 6 to 12 depths from the predawn CTDs. Samples for the $\delta^{15}N$ and $\delta^{18}O$ of nitrate were filtered through 47 mm GF/F (combusted, Whatman, nominal pore size 0.7 µm) and stored in 60 mL HDPE bottles (HCl acid washed) at -20 °C for later analysis.

Particulate nutrients sampling protocols

Particulate organic carbon (POC), particulate organic nitrogen (PON) and particulate phosphorus (POP): Samples were collected from 8 depths from the predawn CTDs and marine snow catcher deployments. For particulate carbon and nitrogen (POC/PON), 2L was filtered onto 25 mm GF/F (combusted, Whatman, nominal pore size 0.7µm) on a plastic filter rig under <12 kPa vacuum pressure. For particulate phosphorus (POP), 1L was filtered onto 25 mm GF/F (combusted and HCl acid washed,

Whatman, nominal pore size 0.7µm) on a plastic filter rig under <12 kPa vacuum pressure. All filters were stored at -80°C for later laboratory analysis.

Particulate lipids, pigments and particulate amino acids: Samples were collected from 8 depths from the predawn CTDs and marine snow catcher (lipids only). For separate lipid, pigment and amino acid samples, 2L was filtered onto 47 mm GF/F (combusted, Whatman, nominal pore size 0.7µm) on a 3-port glass filter rig under <12 kPa vacuum pressure. Filters were stored at -80°C for later laboratory analysis.

δ^{15}N of particulate nitrogen (δ^{15}PN): Samples were collected from 8 depths from the predawn CTDs. Samples for δ^{15}N-particulate nitrogen were collected by filtering 1-2L onto 25 mm GF/F (combusted, Whatman, nominal pore size 0.7 µm) and stored at -80°C for later analysis. Samples for the δ^{15}N and δ^{18}O of nitrate were collected and stored in 60 mL HDPE bottles (HCl acid washed) and stored unfiltered at -20 °C for later analysis.

Stand Alone Pump System (SAPS): Two to three depths were sampled during each SAPS deployment to collect samples for POC, PON, POP, particulate lipids, particulate amino acids and pigments from two fractions: particles >53 µm and particles between 0.7 – 53 µm. The surface mixed layer SAPS was deployed at the depth of the chlorophyll maximum, the mid depth SAPS was deployed at 5 m below the base of the thermocline, and the deep SAPS was deployed at ~50 m below the base of the thermocline (often equivalent to 50 m off the bed). The SAPs was programmed to pump for 1 hour once at that depth. Upon recovery, the 53 µm mesh fraction was washed onto a 47 mm GF/F (combusted, Whatman, nominal pore size 0.7µm) which was stored at -80°C for later analysis. Below the mesh were two 27.3 cm diameter GF/Fs (combusted, Whatman, nominal pore size 0.7 µm) one was the sample GF/F and the second was stored as the blank GF/F, both were stored at -80 °C for later analysis.

SAMPLE INVENTORY:

Dissolved nutrient (DOC, TDN, TDP, DFAA, THAA, CDOM, $\delta^{15}N$) sampling from the stainless steel CTD:

EV009 ROS02, ROS04, ROS07, ROS09, ROS12, ROS16, ROS23
EV012 ROS01, ROS03, ROS05, ROS21
EV015 ROS03, ROS07, ROS09, ROS13, ROS17, ROS21
EV030 ROS01, ROS02, ROS03, ROS06, ROS08
EV033 ROS04, ROS07, ROS09, ROS11, ROS17, ROS21
EV047 ROS01, ROS07, ROS09, ROS12, ROS18, ROS23
EV049 ROS01, ROS07, ROS13, ROS15, ROS19, ROS21
EV098 ROS03, ROS06, ROS09, ROS12, ROS18, ROS23
EV099 ROS03, ROS04, ROS07, ROS11, ROS15, ROS20
EV111 ROS01, ROS03, ROS06, ROS09, ROS12, ROS15, ROS18, ROS23
EV115 ROS03, ROS05, ROS09, ROS11, ROS15, ROS20
EV143 ROS02, ROS07, ROS11, ROS16, ROS18, ROS22
EV148 ROS01, ROS08, ROS09, ROS12, ROS18, ROS24
EV151 ROS01, ROS07, ROS11, ROS14, ROS17, ROS23
EV153 ROS01, ROS03, ROS05, ROS07, ROS11, ROS13, ROS16, ROS21
EV156 ROS01, ROS03, ROS06, ROS08, ROS12, ROS18, ROS23
EV159 ROS04, ROS09, ROS24
EV179 ROS02, ROS05, ROS10, ROS12, ROS14, ROS16, ROS20, ROS24
EV199 ROS01, ROS06, ROS09, ROS13, ROS16, ROS22
EV224 ROS01, ROS03, ROS06, ROS09, ROS12, ROS18, ROS23
EV227 ROS01, ROS04, ROS07, ROS10, ROS12, ROS23
EV246 ROS01, ROS05, ROS09, ROS11, ROS13, ROS15, ROS19, ROS23
EV277 ROS01, ROS03, ROS05, ROS07, ROS09, ROS12, ROS14, ROS18, ROS23
EV293 ROS01, ROS03, ROS05, ROS07, ROS09, ROS11, ROS14, ROS18, ROS23
EV327 ROS03, ROS06, ROS09, ROS12, ROS18, ROS23

Dissolved nutrient (DOC, TDN, TDP, DFAA, THAA, CDOM, $\delta^{15}N$) sampling from the titanium CTD:

EV064 ROS01, ROS04, ROS08, ROS09, ROS12, ROS15, ROS17, ROS19, ROS21, ROS23
EV066 ROS01, ROS03, ROS05, ROS07, ROS09, ROS11, ROS13, ROS15, ROS17, ROS19, ROS21, ROS23
EV067 ROS01, ROS03, ROS05, ROS07, ROS09, ROS11, ROS13, ROS15, ROS17, ROS19, ROS19, ROS21, ROS23
EV069 ROS01, ROS03, ROS05, ROS07, ROS09, ROS11, ROS13
EV077 ROS01, ROS03, ROS04, ROS05, ROS07, ROS09, ROS10, ROS12
EV079 ROS03, ROS06, ROS08, ROS09, ROS10, ROS12
EV084 ROS02, ROS03, ROS04, ROS05, ROS06, ROS07, ROS08, ROS09
EV101 ROS02, ROS03, ROS04, ROS05, ROS06, ROS07, ROS08, ROS10
EV104 ROS02, ROS03, ROS04, ROS06, ROS07, ROS08, ROS09, ROS10
EV131 ROS01, ROS03, ROS05, ROS07, ROS08, ROS11
EV201 ROS01, ROS03, ROS05, ROS07, ROS10, ROS12, ROS14, ROS16, ROS18, ROS18, ROS20, ROS22, ROS24
EV205 ROS01, ROS03, ROS06, ROS10, ROS12, ROS14, ROS16, ROS18, ROS21, ROS24
EV209 ROS01, ROS05, ROS07, ROS10, ROS13, ROS15, ROS18, ROS21, ROS24
EV212 ROS01, ROS04, ROS07, ROS09, ROS13, ROS16, ROS19, ROS22, ROS24

EV216 ROS05, ROS09, ROS12, ROS14, ROS16, ROS21, ROS24
EV219 ROS01, ROS05, ROS09, ROS11, ROS14, ROS16
EV222 ROS01, ROS07, ROS14, ROS17
EV265 ROS01, ROS04, ROS07, ROS09, ROS12, ROS14, ROS15, ROS17, ROS20, ROS22, ROS24
EV267 ROS01, ROS04, ROS06, ROS08, ROS10, ROS12, ROS14, ROS16, ROS18, ROS20, ROS22, ROS24
EV268 ROS01, ROS04, ROS08, ROS11, ROS13, ROS15, ROS17, ROS20, ROS22, ROS24
EV274 ROS04, ROS07, ROS09, ROS12, ROS14, ROS16
EV275 ROS01, ROS02, ROS05, ROS07, ROS10, ROS11, ROS12, ROS13
EV328 ROS01, ROS02, ROS03, ROS04, ROS05, ROS06
EV331 ROS01, ROS02, ROS03, ROS04, ROS05, ROS06
EV334 ROS02, ROS03, ROS04, ROS05, ROS06, ROS07
EV339 ROS02, ROS03, ROS04, ROS05, ROS06, ROS07

Particulate nutrient (POC, PON, POP, LIPIDS, PIGMENTS, AMINO ACIDS, δ^{15}PN) samples collected from the stainless steel CTD:

EV009 ROS02, ROS04, ROS07, ROS09, ROS12, ROS16, ROS23
EV098 ROS03, ROS06, ROS09, ROS12, ROS18, ROS23
EV111 ROS01, ROS03, ROS06, ROS09, ROS12, ROS15, ROS18, ROS23
EV143 ROS02, ROS07, ROS11, ROS16, ROS18, ROS22
EV156 ROS01, ROS03, ROS06, ROS08, ROS12, ROS18, ROS23
EV224 ROS01, ROS03, ROS06, ROS09, ROS12, ROS18, ROS23
EV277 ROS01, ROS03, ROS07, ROS09, ROS12, ROS14, ROS18, ROS23
EV293 ROS01, ROS03, ROS07, ROS09, ROS11, ROS14, ROS18, ROS23
EV327 ROS03, ROS06, ROS09, ROS12, ROS18, ROS23

Marine Snow Catcher samples (POC, PON, POP, LIPIDS):

EV137 10M 49 24.83 °N 08 35.36 °W
EV138 70M 49 24.79 °N 08 35.40 °W
EV185 10M 49 24.09 °N 08 36.75 °W
EV188 70M 49 24.30 °N 08 37.06 °W
EV251 10M 49 24.22 °N 08 37.32 °W
EV258 70M 49 24.90 °N 08 36.32 °W
EV283 80M 48 34.27 °N 09 30.58 °W
EV284 15M 48 34.27 °N 09 30.58 °W

SAPS deployments (POC, PON, POP, LIPIDS, PIGMENTS, AMINO ACIDS):

EV041 70M 49 24.56 °N 08 35.39 °W
10M 49 24.56 °N 08 35.39 °W

EV132 100M 49 24.83 °N 08 35.36 °W
60M 49 24.83 °N 08 35.36 °W
20M 49 24.83 °N 08 35.36 °W

EV186	100M 49 24.21 °N 08 35.65 °W
	60M 49 24.21 °N 08 35.65 °W
	15M 49 24.21 °N 08 35.65 °W
EV253	100M 49 24.43 °N 08 37.10 °W
	45M 49 24.43 °N 08 37.10 °W
	15M 49 24.43 °N 08 37.10 °W
EV254	15M 49 24.43 °N 08 37.10 °W
EV300	100M 49 24.57 °N 08 35.47 °W
	40M 49 24.57 °N 08 35.47 °W
	15M 49 24.57 °N 08 35.47 °W

11. Chlorophyll-*a* & particulate silicate

James Fox (University of Essex), Glen Tarran (Plymouth Marine Laboratory) & Alex Poulton (National Oceanography Centre, Southampton)

Methods

Water samples for total chlorophyll-*a* (chl-*a*) analysis were mainly collected from pre-dawn and midday CTD casts, with samples for size-fractionated chl-*a* collected from various casts, both pre-dawn and midday. Samples for total chl-*a* were collected by filtering 200-250 ml sea water samples through 25 mm diameter Fisherbrand MF300 filters or 25 mm diameter Whatman GFF filters (effective pore size 0.7 µm). Samples for size-fractionated chl-*a* were collected by sequentially filtering 100-250 ml of seawater through 47 mm diameter 20 µm, 2 µm and 0.2 µm filters. Filters were extracted in 8 mL of 90% acetone for 18-20 h and the resulting chl-*a* fluorescence was measured on a Turner Trilogy fluorometer calibrated against a solid standard and a chl-*a* extract (Sigma).

Water samples for analysis of biogenic silica ($bSiO_2$) concentrations were only collected from pre-dawn CTD casts. Samples for $bSiO_2$ were collected by filtering 500 mL seawater samples through 25 mm 0.8 µm pore size Nucleopore filters, oven dried (50-60^{o}C, 10-12 h) and stored in 15 mL centrifuge tubes for later analysis following Poulton et al. (2006).

References

Poulton et al. (2006) Phytoplankton mineralization in the tropical and subtropical Atlantic Ocean. Global Biogeochemical Cycles 20, GB4002.

Table 15. Stations and Niskin bottles sampled for total and size-fractionated Chlorophyll

Date	Time (GMT)	Event no.	Site	Niskin bottles	Notes
02/04/15	1713	001	CCS	1, 7, 10, 14, 21, 23	Test station
03/04/15	1430	005	CCS	21, 22, 23, 24	
03/04/15	1538	006	CCS	3, 5, 7, 9, 11, 13	Titanium CTD
04/04/15	0205	009	CCS	13, 14, 16, 19, 20, 23	Total and Size-frac.
04/04/15	1249	015	CCS	3, 7, 9, 13, 17, 21	
05/04/15	1454	033	CCS	7, 9, 11, 13, 17, 21	
06/04/15	0214	047	CCS	13, 15, 16, 19, 20, 24	Total and Size-frac.
06/04/15	1408	049	Fe08	3, 7, 9, 11, 15, 17, 21	Titanium CTD
08/04/15	2211	064	Fe10	16, 19,20, 21, 22, 23	Titanium CTD
08/04/15	0524	066	Fe08	16, 19, 20, 21, 22, 23, 24	Titanium CTD
08/04/15	1050	067	Fe09	16, 19, 20, 22, 23, 24	Titanium CTD
08/04/15	1600	069	Fe11	10, 11, 12, 13, 14	Titanium CTD
09/04/15	0337	077	Fe12	12, 12, 10 9, 8	Titanium CTD
09/04/15	0723	079	Fe13	8, 9, 10, 11	Titanium CTD
09/04/15	0959	082	Fe13	24, 23, 22, 24	Titanium CTD, total and Size-frac.
09/04/15	1250	084	Fe14	6, 7, 8, 9	Titanium CTD
10/04/15	0207	098	CS2	13, 15, 16, 19, 20, 24	Total and Size-frac.
10/04/15	1206	102	O4	9, 10, 12, 15, 22, 23	Total and Size-frac.
10/04/15	1459	103	O2	9, 11, 13, 20, 21, 23	Total and Size-frac.
11/04/15	0210	111	CCS	10, 13, 15, 16, 19, 20	Total and Size-frac.
11/04/15	1128	115	CCS	7, 9, 13, 16, 19, 23	
12/04/15	0547	131	CCS	5, 7, 8, 9, 11	
13/04/15	2115	143	A	9, 13, 15, 17, 20, 23	Total and Size-frac.
14/04/15	0357	147	J2	9	
14/04/15	0508	148	J2	7, 13, 16, 19, 20, 23	Total and Size-frac.
14/04/15	0625	151	J4	5, 11, 13, 17, 20, 23	Total and Size-frac.
14/04/15	1508	153	J6	6, 8, 12, 17, 20, 23	Total and Size-frac.
15/04/15	0202	156	CCS	7, 13, 14, 16, 19, 23	Total and Size-frac.
15/04/15	1212	159	CCS	10, 15, 18, 20, 22, 23,	[Peak Chl at CCS]
16/04/15	1241	179	CCS	8, 14, 16, 18, 20, 24	Total and Size-frac.
17/04/15	0659	199	CS2	9, 11, 15, 17, 19, 23	Total and Size-frac.
17/04/15	1334	201	Fe01	22, 23, 24, 16, 18, 20, 21	Titanium CTD
18/04/15	0051	205	Fe02	24	Titanium CTD
18/04/15	1045	209	Fe02	17, 18, 19, 20, 22, 23	Titanium CTD
18/04/15	1618	212	Fe03	17, 19, 20, 21, 23, 24	Titanium CTD
19/04/15	0610	216	Fe04	15, 16, 17, 21, 22, 24	Titanium CTD
19/04/15	1055	219	Fe05	9, 10, 13, 14, 15, 16	Titanium CTD
19/04/15	1445	222	Fe06	4, 8, 10, 14, 15, 16	Titanium CTD
20/04/15	0214	224	CCS	10, 13, 14, 16, 19, 24	Total and Size-frac.
20/04/15	1158	227	CCS	8, 12, 14, 16, 20, 23	Total and Size-frac.
20/04/15	1859	233	CCS	8, 10, 12, 23	
21/04/15	0806	241	CCS	6, 12, 16, 18, 21, 24	Total and Size-frac.
21/04/15	1230	246	CCS	21, 19, 17, 15, 13, 9	
22/04/15	0625	265	Fe16	19, 20, 21, 22, 23, 24	Titanium CTD
22/04/15	1014	266	Fe17	7, 10, 13, 16, 19, 22	
22/04/15	1238	267	Fe17	19, 20, 21, 22, 23, 24	Titanium CTD
23/04/15	0900	272	Fe19	13, 14, 16, 17, 18, 20	Titanium CTD
23/04/15	1205	273	Fe20	7, 10, 13, 16, 20, 24	
23/04/15	1312	274	Fe20	10, 12, 13, 14, 15, 16	Titanium CTD
24/04/15	0206	277	CS2	13, 15, 16, 17, 20, 24	Total and Size-frac.
24/04/15	1322	285	CS2	8, 11, 14, 16, 20, 23	Total and Size-frac.
25/04/15	0200	293	CCS	12, 15, 16, 19, 20, 24	Total and Size-frac.
25/04/15	1202	301	CCS	8, 11, 14, 17, 20, 23	Total and Size-frac.
26/04/15	0646	324	CCS	6, 12, 13, 16, 17, 21	Total and Size-frac.

27/04/15	0301	327	A	7, 13, 14, 16, 19, 24	Total and Size-frac.
27/04/15	0803	329	J2	7, 9, 11, 13, 18, 19	Total and Size-frac. [Cocccolithophore bloom]
27/04/15	1221	330	J4	5, 9, 12, 15, 18, 22	Total and Size-frac.
27/04/15	1711	332	J6	9, 13, 15, 18, 21, 24	Total and Size-frac.
28/04/15	0821	341	CCS	9, 12, 17, 20, 22, 24	Total and Size-frac.

12. Primary production, calcite production, phosphorus uptake & size-fractionated primary production

Chris Daniels (National Oceanography Centre - Southampton) & Kyle Mayers (University of Southampton)

Rationale

As part of the pelagic component of the Shelf Sea Biogeochemistry (SSB) research programme we collected samples for phytoplankton enumeration and made biogeochemical rate measurements from six CTD profiles at the two process sites (Central Celtic Sea, Shelf Edge) sampled during DY018. Rate measurements included short term (6 h) measurements of carbon fixation and phosphorus uptake, and the production of dissolved organic carbon (DOC) and phosphorus (DOP), as well as long term (24 h) measurements of calcite production, silica uptake and size-fractionated (0.2-2 µm, 20-20 µm, >20 µm) primary production. Combined these measurements will allow us to examine biogeochemical interactions between carbon (C), phosphorus (P) and silica (Si) uptake (and recycling) by autumnal phytoplankton communities, as well as examine growth dynamics of coccolithophores and diatoms in shelf sea environments. An identical suite of samples and measurements will be collected on the 2015 SSB cruises allowing seasonal changes in these processes to be fully examined. The underlying goal of this work is to address the hypothesis that 'autotroph community structure and resource (nutrients, light) availability influence the stoichiometry of organic matter through increasing C:N:P:Si ratios under resource limited conditions'.

Methods

Biogeochemical rate measurements were made at six process sites (Table 17) during DY029 using radioactive isotopes (^{14}C, ^{33}P, ^{32}Si) following methodology adapted from several references (Table 16). To summarise, carbon fixation (CFIX) and phosphorus uptake (PUP) were made on short term incubations (6 h), and the production of dissolved organic carbon (pDOC) and dissolved organic phosphorus (pDOP) were measured on filtrates from these incubations. Over 24 h, calcite production (CAL), size-fractionated primary production (SF-PP) and silica uptake (SIL) were also measured.

Incubations were carried out in an adapted refrigeration container (see Richier et al. 2014) where light depths in the water column were replicated through the use of LED light panels, grey light (neutral density) filters of varying optical density and a set day length of 9 h. Hence, the light levels (60%, 40%, 20%, 10%, 5% and 1% of incidental irradiance) had absolute light intensities which had been chosen to reflect the average light available at that percentage irradiance depth during November (pre-determined from 5 yrs of satellite PAR data). The absolute instantaneous light intensity for each light depth was checked using a 4 π light sensor (Biospherical Instruments). These absolute irradiance levels for DY029 were: 5.4 mol photons m^{-2} d^{-1} (60%

of average November incidental irradiance), 4.8 mol photons m^{-2} d^{-1} (40%), 2.3 mol photons m^{-2} d^{-1} (20%), 0.8 mol photons m^{-2} d^{-1} (10%), 0.5 mol photons m^{-2} d^{-1} (5%) and 0.2 mol photons m^{-2} d^{-1} (1%). Temperature of the refrigeration container was set at 13°C which was ± 1°C from mixed layer temperatures.

Table 16. Methodological details of the rate measurements made on DY029

Rate measurement	Incubation length	Methodological reference(s)	Synopsis
Carbon fixation (CFIX)	6 h (dawn + 6 h)	(1, 2)	^{14}C-labelled sodium bicarbonate addition; three light and one dark bottle.
DOC production (*p*DOC)	6 h (dawn + 6 h)	(3)	0.2 µm filtrate from CFIX light and dark bottles; 3 depths (60%, 20% and 1%) only; acidified to remove ^{14}C-DIC as ^{14}C-CO_2.
Phosphate uptake(PUP)	6 h (dawn + 6 h)	(4)	^{33}P-labelled orthophosphoric acid addition; three light and one dark bottle; P addition <5% of ambient concentrations.
DOP production (*p*DOP)	6 h (dawn + 6 h)	(4, 5)	0.2 µm filtrate from PUP light and dark bottles; three depths (60, 20 and 1%) only; 1 M NaOH addition to precipitate DIP and centrifuged.
Calcite production (CAL)	24 h (dawn-dawn)	(1)	^{14}C-labelled sodium bicarbonate addition; uses Micro-Diffusion Technique (Balch et al. 2000) to separate inorganic and organic particulate production; three light and one formalin-killed blank; measures coccolithophore calcite production (daily calcification) and community primary production.
Size-fractionated primary production (SF-PP)	24 h (dawn to dawn)	(2)	^{14}C-labelled sodium bicarbonate addition; sequential filtering through 20 µm, 2 µm and 0.2 µm filters.
Silica uptake (SIF)	24 h (dawn to dawn)	(6, 7)	^{32}Si-labelled silicic acid addition; duplicates only; hot NaOH digestion, neutralised with HCl.

Methodological references: (1) Poulton et al. (2014); (2) Poulton et al. (2006a); (3) Lopez-Sandoval et al. (2011); (4) Reynolds et al. (2014); (5) Karl and Tien (1992); (6) Poulton et al. (2006b); (7) Krause et al. (2010).

References

Karl and Tien (1992), MAGIC: A sensitive and precise method for measuring dissolved phosphorus in aquatic environments. Limnology and Oceanography 37, 105-116.

Krause et al. (2010), Production, dissolution, accumulation, and potential export of biogenic silica in a Sargasso Sea mode-water eddy. Limnology and Oceanography 55, 569-579.

Lopez-Sandoval et al. (2011), Dissolved and particulate primary production along a longitudinal gradient in the Mediterranean Sea. Biogeosciences 8, 815-825.

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Reynolds et al. (2014), Evidence for production and lateral transport of dissolved organic phosphorus in the eastern subtropical North Atlantic. Global Biogeochemical Cycles 28, 805-824.

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Table 17. Station details for biogeochemical rate measurements.

Date	Site	Event No.	Niskin bottles	CFIX	*p*DOC	PUP	*p*DOP	CAL	SF-PP
04/04/15	CCS	9	24,20,19,16,14,13,	X	X	X	X	X	X
06/04/15	CCS	47	24,20,19,16,14,13	X	X	X	X	X	X
10/04/15	CS2	98	24,20,19,16,14,13	X	X	X	X	X	X
11/04/15	CCS	111	24,20,19,16,14,13	X	X	X	X	X	X
15/04/15	CCS	156	24,20,19,16,14,13	X	X	X	X	X	X
20/04/15	CCS	224	24,20,19,16,14,13	X	X	X	X	X	X
24/04/15	CS2	277	24,20,19,16,14,13	X	X	X	X	X	X
25/04/15	CCS	293	24,20,19,16,15,12	X	X	X	X	X	X
27/04/15	A	327		X	X	X	X	-	-
27/04/15	J2*	329		-	-	-	-	X	-

* Coccolithophore bloom, only two depths sampled and incubations 6 h rather than 24 h.

13. Iron uptake

Chris Daniels (National Oceanography Centre - Southampton) & Kyle Mayers (University of Southampton)

Rationale

As part of an added value grant combining work packages 1 and 3 of the Shelf Sea Biogeochemistry (SSB) research programme, we made rate measurements of iron (Fe) uptake, carbon (C) fixation and phosphorus (P) uptake from 3 CTD profiles during DY029. Iron (Fe) is an essential micronutrient for phytoplankton which can ultimately limit productivity (e.g. Boyd et al. 2007; Moore et al. 2009). However, our understanding of the mechanisms and rates of microbial Fe uptake is poor. The objective of this work was to gain an enhanced process level understanding of Fe cycling in the Celtic Sea.

Methods

Samples were collected from pre-dawn trace metal clean titanium CTD casts. Unfiltered trace metal clean seawater was collected into an acid washed polycarbonate bottles. Samples for Fe uptake were decanted into acid washed 125mL incubation polycarbonate bottles, while samples for C and P were decanted into acid washed 70 mL flasks.

Samples for Fe uptake were spiked with ~1.7kBq of ^{55}Fe, added as weakly acidified (0.3% HCl) Fe(III)Cl, and then transferred to an incubator reflecting in situ light and temperature conditions. Each bottle was filtered down at a different time point (30 mins, 60 mins, 90 mins, 3 hours, 6 hours and 12 hours). At each point, samples were collected to measure total activity (1 mL), < 0.02 µm activity (1 mL filtered through a 0.02 Anatop), >0.2µm activity (2x ~40 mL through 2x 0.2 µm polycarbonate filters) and >2 µm activity (~40 mL through a 2 µm polycarbonate filter). To differentiate between uptake into cells relative to apparent uptake due to adsorption of 55Fe onto external cell surfaces, 1 of the 0.2µm polycarbonate filters, and the 2 µm polycarbonate filter were rinsed with a buffered Ti-EDTA-citrate solution which scavenges adhered ^{55}Fe (Hudson and Morel 1989). Samples were placed in 5 mL Ultima Gold before being counted in a liquid scintillation counter on board. Samples will be recounted after the cruise in an ultra-low-level spectrometer.

Measurements of C and P uptake were measured following the methodologies outlined in the preceding section, except that the samples were incubated inside the incubator with Fe bottles, and that the samples were filtered onto 0.2 µm and 2 µm polycarbonate filters.

Table 18. Dates and locations of ^{55}Fe uptake experiments

Date	Site	Event no.	CTD no.	Niskin no.	Depth (m)
09/04/15	Fe12	77	33_T	12	20
14/04/15	J2	147	57_T	9	20
18/04/15	Fe02	205	77_T	24	20

References

Boyd et al. (2007) Mesoscale iron enrichment experiments 1993-2005 : Synthesis and future directions. Science 315, 612-617

Moore et al. (2009) Large-scale distribution of Atlantic nitrogen fixation controlled by iron availability. Nature Geoscience 2, 867-871

Hudson and Morel (1989) Distinguishing between extra- and intracellular iron in marine phytoplankton. Limnology and Oceanography 34, 1113-1120

14. Gross & net production estimates from triple oxygen isotopes

Isablel Seguro (University of East Anglia)

Objectives:

1. Infer spatial variations of net (*N*) and gross (*G*) O_2 production rates from
2. O_2/Ar [*N* (O_2/Ar)] and triple oxygen isotopes [*G* (^{17}O)] in the Celtic Sea (spring bloom).
3. Derive 24 h in-situ production rates from diurnal changes at one process station.
4. Calculate seasonally integrated production estimates from cruise-to-cruise changes.
5. Compare *G* (^{17}O) with FRRF-based physiological turnover and CO_2 fixation rates.
6. Use statistical tools to relate *N* and *G* to production estimates based on ^{15}N- and ^{14}C-uptake, respiration rates, light availability, nutrient supply, community structure and other SSB consortium data products.

Introduction:

In order to increase the resolution of dynamic waters such as shelf seas, continuous underway measurement systems have been demonstrated a good choice.

Membrane inlet mass spectrometry is a technique invented by Hoch and Kok in 1963. This technique permits the sampling of dissolved gases from a liquid phase. The principle is a semipermeable membrane that allows dissolved gases pass through but not the liquid into the mass spectrometer flying tube. The advantages of the MIMS are several with the exception of the precision. These can be mounted onboard which permit the analysis of several dissolved gases of seawater in situ and continuously. Phytoplankton photosynthesis and respiration understandings can be achieve from the analysis of stable isotopes distribution of certain gases or to obtaining chemical exchange rates (Beckmann et al., 2009). This is also a very simple way to analyze volatile gases, do not require exhaustive preparation of material for sampling nor the use of chemicals, and data is recorded directly in the computer without the need of post analysis in the laboratory.

The dissolved O_2 in seawater gives an estimation of the NCP. Physical process such us variation in temperature and pressure, transport fluxes, diffusion and bubble injection also changes the amount of dissolved O_2 in seawater. Now is clear that we need a tracer that separates oxygen produced biologically from the one added or removed from physical processes. Argon does not react during photosynthesis or

respiration and have similar solubility and diffusivity than O_2. Variation in O_2 concentration due to biological production can be separated from physical forces using the $\Delta O_2/Ar$ ratio.

Craig and Hayward (1987) were the first ones describing a technique for using ΔO_2 and Ar differences to determinate NCP. The equation that is now used is $\Delta O_2/Ar$ ratio, and is defined as follow in Eq. (1).

$$\Delta O_2/Ar = [c(O_2)/c(Ar)]/[(c_{sat}(O_2)/c_{sat}(Ar)]-1 \quad (1)$$

Were *c* is the dissolved gas concentration (mol m^{-3}) and c_{sat} is the saturation concentration at known temperature, pressure and salinity (Kaiser, 2005).

This technique was considered very sensitive (Hoch and Kok, 1963) but nowadays, even if modern MIMS have high sensitivity (Beckmann et al., 2009) these instruments lack the ultra-high precision of IRMS. Thus, in addition to the underway measurements, discrete samples were taken for calibration purposes and to measure the $^{17}O/^{16}O$ and $^{18}O/^{16}O$ isotope ratio analysis of dissolved oxygen. Triple oxygen isotope measurements combined with O_2/Ar data can be used to estimate the ratio of net community production to gross production and the ratio of gas exchange to gross production. Again, in combination with suitable wind-speed gas-exchange parameterizations this can be used to estimate gross production over large regional scales at timescales of weeks to months.

Methodology:

Continuous measurements of dissolved N_2, O_2, and Ar were made by MIMS on board RRS Discovery. The ship's underway sampling system was used to pump water through a tubular Teflon AF membrane (*Random Technologies*). The membrane was connected to the vacuum of a quadrupole mass spectrometer (*Pfeiffer Vacuum* Prisma). The intake of the underway sampling system is located at the bow at a nominal depth of 5 m. The water from the underway sampling system passed through an open bottle at several litres per minute to remove macroscopic bubbles and to avoid pressure bursts. A flow of about 45 ml/min was continuously pumped from the bucket through the membrane, using a gear pump (*Micropump*). In order to reduce O_2/Ar variations due to temperature effects and water vapour pressure variations, the exchange chamber with the membrane was held at a constant temperature of 9ºC (3 to 5ºC below the sea surface temperature, to avoid temperature-induced supersaturation and subsequent bubble formation) The flight tube was in a thermally insulated box maintained at 50ºC.

In addition to the continuous underway measurements, I also analysed CTD samples with the MIMS in order to characterize the depth profile of the O_2/Ar ratio in regions of the Celtic Sea.

The O_2/Ar ratio measurements will be calibrated with discrete water samples taken from the same seawater outlet as used for the MIMS measurements. 200 cm^3 samples were drawn into pre-evacuated glass flasks

poisoned with 7 mg $HgCl_2$ [*Quay et al.*, 1993]. These samples will be later analysed with an isotope ratio mass spectrometer (IRMS, *Thermo Finnigan*) for their dissolved O_2/Ar ratios and the oxygen triple isotope composition relative to air [*Hendricks et al.*, 2004]. Raw O_2/Ar ion current ratio measurements were made every 10 to 20 s and had a short-term stability of 0.05%.

O_2 concentrations were also measured continuously with an optode (*Aanderaa* model 3830, serial no. 241), readings at 10 s resolution. The measurements were taken from the open bottle connected to the underway sampling system used to measure the O_2/Ar ratios as well. This optode attached to the underway system and both the stain steel and titanium CTDs optode were calibrated by automatic Winkler titration of discrete water samples with potentiometric endpoint detection. Calibration of the underway water was made four times, which were taken in triplicate. The highest error was assumed to be due to the wrong calibration of some of the volume of the bottles. Comparisons between Winkler samples from Niskin bottles fired at the surface and Winkler samples taken from the non-toxic supply at the same time of the surface firing agreed well. That means that the non-toxic underway sea water supply is working in good conditions and the Winkler method is measuring consistently during the cruise.

Figure 13. Winkler station in first plane, MIMS at the end of the bench.

Discrete samples:

The CTD profile has shown a stratified water column during all the cruise sampling. The mixed layer was between 20 – 100 meters deep. Peaks of chlorophyll maximum or oxygen were found within the mixed layer as expected for the spring season.

Discrete Winkler duplicate samples were taken from 3 - 4 Niskin bottles to calibrate the optode of the stain steel and titanium CTD. Samples were drawn carefully into borosilicate glass bottles and later analyzed by whole-bottle Winkler titration to a potentiometric endpoint. Chris Daniels and Chata Seguro did sampling and analysis. The data from the Winkler measurements was given to Chris, please read his cruise report for more information.

Acknowledgements:

I would like to thank scientists, crew, officers and engineers of RRS Discovery Cruise DY029 for the help and good environment during the entire cruise, especially to Alex Poulton who had always time to speak about science and have managed perfectly this ambitious cruise and to the MSC group for their training and all the fun!

The following samples were collected during DY029

Event	CTD	Latitude N	Longitude W	Start date	Start time (GMT)	Time on deck	O_2/Ar	$^{16,17,18}O$	CTD Optode calibration	TEP
15	8	49 23 81	8 36 27	04/04/15	12:49:00	13:26:00	✓	✓	-	-
33	11	49 24 327	8 35 718	05/04/15	14:52:00	15:34:00	✓	✓	-	✓
49	14	48 23 316	9 54 872	06/04/15	14:08:00	14:49:00	✓	✓	-	-
68	29	48 25 538	9 52 741	08/04/15	13:58:00	14:54:00	✓	✓	-	-
85	39	48 29 496	9 48 528	09/04/15	14:01:00	14:20:00	✓	✓	-	-
90	40	48 34 452	9 30 496	09/04/15	18:06:00	18:28:00	✓	✓	-	✓
99	42	48 34 270	9 30 595	10/04/15	07:07:00	07:43:00	✓	✓	-	-
102	45	48 51 200	9 11 970	10/04/15	12:06:00	12:29:00	✓	✓	✓	-
103	46	49 07 792	8 54 271	10/04/15	14:59:00	15:21:00	✓	✓	-	-
104	47	49 07 700	8 54 270	10/04/15	15:45:00	16:05:00	-	-	✓	-
111	49	49 23 824	8 34 894	11/04/15	02:10:00	02:37:00	-	-	✓	-
115	50	49 23 809	8 36 025	11/04/15	11:28:00	11:58:00	✓	✓	✓	-
143	53	51 12 827	6 7 725	13/04/15	21:15:00	21:34:00	✓	✓	✓	✓
144	54	51 12 830	6 7 780	13/04/15	22:03:00	22:16:00	-	-	✓	-
148	58	50 49 706	6 39 977	14/04/15	05:08:00	05:24:00	✓	✓	-	-
151	59	50 25 210	7 13 692	14/04/15	10:15:00	10:43:00	✓	✓	✓	-
152	60	50 25 210	7 13 691	14/04/15	11:07:00	11:23:00	-	-	✓	-
153	61	50 00 720	7 46 582	14/04/15	15:08:00	15:59:00	-	✓	✓	-
154	62	50 1 050	7 45 990	14/04/15	17:39:00	17:51:00	-	-	✓	-
155	63	50 1 051	7 45 985	14/04/15	18:19:00	18:40:00	✓	✓	-	-
159	66	49 23 540	8 35 605	15/04/15	12:12:00	12:43:00	✓	✓	-	✓
173	68	49 23 541	8 35 603	16/04/15	08:01:00	08:24:00	✓	✓	-	-
179	69	49 23 760	8 36 896	16/04/15	12:41:00	13:04:00	✓	✓	✓	-
180	70	49 23 760	8 36 897	16/04/15	13:27:00	13:34:00	-	-	✓	-
199	71	48 34 313	9 30 632	17/04/15	06:59:00	07:30:00	✓	✓	-	-
200	72	48 12 292	10 3 233	17/04/15	11:22:00	13:08:00	✓	✓	✓	-
201	73	48 12 290	10 3 230	17/04/15	13:34:00	15:45:00	-	-	✓	-
209	81	48 18 000	9 48 030	18/04/15	10:45:00	11:58:00	-	-	✓	-
210	82	48 17 998	9 48 026	18/04/15	12:41:00	13:23:00	-	-	✓	-
216	86	48 22 207	9 37 729	19/04/15	06:10:00	07:18:00	-	-	✓	-
220	90	48 22 687	9 36 516	19/04/15	12:06:00	12:50:00	-	-	✓	-
224	94	48 24 030	8 37 139	20/04/15	02:14:00	02:40:00	✓	✓	-	-

Event	CTD	Latitude N	Longitude W	Start date	Start time (GMT)	Time on deck	O_2/Ar	^{16,17,18}O	CTD Optode calibration	TEP
226	96	49 24 120	8 37 139	20/04/15	09:00:00	09:23:00	✓	✓	✓	-
227	97	49 24 066	8 37 213	20/04/15	11:58:00	12:29:00	✓	✓	-	-
232	98	49 25 308	8 37 062	20/04/15	15:40:00	16:00:00	✓	✓	-	-
233	99	49 24 352	8 37 146	20/04/15	18:59:00	19:21:00	✓	✓	-	-
246	101	49 24 073	8 37 287	21/04/15	12:30:00	13:02:00	✓	✓	✓	-
247	102	49 24 070	8 37 290	21/04/15	13:22:00	13:44:00	-	-	✓	-
265	103	48 25 259	9 56 492	22/04/15	06:25:00	08:34:00	-	-	✓	-
266	104	48 32 008	9 56 010	22/04/15	10:14:00	10:55:00	✓	✓	✓	-
272	108	48 36 996	9 50 021	23/04/15	09:00:00	10:07:00	-	-	✓	-
273	109	48 37 515	9 47 578	23/04/15	12:05:00	12:44:00	✓	✓	✓	-
280	115	48 36 232	9 26 686	24/04/15	08:41:00	09:04:00	-	-	✓	-
285	116	48 34 181	9 30 565	24/04/15	13:22:00	13:49:00	✓	✓		-
291	118	48 34 000	9 30 560	24/04/15	16:08:00	16:27:00	-	-	✓	-
299	123	49 24 384	8 35 895	25/04/15	10:02:00	10:22:00	-	-	✓	-
301	124	48 24 568	8 35 477	25/04/15	12:02:00	12:28:00	✓	✓	-	-
327	131	51 12 786	6 7 801	27/04/15	3:01:00	03:25:00	✓	✓	-	-
329	133	50 49 681	6 39 935	27/04/15	8:03:00	08:25:00	✓	✓	-	-
330	134	50 25 199	7 13 657	27/04/15	12:21:00	12:52:00	✓	✓	-	-
331	135	50 25 200	7 13 660	27/04/15	13:31:00	13:28:00	-	-	✓	-
332	136	50 00 789	7 46 583	27/04/15	17:11:00	17:33:00	✓	✓	-	-
341	140	49 24 354	8 34 848	28/04/15	8:21:00	08:46:00	✓	✓	-	-

15. Bacterial production measurements

Elaine Mitchell & Callum Whyte (Scottish Association of Marine Sciences)

Introduction

Radiolabelled leucine methods were used to determine bacterial production in the Celtic Sea. Water column and marine snowcatcher samples were chosen to correspond to respiration studies. A full list of bacterial production samples taken and analysed on board are shown in Table 19.

Method

Water samples were collected from the CTD in acid washed polycarbonate bottles then incubated for bacterial production. Aliquots of 10ul leucine working solution (0.01 MBq ml-1) were pipetted into each 2ml sterile centrifuge tube then additions of 1.6ml sample added. For each depth two samples in duplicate were run for T0, T1, T2 and T3, and incubated in a coolbox in the RN container at above and below thermocline temperatures. Samples were fixed with 80ul of 20% paraformaldehyde (giving a final concentration of 1%). Samples were filtered with 25mm GFF and 0.2um polycarbonate filters pre-soaked in 1mM non labelled leucine in separate petri dishes, placed on the 25mm filter rig with the GFF as a backing filter. The sample pipetted into each filter holder and then deionised water used to rinse any remaining sample from each vial. Both samples at each time point were combined and filtered as one. The 0.2um polycarbonate filter was placed into a scintillation vial and dried overnight in the fume hood, 4ml Optiphase Hi-Safe II scintillant added and samples read in the scintillation counter after 24 hours. Marine snowcatcher samples were analysed on 3 fractions, suspended, slow and fast sinking using the method describe above. Marine snowcatcher fast fractions samples were taken from a quarter tray approx. 40ml shared with respiration studies.

Calibration experiment- Leucine

Three replicate water column samples A, B and C were prepared into a 1litre polycarbonate bottle, 900ml of each filtered through a 0.2um filter vacuum cap with 100ml unfiltered making up the volume. Each replicate was sampled at T0, T6, T12, T18, and T24 for leucine, bacterial abundance counts for flow cytometer and dapi slide prep. Samples were incubated in a CT container at 10ºC with 10% light, and then processed as water column methods for leucine.

Table 19. Sampling details for Leucince uptake measurements

Date	CTD	Event No.	Depth (m)	Niskin	Comments	Coordinates
04/04/2015	CT 06-SS	9	5	24	Pre-dawn	Lat: 49 23.37
			8	21		Long: 8 35.59
			18	17		
			23	14		
			35	13		
			70	8		
06/04/2015	CT 135-S	47	5	24	Pre-dawn	Lat: 49 24.38
			8	20		Long: 8 35.28
			18	16		
			23	15		
			35	13		
			70	8		
10/04/2015	CT 41-SS	98	5	24	Pre-dawn	Lat: 48 34.26
			8	20		Long: 9 30.59
			16	19		
			29	15		
			45	13		
			80	7		
11/04/2015	CT 49-SS	111	5	20	Pre-dawn	Lat: 49 23.82
			10	19		Long: 8 34.89
			15	16		
			20	15		
			30	13		
			70	7		
12/04/2015	MSC (Tom)	136	10		Fast	Lat: 49 24.83
			10		Slow	Long: 8 35.36
			10		Suspended	
12/04/2015	MSC (Tom)	141	70		Fast	Lat: 49 24.77
			70		Slow	Long: 8 35.47
			70		Suspended	
					Dilution 1:1 (suspended:Fast)	
15/04/2015	CT 64-SS	156	5	20	Pre-dawn	Lat: 49 24.57
			10	19		Long: 8 35.15
			16	16		
			25	14		
			35	10		
			70	7		

16/04/2015	MSC (Tom)	182	10		Fast	Lat: 49 23.86
			10		Slow	Long: 8 36.14
			10		Suspended	
					Dilution 1:1 (suspended:Fast)	
16/04/2015	MSC (Tom)	191	70		Fast	Lat:49 24.29
			70		Slow	Long: 8 37.06
			70		Suspended	
					Dilution 1:1 (suspended:Fast)	
20/04/2015	CT 94-SS	224	5	20	Pre-dawn	Lat: 49.24.03
			11	19		Long: 8 17.13
			15	16		
			20	14		
			28	13		
			70	7		
21/04/2015	CT 100-SS	241	20	18	BP Calibration Exp	Lat: 49 24.09
			20	19		Long: 8 37.22
			20	20		
21/04/2015	MSC (Tom)	250	10		Fast	Lat: 49 24.13
			10		Slow	Long: 8 37.35
			10		Suspended	
					Dilution 1:1 (Suspended:Fast)	
21/04/2015	MSC (Tom)	259	70		Fast	Lat: 49 24.99
			70		Slow	Long: 8 35.93
			70		Suspended	
					Dilution 1:1 (Suspended:Fast)	
24/04/2015	CT 113-SS	277	5	24	Pre-dawn	Lat: 48 34.26
			13	19		Long: 9 30.37
			18	16		
			24	15		
			30	13		
			70	8		
25/04/2015	CT 120-SS	293	5	24	Pre-dawn	Lat: 49 24.09
			12	19		Long: 8 37.17
			18	16		
			24	15		
			35	12		
			70	8		
25/04/2015	MSC (Hardy)	302	10		Suspended	Lat: 49 24.56
	(Hardy)	302	10		Fast	Long: 8 35.47
	(Tom)	303	10		Fast	
	(Jerry)	304	10		Fast	
					Dilution 1:1 (Suspended:Fast)	
25/04/2015	MSC (Hardy)	310	70		Suspended	Lat: 49 24.49
	(Hardy)	310	70		Fast	Long: 8 35.23
	(Jerry)	311	70		Fast	
	(Tom)	312	70		Fast	

					Dilution 1:1 (Suspended:Fast)	
27/04/2015	CT 131-SS	327	5	20	Pre-dawn	Lat: 51 12.78
			10	19		Long: 6 7.80
			15	16		
			20	14		
			30	13		
			70	7		

16. Dissolved organic material degradation

Callum Whyte & Elaine Mitchell (Scottish Association of Marine Sciences)

Introduction

Dissolved organic matter degradation experiments were carried out to determine remineralization rates in the Celtic Sea. Water was collected at four stations, 2 at Central Celtic Sea (CCS) during Leg 1; one at the Celtic Shelf (CS2) and one at Central Celtic Sea (CCS) during Leg 2 of the cruise, for comparison of changes due to seasonal mixing see Table 20.

Method

Water samples were filtered through pre-combusted (450 degree C for 6hrs) GF/F filters (pore size ~ 0.7μm) and transferred to 150ml amber bottles. A microbial culture was added by filtering water from the same depth through a GF/C filter (pore size ~1.2μm) and inoculated at 5% of the total volume. The degradation experiments were set up in duplicate for each depth, surface mixed layer, thermocline and ~100M (i.e. below thermocline). Bottles were then incubated in the dark either in the CT room or cold room at temperatures as similar to in situ as possible for a period of 80 days. During the incubation period 7 samples were collected (days 0,3,6,10,15,25 and 80) from amber bottles using an acid washed glass syringe with a 25mm pre-combusted GF/F filter. The syringe first rinsed with deionised water 3 times before collecting samples for dissolved organic carbon (DOC), total dissolved nitrogen (TDN), total dissolved phosphorous (TDP), inorganic nutrients, bacterial abundance, FISH, DOM fluorescence and amino acids. Analysis of samples will be completed at SAMS, with the following exceptions: DOM fluorescence and amino acids are to be measured by C Davis (Liverpool). Bacterial abundance samples produced during the cruise were processed by Glen Tarran (PML), the interpretation of these data files will be completed at SAMS as well as the analysis of any samples for bacterial abundance produced post cruise.

Table 20. DOM Degredation experiments

Date	CTD	Event No.	Depth (m)	Niskin	Comments	Coordinates
03/04/2015	CT 03-SS-RA	5	100	7	Below Thermocline	Lat: 49 23.39
			40	22	Thermocline	Long: 8 35.54
			20	23	Surface mixed layer	
11/04/2015	CT 50-SS	115	60	7	Below Thermocline	Lat: 49 23.80
			31	11	Thermocline	Long: 8 36.02
			13	16	Surface mixed layer	
18/04/2015	CT 82-SS-RA	210	90	22	Below Thermocline	Lat: 48 17.99
			40	23	Thermocline	Long: 9 48.02
			10	24	Surface mixed layer	
20/04/2015	CT 97-SS	227	70	5	Below Thermocline	Lat: 49 24.06
			36	12	Thermocline	Long: 8 37.21
			14	20	Surface mixed layer	

17. Community & bacterial respiration

Elena Garcia Martin & Jose Lozano (University of East Anglia)

Background

Dissolved oxygen (O_2) in seawater is produced by photosynthesis and consumed by respiration and photochemical reactions in the surface waters. Community respiration (CR) represents the magnitude of biologically fixed carbon that is available for export to the deep ocean or for transference to upper levels of the marine food-web. Bacteria play an important role in this balance, although their contribution to community respiration has been difficult to characterize due to methodological difficulties to separate them from the rest of the plankton community. The possible biases that the separation could cause in the bacterial respiration rates could be minimised with the applicability of the in vivo INT reduction method (ivINT). This method allows size fraction without distorting the natural community as the size fraction is performed after the incubation. Moreover, the short incubation time needed (1-4h) reduces the likelihood of community structure changes and agrees with the incubation times for bacterial production determinations. It has been successfully applied to samples from the water column and in this cruise a modification of the method was applied to the marine snow.

The aims of this work were:

1. To determine the daily plankton community respiration with Winkler technique (CR_{O2}) and oxygen optode throughout the water column from CTD samples.
2. To determinate plankton community (CR_{INT}) and bacterial respiration (BR_{INT}) with the ivINT method at short incubation times from CTD samples.
3. To quantify community and bacterial respiration of the three fractions of the Marine Snow Catcher (MSC), i) suspended, ii) slow sinking and iii) fast sinking, above and below the thermocline with Winkler technique and ivINT method.
4. To log and quantify continuously the respiration of fast and suspended particles with oxygen optodes.

1.- Sampling and analytical methodology of CTD samples.

Water samples (5-6 L) were collected from predawn CTD casts at each station from 4-5 depths in the euphotic zone and 1 depth in the aphotic zone (see Table 21 for specific details of the depths and stations) in

10-20 L carboys. The depth of the aphotic sampling was coincident with the depth of the deep deployment of the MSC, around 30-40 m below the thermocline.

Each carboy was subsampled for measuring community respiration by in vitro changes of dissolved oxygen concentration, community and bacterial respiration by the size-fractionated in vivo INT reduction capacity method and oxygen optodes (see below).

1.1-Community respiration by in vitro changes of dissolved oxygen concentration

CR_{O2} was measured by monitoring changes in oxygen concentrations after 24h dark bottle incubations. Dissolved oxygen concentration was measured by automated precision Winkler titration performed with a Metrohm 765 Titrino titrator, utilising a photometric end point (Carritt & Carpenter, 1966).

Ten gravimetrically calibrated 60 mL glass Winkler bottles were carefully filled with water from each depth. Water was allowed to overflow during the filling, and special care was taken to prevent air bubble formation in the silicone tube. Five bottles were fixed at start of the incubation ("zero") with 0.5 mL of sulphate manganese and 0.5 mL of a solution of sodium iodine/sodium hydroxide. The other five bottles were placed in water temperature controlled incubators inside the CT room for 24 hours. The incubation temperatures were ±0.5 °C of the in situ temperature. Bottles were removed from the incubators after the 24 hours and fixed as the "zero". All bottles were analysed within the next 24 hours. Community respiration was calculated from the difference in oxygen concentration between the means of the "zero" measurements and the replicate dark incubated samples.

The concentrations of the thiosulphate used were ca. 0.14 and 0.17 N. Thiosulphate was calibrated every day before the analysis of the samples and the coefficient of variation of the calibration was <0.2%.

1.2- *In vivo* community and bacterial respiration (CR_{INT} and BR_{INT}) by INT reduction method.

Five 200 mL dark glass bottles were filled with seawater from each 10 litre carboy from the CTD. Two replicates were immediately fixed by adding formaldehyde (2% w/v final concentration) and used as killed controls. Twenty minutes later all five replicates were inoculated with a sterile solution of 7.9 mM 2-(ρ-iodophenyl)-3-(ρ-nitrophenyl)-5phenyl tetrazolium salt (INT) to give a final concentration of 0.8 mM. The solution was freshly prepared for each experiment using Milli-Q water. Samples were incubated in the same temperature controlled water bath as the dissolved oxygen bottles for ca. 0.5- 1 hour and then fixed by adding formaldehyde, as for the killed controls. After 20 minutes, samples were sequentially filtered through 0.8 and onto 0.2 μm pore size polycarbonate filters, air-dried, and stored frozen in 1.5 mL cryovials at –20°C until further processing (laboratory at UEA). The CR_{INT} (i.e. the sum of respiration of the >0.8 μm and 0.2-

0.8 µm fractions) and BR_{INT} (considered as the respiration of the 0.2-0.8 µm fraction) will be measured following Martínez-García et al. (2009).

A time-course experiment was carried out in order to know the optimal incubation time that these samples should be incubated.

Optimal incubation time test: 14 samples of 100 mL of surface water CTD were collected and dispensed to glass bottles. Incubations were undertaken in the dark for 0, 0.5, 1, 1.5 and 2 hours at in situ temperature. Optimal incubation time was considered as the time period, prior to saturation of the formazan concentration, during which the relationship between concentration versus time remained linear.

1.3- Continuous monitoring of in vitro oxygen evolution.

Changes in oxygen concentration were measured continuously with three optode systems (YSI ProODO). Prior to each experiment, all the three sensors were air-calibrated simultaneously. Two glass optode chambers of 100 mL were filled from water samples collected from one depth sampled (see Table 21, for the sampling depth at each station). Water sample (120-150 mL) from the same depth was collected and filtered by 0.2 µm pore size polycarbonate filters. A third chamber of 100 mL was filled with the former filtered sea water (FSW) and monitored continuously with a third optode sensor. The filtered water was used as a background for abiotic changes in oxygen concentration associated to any temperature changes that the samples could have experienced during the incubation inside the water bath. Chambers containing samples were gently stirred but not the 0.2 µm FSW sample. Incubation was performed at the in situ temperature conditions ±0.5 °C inside a dark water bath (Figure 15). After half an hour of acclimation, oxygen concentration was recorded every three minutes during 21-24 hours in a chart recorded.

Figure 15. YSI PrODO optodes deployment and the water bath used.

2.- Sampling and analytical methodology of MSC samples.

Small marine snow catchers were used during this cruise. MSC were deployed unsuccessfully at the CCS station during the evening of the 5th April. Due to meteorological conditions no samplings was done in the Shelf Edge process station (see table 22 for station details). Two depths were sampled at each station: 10 m and 70 m. The sampling was done early evening for the shallower deployment and after the sunset for the deep one, avoiding any external light.

Following deployment and after 1 hour 20 minutes period of settling water samples from the suspended, slow and fast sinking fractions were collected from a small Marine Snow Catcher (see Table 22 for sampling data). Suspended water was collected siphoning the water required from the top tap of the MSC and the slow sinking waster was collected from the lower tap (Figure 16a).

Water samples (2 - 6 L) of suspended material and slow sinking were collected in 2-10 L carboys and transported in darkness to the Controlled Temperature room of the RRS Discovery for subsequent subsampling and analysis of community and bacterial respiration, as outlined below. Special care was taken at all moments to prevent the exposure of the samples to light, the room was completely in darkness and two red lights were used while handling the samples (Figure 16b). Suspended water was used to rinse all the Winkler and ivINT bottles before collecting the water samples. The fast sinking material was collected from the tray at the bottom of the MSC. The tray was transported to the control temperature room and the whole sample was used for respiration measurements. Particles were collected with a turkey baster and put into a 1 L plastic beaker from where it was subsampled to the different methodologies. As the water volume was not enough for the three techniques, 1:1 dilutions (suspended: fast) were applied.

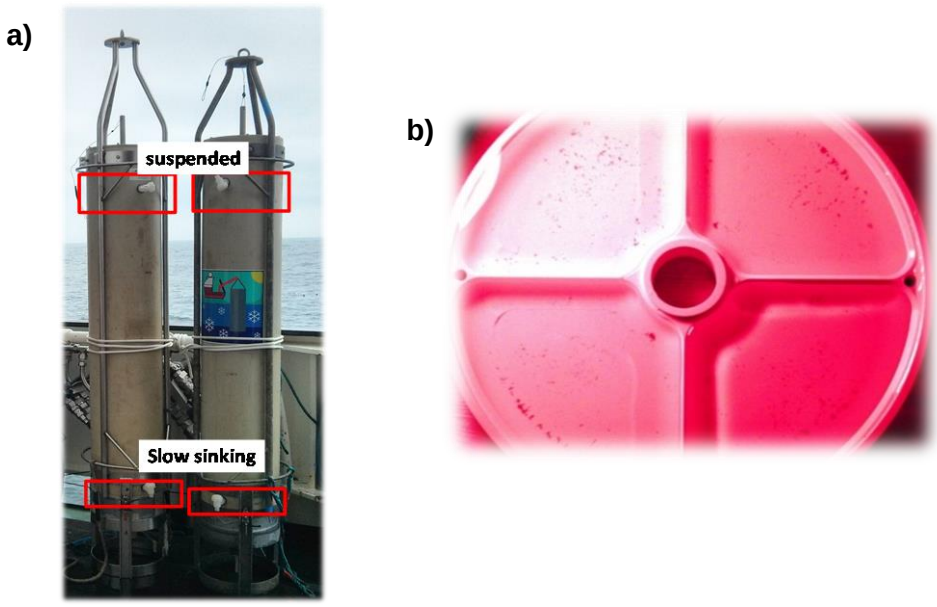

Figure 16. Small Marine Snow Catcher (a) and the tray with fast sinking particles (b) (picture by Chata Seguro).

2.1- Community respiration by in vitro changes of dissolved oxygen concentration

CR was measured by monitoring changes in oxygen concentrations after 24h dark bottle incubations as outlined before (section 1.1). Ten gravimetrically calibrated 60 mL glass Winkler bottles were carefully filled with water from the suspended and the other ten with slow sinking fraction of the two MSC. The sampling methodology differed for the fast sinking fraction. 15 mL sample of fast sinking particles were collected with a 10 mL precise pipette and put into 10 gravimetrically calibrated 35 mL glass Winkler bottles. Then, all of them were topped up with suspended water (15-20 mL). In case of enough water one or two bottles were filled only with fast sinking particles. Five replicate bottles of each fraction were fixed at the start of the incubation ("zero") and the other five bottles were placed in a water temperature controlled incubators inside the CT room for 24 hours. Non diluted bottles were always used as incubated bottles, to check the possible differences between diluted and not diluted fast sinking particle incubations. After 24 hours, the incubated samples were fixed as the "zero" ones. Respiration was estimated by changes in oxygen concentration as described above (see section 1.1 for further details).

2.2- *In vivo* community and bacterial respiration (CR_{INT} and BR_{INT}) by INT reduction assay.

Community and bacterial respiration was measured by the ivINT reduction method as outlined in section 1.2. For the Marine Snow catcher samples, five 80-100 mL dark glass bottles were filled with suspended and slow sinking seawater samples from the carboys collected. Five 50 mL dark glass bottles were filled with 15 mL of fast sinking sample and 15 mL of suspended one, maintaining the same dilution ratio as the Winkler technique. See section 1.2 for further details of the analysis.

An optical sonication time test was performed to check the optimal time to detach the bacteria from the particles in order to get them through the 0.8 µm pore size filter and retained in the 0.2 µm one.

Dilution test: A dilution test was applied in the CCS station in order to test if the dilution applied to the fast sinking particles affected the respiration rates measured with the Winkler and ivINT technique. Ten gravimetrically calibrated 30 mL glass Winkler bottles were carefully filled with suspended water, ten with fast sinking water and another ten with 15 mL of suspended water and 15 mL of fast sinking particles (dilution 1:1). Five replicate bottles of each treatment were fixed at start of the incubation ("zero") with 0.5 mL of sulphate manganese and 0.5 mL of a solution of sodium iodine/sodium hydroxide. The other five replicates bottles of each treatment were placed in water temperature controlled incubators inside the CT room for 24 hours. After 24 hours, all incubated replicates were fixed as the "zero" ones.

Optimal sonication time test: One sample of 30 mL water (15:15 suspended: fast sinking particles) were collected in a glass bottle and put inside an ultrasound bath for 0, 10, 20, 30 and 50 seconds. After the

sonication time, samples were fixed with glutaraldehyde for citometry counts (see Whyte and Mitchell report and Tarran report for further information on the methodology).

2.3- Continuous monitoring of in vitro oxygen evolution.

Oxygen concentration was recorded continuously from the suspended and fast sinking particles at the 3 MSC samplings. The third YSI oxygen sensor was fitted with 0.2 µm filtered suspended water. Further information of the methodology could be found in section 1.3.

3.- Preliminary results.

9 vertical profiles of six depths were sampled for community and bacterial respiration rates (Winkler and ivINT method).

8 incubations for continuous oxygen consumption (ProODO YSI optodes) were run with water samples from the CTD.

3 MSC were sampled to calculate the carbon remineralization rates of the different fractions above and below the thermocline.

1 time-course experiment for the ivINT reduction capacity method was done with sample taken from the CTD.

1 time course experiment for the optimal sonication time to detach bactetia from particles was done with fast sinking particles collected by the MSC.

1 dilution tests were performed in order to check if the dilution of the fast sinking particles with suspended water from the same depth affected the remineralization rates (Winkler and ivINT method).

Respiration analyses with Winkler technique were all performed on board, but data will be processed on return.

4.- Problems encountered.

The depth of the MSC could be subjected to error as the only way to measure the deployment was by measuring the metres of wire out. The MSC could have been not deployed completely straight, existing the possibility of an angle between the wire and the water, would could affect to the real depth (several cm for the shallow deployment, and around one meter for the deep MSC deployment). Some kind of sensor

(salinity, pressure, etc) should be settled within the MSC for being sure of the depth sampled. Nutrients measurements were taken in the all MSC casts to verify the depths sampled.

Acknowledgements:

We would like to acknowledge the crew of the RSS Discovery and the NMF people for their help and patience in the deployment of the Marine Snow Catcher. Equally importantly, the chief scientist Alex Poulton and our other scientific colleagues on board who generously assisted and supported our work throughout DY029.

References

Carritt, D.E. and Carpenter, J.H., 1966. Comparison and evaluation of currently employed modifications of the Winkler method for determining dissolved oxygen in seawater; a NASCO Report. Journal of Marine Research, 24: 286-319.

Martínez-García, S., Fernández, E., Aranguren-Gassis, M., Teira, E., 2009. *In vivo* electron transport system activity: a method to estimate respiration in natural marine microbial planktonic communities. Limnology and Oceanography Methods 7, 459-469.

Table 21. Station and CTD cast details for respiration measurements.

Date	CTD	Event	Latitude	Longitude	Niskin bottle	Depth (m)	Variable
04/04/2015	006SS	9	49 23.371 N	8 35.592 W	24	5	Winkler, ivINT, O2 sensors
					20	8	Winkler, ivINT
					17	18	Winkler, ivINT
					14	23	Winkler, ivINT
					13	35	Winkler, ivINT
					8	70	Winkler, ivINT
04/04/2015	008SS	15	49 25.81 N	8 36.21 W	22	5	optimal incubation time ivINT
06/04/2015	013SS	47	49 24.31 N	8 35.19 W	24	5	Winkler, ivINT, O2 sensors
					20	8	Winkler, ivINT
					16	18	Winkler, ivINT
					15	23	Winkler, ivINT
					13	35	Winkler, ivINT
					8	70	Winkler, ivINT
10/04/2015	041SS	98	48 34.268 N	9 30.596 W	24	5	Winkler, ivINT, O2 sensors
					20	8	Winkler, ivINT
					19	16	Winkler, ivINT
					15	29	Winkler, ivINT
					13	45	Winkler, ivINT
					7	80	Winkler, ivINT
11/04/2015	049S	111	49 23.824 N	8 34.894 W	20	5	Winkler, ivINT, O2 sensors
					19	10	Winkler, ivINT
					16	15	Winkler, ivINT
					15	20	Winkler, ivINT
					13	30	Winkler, ivINT
					7	70	Winkler, ivINT
14/04/2015	058SS	148	50 49.706 N	6 39.977 W	23	5	Winkler, ivINT, O2 sensors
					20	10	Winkler, ivINT
					19	20	Winkler, ivINT
					16	30	Winkler, ivINT
					13	40	Winkler, ivINT
					6	70	Winkler, ivINT
15/04/2015	064SS	156	49 24.575 N	8 35.158 W	20	5	Winkler, ivINT, O2 sensors
					19	10	Winkler, ivINT
					14	16	Winkler, ivINT
					16	25	Winkler, ivINT
					10	35	Winkler, ivINT
					7	70	Winkler, ivINT
20/04/2015	094SS	224	48 24.030 N	8 37.13 W	20	5	Winkler, ivINT, O2 sensors
					19	11	Winkler, ivINT
					16	15	Winkler, ivINT
					14	20	Winkler, ivINT

					13	28	Winkler, ivINT
					7	70	Winkler, ivINT
24/04/2015	113SS	277	48 34.262 N	9 30.577 W	24	5	Winkler, ivINT, O2 sensors
					19	13	Winkler, ivINT
					16	18	Winkler, ivINT
					15	24	Winkler, ivINT
					13	30	Winkler, ivINT
					8	70	Winkler, ivINT
25/04/2015	120SS	293	49 24.091 N	8 37.166 W	24	5	Winkler, ivINT
					19	12	Winkler, ivINT
					16	18	Winkler, ivINT
					15	24	Winkler, ivINT
					12	35	Winkler, ivINT
					8	70	Winkler, ivINT
27/04/2015	131SS	327	51 12.786 N	6 7.801 W	20	5	Winkler, ivINT, O2 sensors
					19	10	Winkler, ivINT
					16	15	Winkler, ivINT
					14	20	Winkler, ivINT
					13	30	Winkler, ivINT
					7	70	Winkler, ivINT

18 Measurements of zooplankton community respiration by changes in O_2 concentration and continuous oxygen decrease using oxygen optodes.

Elena Garcia Martin & Jose Lozano (University of East Anglia)

Sari Giering & Seona Wells (University of Aberdeen)

Background

Zooplankton contributes to the carbon biogeochemical cycle through their physiological processes (feeding and respiration rates) and represents the link between the microbial autotrophic and the nekton community.

During this program of research the turnover of organic matter (respiration rates) of zooplankton community divided in three different size fractions was examined.

Collection of the samples

Zooplankton community of three different locations (see Table 1 for dates and locations) were sampled using WP2 Nets of 200 and 63 µm mesh sizes during the previous night of the experiments. Collected zooplankton was size-fractioned into 63-200 µm, 200-500 µm, and >500 µm and stored in three different buckets filled with filtered sea water (FSW) until the initial of the experiments the following early morning.

Sea water from the continuous 5 m non-toxic supply was filtered through 0.8/0.2 µm (Pall AcroPack cartridge) and collected in a 25 L carboy during the evening of the zooplankton collection and left in the control temperature room until the sampling on the following morning. The FSW was always less than one day old when used for the experiments.

Experimental procedure

Three different size range animals were selected: 63 µm, 200-500 µm and > 500 µm.

The number of individuals selected was dependent on their body size and the volume of the bottles chosen. Thus, respiration of:

- 15 individuals > 500 µm were measured in 100 mL bottles,
- 30 organisms of 200-500 µm were measured in 100 mL bottles and,

- 60 individuals of 63 µm were placed into 35 mL Winkler bottles or 10-15 individuals in 4-5 mL bottles for the optical sensors.

The measurement of the respiration of the different size classes was done consecutively, starting with the >500 µm sample, then the 63 µm ones, and finalizing with the 200-500 µm zooplankton community. This was done in order to be able to measure concurrently the discrete Winkler O_2 samples and the continuous measurements with O_2 optical sensors. The experimental information can be found in Table 23.

Respiration rates

1.1 Measurements of zooplankton respiration by in vitro changes of dissolved oxygen concentration.

Dissolved O_2 was determined by automated Winkler titration using photometric end-point detection as described in Williams and Jenkinson (1981). Twenty gravimetrically calibrated 100 mL glass Winkler bottles, for the large and medium fraction, and 35 mL glass bottles for the smallest fraction were carefully filled with 0.8/0.2 µm FSW. Ten bottles were used to measure the respiration of the zooplankton community while the other 10 were used as a control of the oxygen decrease associated to any bacteria or living organisms in the FSW. The different animals were selected with the aid of a binocular microscope and placed into the ten correspondent bottles. The control bottles were subjected to a similar procedure as the zooplankton bottles: the tweezers were inserted in the water containing the zooplankton sample and subsequently in the Winkler bottles the same number of times as for the zooplankton ones. Then, any possible living organisms introduced in the zooplankton bottles by small drops of water or attached to the tweezers, were inserted to the control ones. All bottles were left open while collecting the animals, so atmospheric-water O_2 interchanges could have been occurred during the selection of the animals, but it should not affect the rate of the respiration (difference in the O_2 concentration at the initial and final incubation time).

All bottles were closed at the same time. Five bottles of each treatment (control and zooplankton ones) were fixed at start of the incubation ("zero") with 1 or 0.25 mL (100 or 35 mL bottles, respectively) of sulphate manganese and 1 or 0.25 mL of a solution of sodium iodine/sodium hydroxide. The other five bottles were placed in water temperature controlled incubators inside the control temperature room for 2.5-4 hours. The incubation temperatures were ± 0.5 °C of the in situ temperature. Bottles were removed from the incubators after the incubation time and fixed as the "zero". All bottles were analysed within the next 24 hours.

Zooplankton community respiration was calculated from the difference in oxygen concentration between the means of the "zero" measurements and the replicate dark incubated samples. The respirations measured in the FSW in the three different fractions were not statistically different from zero. Thus, the respiration measured in the zooplankton bottles could be attributed primarily to zooplankton individuals.

Two extra bottles of each size-fraction were filled with zooplankton samples for particulate organic matter analysis (see Giering & Wells report for further information).

1.2. Measurements of zooplankton respiration by continuous O_2 optical sensors.

Two different size chambers were used for the O_2 continuous recording:

a) 100 mL for the two largest fractions and

b) 5 mL for the smallest fraction.

Three YSI ProODO optical sensors were used simultaneously: one of them was inserted in the chamber containing zooplankton sample, a second one was inserted in a chamber containing 0.8/0.2 µm FSW and the third one was used to measure the oxygen concentration of FSW sample filtered through 0.2 µm pore size polycarbonate filters. The former sample was considered to be free of any living organisms (except virus) and was used as a background for abiotic changes in oxygen concentration associated to any temperature changes that the samples could have experienced during the incubation inside the water bath. The three sensors were air-calibrated simultaneously, at the beginning of the experiment. Incubations were performed at the in situ temperature conditions ±0.5 °C inside a dark water bath. After half an hour of acclimation, oxygen concentration was recorded every three minutes during 2.8 - 4 hours in a chart recorded.

Oxygen consumption rates were determined as the slope of the oxygen concentration decrease as a function of time.

Particulate organic carbon content

The two chamber used with the oxygen sensors and the two extra Winkler ones filled with zooplankton samples were filtered for particulate organic carbon analyses.

References

Carritt, D.E. and Carpenter, J.H., 1966. Comparison and evaluation of currently employed modifications of the Winkler method for determining dissolved oxygen in seawater; a NASCO Report. Journal of Marine Research, 24: 286-319.

Table 22. Net casts sampled for zooplankton community respiration.

Date	Net number	Event Number	Latitude	Longitude	Depth opened	Depth closed	Mesh size (µm)
07/04/2015	23	55	48 23.31	9 54.87 W	50	0	WP2 200 µm
	24	56			50	0	WP2 200 µm
	25	57			50	0	WP2 63 µm
18/04/2015	84	214	48 22.20	9 37.73 W	30	0	WP2 200 µm
	85	215	48 22.19	9 37.79 W	30	0	WP2 63 µm
22/04/2015	107	269	48 36.99	9 50.01 W	30	0	WP2 63 µm
	108	270			30	0	WP2 200 µm

Table 23. Summary of the characteristics of the different zooplankton respiration experiments performed.

Date	Size fraction	N organisms (discrete sample)	Bottle volume discrete O_2 sample (ml)	N organisms (optical sample)	Bottle volume optical O_2 sample (ml)	Incubation temperature discrete O_2 (ºC)	Incubation temperature optical O_2 sample (ºC)	Incubation time (h)
08/04/2015	>500 µm	15	100	15	100	9.3	9.5	2.8
	200-500 µm	30	100	30	100			3.1
	63 µm	60	35	10	5			3.5
19/04/2015	>500 µm	15	100	15	100	10.8	10.8	2.75
	200-500 µm	30	100	30	100			3.5
	63 µm	60	35	10	5			4.1
23/04/2015	>500 µm	15	100	15	100	10.2	10.4	2.8
	200-500 µm	30	100	30	100	10.8	10.8	3.9
	63 µm	60	35	10	5	10.8	10.8	3.4

19. Pelagic nitrogen regeneration & assimilation rates

Darren Clark (Plymouth Marine Laboratory)

Background

Bacterial degradation of particulate and dissolved organic matter (P/DOM) simultaneously regenerates inorganic nutrients and renders the residual material of lower nutritional quality. Given sufficient time, the exposure of POM and DOM to a sufficiently broad range of microbes with their associated biochemical machinery renders organic material recalcitrant. This material represents a uantitatively significant form of carbon storage. The preferential regeneration and retention of nutrients such as nitrogen and phosphorous during this process, generically termed the microbial carbon pump, sustains productivity of the shelf sea region.

During this program of research, the nutrient recycling processes of NH_4^+ regeneration and nitrification were examined. The former is primarily associated with bacterial degradation of organic molecules and excretion processes associated with microplankton. The latter is the two stage oxidation of NH_4^+ to NO_2^- to NO_3^-, facilitated by specific clades of bacteria and archaea. In combination, NH_4^+ regeneration and nitrification have the capacity to significantly influence the concentration and composition of the dissolved inorganic nitrogen (DIN) pool, which sustains autotrophic primary production.

The processes of inorganic nitrogen assimilation were also investigated. Primarily these are autotrophic processes although bacteria may also make a contribution to observed rates. Three forms of inorganic nitrogen were used for this study; NH_4^+, NO_2^-, NO_3^-.

The rates of N-regeneration and assimilation were derived using stable isotope techniques during both observational CTD casts and Marine Snow Catcher (MSC) deployments. The aim of this research was to understand variability in N-cycle processes by investigating how rates related to water column structure and particle loading.

Experiments

Marine Snow Catcher

Marine Snow Catcher (MSC, 100 L volume) experiments: The regeneration of N associated with 3 particle fractions (suspended, slow and fast sinking) was determined during MSC deployments at depths within the photic zone (approximately 10 meters) and at a depth in the lower mixed layer (approximately 70 meters).

The rates of NH_4^+ regeneration, NH_4^+ oxidation and NO_2^- oxidation were measured on each fraction. Method details are provided below.

Observational casts

At observational stations water was collected at three depths (approximately 5, 30 and 70 meters). The regeneration and assimilation of each form of dissolved inorganic nitrogen (DIN; NH_4^+, NO_2^-, NO_3^-) was measured at each depth.

Methods

The regeneration of inorganic nitrogen was investigated using ^{15}N dilution methods (Clark et al 2006, 2007). The MSC was used to collected seawater from a specific depth. N-regeneration rates were determined in three particulate fractions (suspended particle (SP); slow sinking particle (SSP); fast sinking particle (FSP)). Following deployment and a 2 hour period of settling, 15L of SP seawater was collected from the MSC. 1.5L of this water was added to each of 3 2.2 L bottles containing either $^{15}NO_3^-$, $^{15}NO_2^-$ or $^{15}NH_4^+$. The ^{15}N addition was estimated to provide a 20% enrichment of the DIN pool, based on recently determined nutrient concentration profiles. A further 4.0L of water containing SSP was collected from the MSC directly into bottles containing ^{15}N. FSP were recovered in a tray from the MSC, and in a constant temperature room under low intensity red light the particle tray was screened for magnetic particles. FSP were then transferred to 2.2L bottles containing ^{15}N. One third of the total FSP load (equating to the FSP content of approximately 100 L of seawater) was added to each of 3 bottles (each representing one process). SP water was used to dilute the FSP to a total volume of 1.5L. The 9 x 2.2 L bottles (3 processes, 3 particles fractions) were placed in a temperature controlled room for 30 minutes to ensure that the isotope was homogenously distributed. Following this period, bottles were used to fill 1.0L incubations bottles and placed in an incubator simulating appropriate light and temperature for a period of 24 hours. The remaining ^{15}N amended seawater was filtered using 47mm GF/F. The filter was retained to enable a measure of particulate carbon and nitrogen content. The filtrate was used to derive the pre-incubation DIN concentration and isotopic enrichment by synthesising indophenol from ammonium and sudan-1 from nitrite (nitrate is quantitatively reduced to nitrite prior to further analysis). Following the incubation period, samples were filtered using GF/F. The filter was retained to enable an estimation of the particulate carbon and nitrogen content of the incubated sample. The filtrate was used to generate post-incubation samples for DIN concentration and isotopic enrichment.

Indophenol was synthesised in samples by adding the first reagent (4.7 g phenol and 0.32 g sodium nitroprusside in 200 mL Milli Q water) in the proportion of 1 mL per 100 mL of sample volume, mixing the sample and leaving for 5 minutes. The second reagent (1.2 g sodium dichloro-isocyanurate and 2.8 g sodium hydroxide in 200 mL Milli Q) was then added in the proportion of 1 mL per 100 mL sample volume, mixed

and left for 5 hours at room temperature for indophenol development. Indophenol was collected by solid-phase extraction (SPE) as described below. Sudan-1 was synthesised by adding the first reagent (0.8 g of aniline sulphate in 200 mL 3M HCl) to samples in the proportion 0.5 mL per 100 mL sample volume. Samples were mixed and left for 5 minutes to homogenise after which sample pH was verified to be < 2.0. Reagent 2 (24 g NaOH and 0.416 g 2-napthol in 200 mL Milli Q) was added in the proportion 0.5 mL per 100 mL sample volume. Samples were again mixed, left for 5 minutes before sample pH was verified to be approximately 8.0. Sudan-1, the development of which was complete after 30 minutes of incubation at room temperature, was collected by SPE as described below.

Deuterated internal standards were added to samples immediately prior to SPE collection. Deuterated indophenol and deuterated sudan-1 were synthesised according to methods described previously (Clark et al. 2006; 2007). Standard solutions in methanol were prepared (100 $ng \cdot \mu L^{-1}$) and the concentration verified against analytical standard solutions (Sigma-Aldrich). Appropriate volumes of deuterated internal standards (i.e. comparable to sample size) were added to samples following acidification by citric acid and prior to SPE collection.

Indophenol and sudan-1 were collected by SPE using 6 mL/500 mg C18 cartridges (Biotage, UK) which were prepared for sample collection by first rinsing with 5 mL methanol, followed by 5 mL Milli Q water and 5 mL 0.22 µm filtered seawater. Prior to sample collection seawater samples were acidified with 1 M citric acid to a pH of 5.5, before collection by SPE under low vacuum (120 mmHg) at a flow rate of approximately 1 mL per minute without drying. Samples were then rinsed with 5 mL 0.22 µm filtered seawater and 5 mL Milli Q water before being air dried under high vacuum (360 mmHg). Samples were stored frozen until further processing at the land based laboratory.

The assimilation of inorganic nitrogen was investigated using methods described in Clark et al 2011; 2014. Briefly, seawater collected from a specific depth was separately amended with separate ^{15}N solutions of NH_4^+, NO_2^-, NO_3^- to a final concentration equivalent to <10% of ambient. Volumes were incubated for 3-4 hours under appropriate temperature and light conditions before collection by filtration using 25mm GF/F. The concentration of particulate nitrogen and its natural abundance of ^{15}N was derived from material collected by filtration from additional volumes of un-amended seawater. The concentration of particulate nitrogen and its enrichment with ^{15}N was determined by isotope ratio mass spectrometry from which the rates of nitrogen assimilation were derived.

Table 24. Observational casts

Event	Date	Gear	Depth (m)	CTD bottle	Process
009	04/04/15	CTD (SS)	5	22	NH_4^+ assimilation
009	04/04/15	CTD (SS)	5	22	NO_2^- assimilation
009	04/04/15	CTD (SS)	5	22	NO_3^- assimilation
009	04/04/15	CTD (SS)	35	11	NH_4^+ assimilation
009	04/04/15	CTD (SS)	35	11	NO_2^- assimilation
009	04/04/15	CTD (SS)	35	11	NO_3^- assimilation
009	04/04/15	CTD (SS)	70	6	NH_4^+ assimilation
009	04/04/15	CTD (SS)	70	6	NO_2^- assimilation
009	04/04/15	CTD (SS)	70	6	NO_3^- assimilation
009	04/04/15	CTD (SS)	5	22	NH_4^+ regeneration
009	04/04/15	CTD (SS)	5	22	NO_2^- regeneration
009	04/04/15	CTD (SS)	5	22	NO_3^- regeneration
009	04/04/15	CTD (SS)	35	11	NH_4^+ regeneration
009	04/04/15	CTD (SS)	35	11	NO_2^- regeneration
009	04/04/15	CTD (SS)	35	11	NO_3^- regeneration
009	04/04/15	CTD (SS)	70	6	NH_4^+ regeneration
009	04/04/15	CTD (SS)	70	6	NO_2^- regeneration
009	04/04/15	CTD (SS)	70	6	NO_3^- regeneration
047	06/04/15	CTD (SS)	5	22	NH_4^+ assimilation
047	06/04/15	CTD (SS)	5	22	NO_2^- assimilation
047	06/04/15	CTD (SS)	5	22	NO_3^- assimilation
047	06/04/15	CTD (SS)	35	11	NH_4^+ assimilation
047	06/04/15	CTD (SS)	35	11	NO_2^- assimilation
047	06/04/15	CTD (SS)	35	11	NO_3^- assimilation
047	06/04/15	CTD (SS)	70	6	NH_4^+ assimilation
047	06/04/15	CTD (SS)	70	6	NO_2^- assimilation
047	06/04/15	CTD (SS)	70	6	NO_3^- assimilation
047	06/04/15	CTD (SS)	5	22	NH_4^+ regeneration
047	06/04/15	CTD (SS)	5	22	NO_2^- regeneration
047	06/04/15	CTD (SS)	5	22	NO_3^- regeneration
047	06/04/15	CTD (SS)	35	11	NH_4^+ regeneration
047	06/04/15	CTD (SS)	35	11	NO_2^- regeneration
047	06/04/15	CTD (SS)	35	11	NO_3^- regeneration
047	06/04/15	CTD (SS)	70	6	NH_4^+ regeneration
047	06/04/15	CTD (SS)	70	6	NO_2^- regeneration
047	06/04/15	CTD (SS)	70	6	NO_3^- regeneration
098	10/04/15	CTD (SS)	5	22	NH_4^+ assimilation
098	10/04/15	CTD (SS)	5	22	NO_2^- assimilation
098	10/04/15	CTD (SS)	5	22	NO_3^- assimilation
098	10/04/15	CTD (SS)	45	11	NH_4^+ assimilation
098	10/04/15	CTD (SS)	45	11	NO_2^- assimilation

098	10/04/15	CTD (SS)	45	11	NO_3^- assimilation
098	10/04/15	CTD (SS)	80	5	NH_4^+ assimilation
098	10/04/15	CTD (SS)	80	5	NO_2^- assimilation
098	10/04/15	CTD (SS)	80	5	NO_3^- assimilation
098	10/04/15	CTD (SS)	5	22	NH_4^+ regeneration
098	10/04/15	CTD (SS)	5	22	NO_2^- regeneration
098	10/04/15	CTD (SS)	5	22	NO_3^- regeneration
098	10/04/15	CTD (SS)	45	11	NH_4^+ regeneration
098	10/04/15	CTD (SS)	45	11	NO_2^- regeneration
098	10/04/15	CTD (SS)	45	11	NO_3^- regeneration
098	10/04/15	CTD (SS)	80	5	NH_4^+ regeneration
098	10/04/15	CTD (SS)	80	5	NO_2^- regeneration
098	10/04/15	CTD (SS)	80	5	NO_3^- regeneration
111	11/04/15	CTD (SS)	5	22	NH_4^+ assimilation
111	11/04/15	CTD (SS)	5	22	NO_2^- assimilation
111	11/04/15	CTD (SS)	5	22	NO_3^- assimilation
111	11/04/15	CTD (SS)	30	11	NH_4^+ assimilation
111	11/04/15	CTD (SS)	30	11	NO_2^- assimilation
111	11/04/15	CTD (SS)	30	11	NO_3^- assimilation
111	11/04/15	CTD (SS)	70	5	NH_4^+ assimilation
111	11/04/15	CTD (SS)	70	5	NO_2^- assimilation
111	11/04/15	CTD (SS)	70	5	NO_3^- assimilation
111	11/04/15	CTD (SS)	5	22	NH_4^+ regeneration
111	11/04/15	CTD (SS)	5	22	NO_2^- regeneration
111	11/04/15	CTD (SS)	5	22	NO_3^- regeneration
111	11/04/15	CTD (SS)	30	11	NH_4^+ regeneration
111	11/04/15	CTD (SS)	30	11	NO_2^- regeneration
111	11/04/15	CTD (SS)	30	11	NO_3^- regeneration
111	11/04/15	CTD (SS)	70	5	NH_4^+ regeneration
111	11/04/15	CTD (SS)	70	5	NO_2^- regeneration
111	11/04/15	CTD (SS)	70	5	NO_3^- regeneration
156	15/04/15	CTD (SS)	5	22	NH_4^+ assimilation
156	15/04/15	CTD (SS)	5	22	NO_2^- assimilation
156	15/04/15	CTD (SS)	5	22	NO_3^- assimilation
156	15/04/15	CTD (SS)	25	11	NH_4^+ assimilation
156	15/04/15	CTD (SS)	25	11	NO_2^- assimilation
156	15/04/15	CTD (SS)	25	11	NO_3^- assimilation
156	15/04/15	CTD (SS)	70	5	NH_4^+ assimilation
156	15/04/15	CTD (SS)	70	5	NO_2^- assimilation
156	15/04/15	CTD (SS)	70	5	NO_3^- assimilation
156	15/04/15	CTD (SS)	5	22	NH_4^+ regeneration
156	15/04/15	CTD (SS)	5	22	NO_2^- regeneration
156	15/04/15	CTD (SS)	5	22	NO_3^- regeneration
156	15/04/15	CTD (SS)	25	11	NH_4^+ regeneration
156	15/04/15	CTD (SS)	25	11	NO_2^- regeneration

156	15/04/15	CTD (SS)	25	11	NO_3^- regeneration
156	15/04/15	CTD (SS)	70	5	NH_4^+ regeneration
156	15/04/15	CTD (SS)	70	5	NO_2^- regeneration
156	15/04/15	CTD (SS)	70	5	NO_3^- regeneration
224	15/04/15	CTD (SS)	5	22	NH_4^+ assimilation
224	15/04/15	CTD (SS)	5	22	NO_2^- assimilation
224	15/04/15	CTD (SS)	5	22	NO_3^- assimilation
224	15/04/15	CTD (SS)	28	11	NH_4^+ assimilation
224	15/04/15	CTD (SS)	28	11	NO_2^- assimilation
224	15/04/15	CTD (SS)	28	11	NO_3^- assimilation
224	15/04/15	CTD (SS)	70	5	NH_4^+ assimilation
224	15/04/15	CTD (SS)	70	5	NO_2^- assimilation
224	15/04/15	CTD (SS)	70	5	NO_3^- assimilation
224	15/04/15	CTD (SS)	5	22	NH_4^+ regeneration
224	15/04/15	CTD (SS)	5	22	NO_2^- regeneration
224	15/04/15	CTD (SS)	5	22	NO_3^- regeneration
224	15/04/15	CTD (SS)	28	11	NH_4^+ regeneration
224	15/04/15	CTD (SS)	28	11	NO_2^- regeneration
224	15/04/15	CTD (SS)	28	11	NO_3^- regeneration
224	15/04/15	CTD (SS)	70	5	NH_4^+ regeneration
224	15/04/15	CTD (SS)	70	5	NO_2^- regeneration
224	15/04/15	CTD (SS)	70	5	NO_3^- regeneration
277	24/04/15	CTD (SS)	7	21	NH_4^+ assimilation
277	24/04/15	CTD (SS)	7	21	NO_2^- assimilation
277	24/04/15	CTD (SS)	7	21	NO_3^- assimilation
277	24/04/15	CTD (SS)	30	11	NH_4^+ assimilation
277	24/04/15	CTD (SS)	30	11	NO_2^- assimilation
277	24/04/15	CTD (SS)	30	11	NO_3^- assimilation
277	24/04/15	CTD (SS)	70	6	NH_4^+ assimilation
277	24/04/15	CTD (SS)	70	6	NO_2^- assimilation
277	24/04/15	CTD (SS)	70	6	NO_3^- assimilation
277	24/04/15	CTD (SS)	7	21	NH_4^+ regeneration
277	24/04/15	CTD (SS)	7	21	NO_2^- regeneration
277	24/04/15	CTD (SS)	7	21	NO_3^- regeneration
277	24/04/15	CTD (SS)	30	11	NH_4^+ regeneration
277	24/04/15	CTD (SS)	30	11	NO_2^- regeneration
277	24/04/15	CTD (SS)	30	11	NO_3^- regeneration
277	24/04/15	CTD (SS)	70	6	NH_4^+ regeneration
277	24/04/15	CTD (SS)	70	6	NO_2^- regeneration
277	24/04/15	CTD (SS)	70	6	NO_3^- regeneration
293	25/04/15	CTD (SS)	5	22	NH_4^+ assimilation
293	25/04/15	CTD (SS)	5	22	NO_2^- assimilation
293	25/04/15	CTD (SS)	5	22	NO_3^- assimilation
293	25/04/15	CTD (SS)	35	13	NH_4^+ assimilation
293	25/04/15	CTD (SS)	35	13	NO_2^- assimilation

293	25/04/15	CTD (SS)	35	13	NO_3^- assimilation
293	25/04/15	CTD (SS)	70	6	NH_4^+ assimilation
293	25/04/15	CTD (SS)	70	6	NO_2^- assimilation
293	25/04/15	CTD (SS)	70	6	NO_3^- assimilation
293	25/04/15	CTD (SS)	5	22	NH_4^+ regeneration
293	25/04/15	CTD (SS)	5	22	NO_2^- regeneration
293	25/04/15	CTD (SS)	5	22	NO_3^- regeneration
293	25/04/15	CTD (SS)	35	13	NH_4^+ regeneration
293	25/04/15	CTD (SS)	35	13	NO_2^- regeneration
293	25/04/15	CTD (SS)	35	13	NO_3^- regeneration
293	25/04/15	CTD (SS)	70	6	NH_4^+ regeneration
293	25/04/15	CTD (SS)	70	6	NO_2^- regeneration
293	25/04/15	CTD (SS)	70	6	NO_3^- regeneration
327	27/04/15	CTD (SS)	5	22	NH_4^+ assimilation
327	27/04/15	CTD (SS)	5	22	NO_2^- assimilation
327	27/04/15	CTD (SS)	5	22	NO_3^- assimilation
327	27/04/15	CTD (SS)	30	11	NH_4^+ assimilation
327	27/04/15	CTD (SS)	30	11	NO_2^- assimilation
327	27/04/15	CTD (SS)	30	11	NO_3^- assimilation
327	27/04/15	CTD (SS)	70	5	NH_4^+ assimilation
327	27/04/15	CTD (SS)	70	5	NO_2^- assimilation
327	27/04/15	CTD (SS)	70	5	NO_3^- assimilation
327	27/04/15	CTD (SS)	5	22	NH_4^+ regeneration
327	27/04/15	CTD (SS)	5	22	NO_2^- regeneration
327	27/04/15	CTD (SS)	5	22	NO_3^- regeneration
327	27/04/15	CTD (SS)	30	11	NH_4^+ regeneration
327	27/04/15	CTD (SS)	30	11	NO_2^- regeneration
327	27/04/15	CTD (SS)	30	11	NO_3^- regeneration
327	27/04/15	CTD (SS)	70	5	NH_4^+ regeneration
327	27/04/15	CTD (SS)	70	5	NO_2^- regeneration
327	27/04/15	CTD (SS)	70	5	NO_3^- regeneration

Table 25. Marine Snow catcher deployments

Event	Date	Gear	Depth (m)	Process
133	12/04/15	MSC	10	NH_4^+ regeneration
133	12/04/15	MSC	10	NO_2^- regeneration
133	12/04/15	MSC	10	NO_3^- regeneration
139	12/04/15	MSC	70	NH_4^+ regeneration
139	12/04/15	MSC	70	NO_2^- regeneration
139	12/04/15	MSC	70	NO_3^- regeneration
183	16/04/15	MSC	10	NH_4^+ regeneration
183	16/04/15	MSC	10	NO_2^- regeneration
183	16/04/15	MSC	10	NO_3^- regeneration
189	16/04/15	MSC	70	NH_4^+ regeneration
189	16/04/15	MSC	70	NO_2^- regeneration
189	16/04/15	MSC	70	NO_3^- regeneration
248	21/04/15	MSC	10	NH_4^+ regeneration
248	21/04/15	MSC	10	NO_2^- regeneration
248	21/04/15	MSC	10	NO_3^- regeneration
257	21/04/15	MSC	70	NH_4^+ regeneration
257	21/04/15	MSC	70	NO_2^- regeneration
257	21/04/15	MSC	70	NO_3^- regeneration

Status of samples and data availability.

No data is available during the cruise. The samples are stored at -20°C in the form of solid-phase extraction cartridges and GF/F filters to be analysed at the land-based laboratory. The former will be used for isotope dilution studies and the later for quantifying the carbon and nitrogen content of incubated samples and for assimilation rate determinations. Analysis will take approximately 6 weeks, after which a high quality data set is expected to be delivered.

References

Clark, D. R., T. W. Fileman, and I. Joint (2006), Determination of ammonium regeneration rates in the oligotrophic ocean by gas chromatography/mass spectrometry. Mar. Chem. 98: 121-130.

Clark, D. R., A. P. Rees, and I. Joint (2007), A method for the determination of nitrification rates in oligotrophic marine seawater by gas chromatography/mass spectrometry. Mar. Chem. 103: 84-96.

Clark, D. R, Miller, P, Woodward, M and Rees, A. (2011). Inorganic nitrogen assimilation and regeneration in the coastal upwelling region of the Iberian Peninsula. Limnol. Oceanogr., 56(5), 2011, 1689–1702.

22. Nitrous oxide & methane concentrations

Andy Rees (Plymouth Marine Laboratory)

Background

Nitrous oxide and methane are biogenically produced trace gases whose atmospheric concentrations are increasing at a rate in the order of 0.7 ppbv y-1. Both gases are radiatively active, contributing approximately 6% and 15% of "greenhouse effect" respectively, whilst N_2O contributes to stratospheric ozone depletion and CH_4 limits tropospheric oxidation capacity.

The oceans are generally considered to be close to equilibrium relative to the atmosphere for both gases, however oceanic source/sink distributions are largely influenced by oxygen and nutrient status and regulatory processes are complicated and are currently not well understood. Shelf seas and ocean areas overlying sub-oxic waters and upwelling areas dominate the ocean source and saturations of up to 300% have been reported.

Aim:- To perform vertical profiles of N_2O and CH_4 concentration in order to assess variability in the source-sink strength and exchange of both gases across benthic-pelagic, pycnocline and ocean-atmosphere boundaries within the Celtic Sea.

Methods

Samples were collected from CTD bottles at stations identified below. 1 litre seawater samples were equilibrated with compressed air and headspace analysis performed onboard using flame ionisation detection-gas chromatography (FID-GC) and electron capture detection-gas chromatography (ECD-GC) for CH_4 and N_2O respectively[1]. Atmospheric concentrations were determined by the same methods using samples collected from the ships bow into a sealed Tedlar bag.

References

[1] Upstill-Goddard R.C., A.P. Rees & N.J.P. Owens (1996) Simultaneous high-precision measurements of methane and nitrous oxide in water and seawater by single phase equilibration gas chromatography Deep-Sea Research I. Vol. 43, No. 10, PP. 1669-1682.

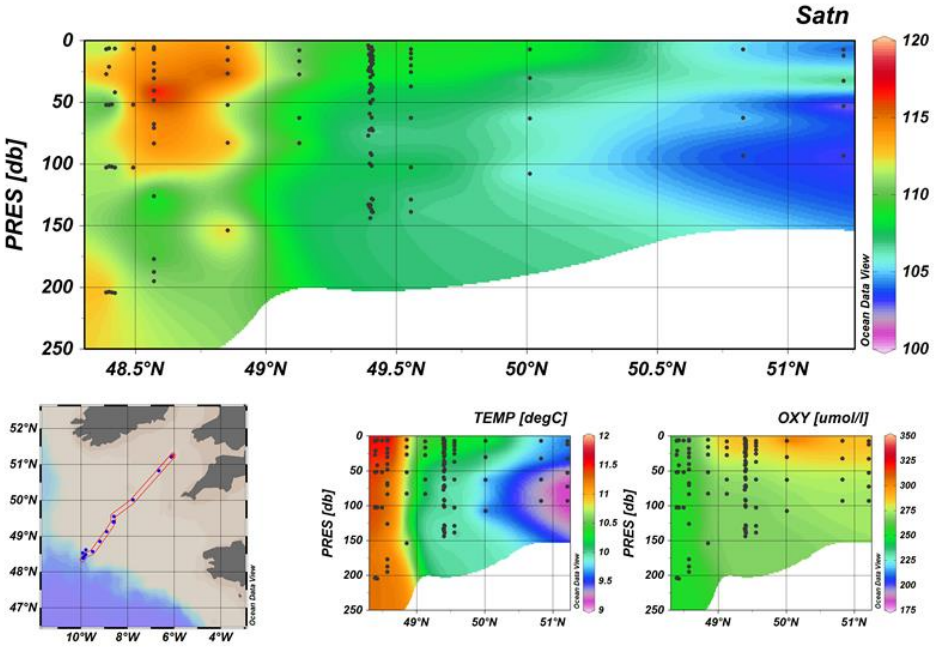

Figure 17. N_2O saturation (%) relative to atmospheric equilibrium during DY029, April 2015

Table 26. N_2O, CH_4 Sampling details

Day	Station	CTD	Lat (°N)	Long (°W)	Niskin	Depths Sampled
4	ccs	6	49.5561	8.5931	1,3,5,10,13,15,17,19,21,24	135,125,100,60,35,23,18,12,8,5
4	ccs	8	49.398	8.604	1,5,9,13,19,21	135,100,60,25,10,5
5	ccs	11	49.4055	8.5951	2,5,7,11,17,21	135,100,70,40,15,5
6	ccs	13	49.4051	8.5881	2,4,5,10,13,15,17,19,21,24	135,125,90,60,35,23,18,12,8,5
6	Fe08	14	48.3886	9.9145	17,21,1	25,5,2100
6	Fe08	16	48.3886	9.9145	8,21,23,24	1750,1500,100,50
6	Fe08	17	48.3886	9.9145	1,9,17	1250,950,800
7	Fe08	18	48.3885	9.9145	1,9,17,24	600,400,200,5
7	Fe09	19	48.3993	9.9013	23,15,2,1	20,1500,1850,1250
7	Fe09	21	48.3993	9.9013	8,16,23,24	950,800,100,50
7	Fe09	22	48.3993	9.9013	1,9,17	600,450,200
7	Fe10	23	48.4101	9.89	1,17,23,24	1400,1000,100,50
7	Fe10	24	48.4101	9.89	1,7,15,20	800,600,400,200
8	Fe11	29	48.4223	9.8783	24,22,15,2	5,40,700,900
8	Fe11	31	48.4223	9.8783	24,18,7	100,200,500
9	Fe13	36	48.4393	9.8568	24,23,21,20,19,13,7	5,25,50,100,200,300,370
9	Fe14	39	48.4915	9.8088	1,6,11,16,21,24	240,200,150,100,50,5
10	cs2	41	48.5711	9.51	2,7,8,13,17,19,24	190,80,65,45,22,16,5
10	O4	45	48.8535	9.1995	1,2,10,15,22,23	150,80,50,25,14,4
10		46	49.1283	8.9045	2,9,20,21,23	80,50,25,15,6
11	ccs	49	49.397	8.5815	2,7,10,15,19,21	130,70,40,20,10,5
13	A	53	51.2138	6.13	1,6,10,15,19,23	90,70,50,30,10,5
14	J2	58	50.8285	6.6663	1,7,16,22	90,60,30,5

Day	Station	CTD	Lat (°N)	Long (°W)	Niskin	Depths Sampled
14	J6	61	50.0116	7.7763	2,6,12,22	105,60,30,5
15	ccs	64	49.4095	8.586	2,4,7,9,10,13,15,16,19,24	135,125,70,45,35,25,16,13,10,5
15	ccs	66	49.3923	8.5933	2,7,18,24,	132,75,22,5
16	ccs	69	49.396	8.6148	21,23	10,5
17	Fe01	72	48.2048	10.0538	1,7,20,21,23,24,	2250,1700,950,80,25,5
17	Fe01	74	48.2048	10.0538	2,9,17	1300,850,700
17	Fe01	75	48.2048	10.0538	1,9,17	550,850,700
17	Fe02	76	48.2395	9.9655	1,15,24	1990,1550,950
18	Fe02	78	48.2395	9.9655	24,22,1	50,725,500
18	Fe02	79	48.2395	9.9655	15,23,24	200,100,5
18	Fe03	83	48.3408	9.7045	23,17,12,2	100,850,1050,1300
18	Fe03	85	48.3408	9.7045	8,15,23	500,200,50
19	Fe04	87	48.3701	9.62883	18,6,1	550,750,50
19	Fe04	88	48.3701	9.62883	17,15,13,7,1	5,50,100,250,400
19	Fe06	93	48.4088	9.52616	1,6,11,17,18,24	455,350,200,100,50,5
20	ccs	94	49.4006	8.619	2,3,7,8,10,13,15,17,19,24	140,130,70,48,38,28,20,15,11,5
21	ccs	101	49.4011	8.6215	2,6,10,14,20,24	132,90,50,35,15,2
22	Fe17	104	48.5333	9.93333	9,2,11,14,19,23	250,504,100,60,25,5
23	Fe20	109	48.6251	9.79383	2,3,6,12,18,23	500,250,100,50,15,5
24	cs2	113	48.5713	9.5095	2,4,5,8,10,13,15,17,21,24	185,175,125,70,40,30,24,18,7,5
24	cs2	116	48.5696	9.50933	1,4,6,11,16,23	195,100,70,30,15,5
25	ccs	124	49.4093	8.5913	2,3,8,11,17,23	133,90,45,30,15,5
27	A	131	51.2130	6.1302	2,7,8,13,17,21	95,70,50,30,15,5
27	J2	133	50.8280	6.6655	2,6,22	90,40,5
27	J4	134	50.4200	7.2277	2,6,10,23	97,50,26,5
27	J6	136	50.0132	7.7763	1,7,14,23	105,45,30,5
28	ccs	140	49.4058	8.5808	2,4,7,10,16,19,21,23	135,100,60,46,35,25,15,5

21. Abundance & composition of microbial plankton communities

Glen Tarran (Plymouth Marine Laboratory)

Objectives

To determine the distribution, abundance and community structure of nano- and picophytoplankton, and heterotrophic bacteria by flow cytometry and microplankton and mesophytoplankton by microscopy from CTD casts

Pico- and nanoplankton community structure and abundance by flow cytometry.

Seawater samples were collected in clean 250 mL polycarbonate bottles from a Seabird CTD system containing either a 24 bottle rosette of 20 L Niskin bottles on a stainless steel frame or a rosette of up to 24 10 L Niskin bottles on a titanium frame from CTD casts. Samples for enumeration of phytoplankton were stored in a refrigerator and all samples analysed within 1.5 hours of collection on high flow rate (Approx. 170 µL min^{-1}) for 4 minutes. Samples for bacteria enumeration were fixed immediately after collection with glutaraldehyde solution (0.5 %final concentration) and left to fix in a fridge for 30 mins. Samples were then stained with the DNA stain SYBR Green I (Sigma) for 1 hour in the dark at room temperature before analysis by flow cytometry, either at medium or low flow rate (approx. 54 or 13.5 µL min^{-1} respectively) for 1 or 2 minutes, depending on the event rate s^{-1}. All samples were generally analysed within 3 hours of surfacing. Samples were measured using a Becton Dickinson FACSort flow cytometer which characterised and enumerated *Prochlorococcus* sp. and *Synechococcus* sp. (cyanobacteria), and pico- and eukaryote phytoplankton and heterotrophic bacteria, based on their light scattering and autofluorescence properties. Data were saved in listmode format and analysed onboard. Table 27 summarises the CTD casts sampled and analysed during the cruise.

During iron transects, the nearest sample to the surface was at 20 m, so, in order to increase near-surface resolution, samples were collected from the clean seawater supply in the clean seawater laboratory. These samples are identified in Table 27 as samples at 6 m where the titanium frame was used.

Microplankton and mesophytoplankton community structure and abundance by microscopy

Seawater samples were collected in 250 mL amber glass jars containing 5 mL Lugol's iodine solution as a preservative. Samples were generally collected from predawn CTDs at 6 nominal light depths: 60, 40, 20, 10,

5, and 1% of surface light. Samples will be returned to the laboratory for microscopic analysis after the cruise. Table 27 summarises the CTD casts sampled during the cruise (items in bold).

Table 27. Sampling for phytoplankton, and heterotrophic bacteria and flagellate community structure / abundance. Casts / depths in bold were also sampled for microplankton community structure / abundance (Lugol's).

DATE	EVENT	STATION	CTD	TIME on deck (GMT)	LAT N	LONG E	NOMINAL DEPTHS SAMPLED NISKIN BOTTLES SAMPLED
04-Apr	**9**	**CCS**	**C006SS**	**02:41**	**49.39**	**-8.59**	**5 8 12 18 23 35** 60 70 100 125 135 24 20 19 17 14 13 10 8 5 3 1
04-Apr	15	CCS	C008SS	13:27	49.40	-8.60	5 10 15 20 25 35 60 70 100 125 135 22 20 18 16 14 12 10 8 5 4 2
05-Apr	33	CCS	C011SS	15:34	49.41	-8.60	5 10 15 20 25 35 60 70 100 125 135 22 20 18 16 14 12 10 8 6 4 2
06-Apr	**47**	**CCS**	**C013SS**	**02:47**	**49.41**	**-8.59**	**5 8 12 18 23 35** 60 70 90 125 135 24 20 19 16 15 13 10 8 5 4 2
06-Apr	49	Fe08	C014SS	14:52	48.39	-9.91	5 15 25 40 60 80 120 150 180 200 24 21 19 17 15 13 11 9 7 5 3 1
08-Apr	66	Fe08	C027T	08:21	48.39	-9.91	20 50 75 100 150 200 250 300 500 700 1000 1500 24 23 22 21 20 19 18 17 15 12 9 7
08-Apr	67	Fe09	C028T	12:54	48.40	-9.90	20 60 80 100 150 200 250 300 500 950 1500 24 22 21 20 19 18 17 16 13 8 4
09-Apr	77	Fe12	C033T	04:27	48.43	-9.87	20 60 80 100 150 200 300 400 450 550 650 12 10 9 8 7 6 5 4 3 2 1
09-Apr	79	Fe13	C035T	08:19	48.44	-9.86	20 50 80 100 150 200 300 400 475 11 10 9 8 7 6 5 4 2
09-Apr	84	Fe14	C038T	13:20	48.49	-9.81	20 40 50 80 100 150 200 243 10 8 7 6 5 4 3 1
10-Apr	**98**	**CS2**	**C041SS**	**02:39**	**48.57**	**-9.51**	**5 8 16 22 29 45** 65 80 180 190 24 20 19 16 15 13 10 8 7 4 2
10-Apr	101	O4	C044T	11:19	48.85	-9.20	20 25 40 60 80 110 140 152 10 8 7 6 5 4 3 2
10-Apr	102	O4	C045SS	12:29	48.85	-9.20	4 14 25 35 50 60 80 23 22 15 12 10 9 2
10-Apr	103	O2	C046SS	15:21	49.13	-8.90	6 15 25 33 50 60 80 23 21 20 13 11 9 2
11-Apr	**111**	**CCS**	**C049SS**	**02:37**	**49.40**	**-8.58**	**5 10 15 20 30** 40 **50** 70 120 130 20 19 16 15 13 10 8 7 4 2
12-Apr	131	CCS	C052T	06:17	49.41	-8.59	6 20 30 40 80 100 120 135 11 9 8 7 5 3 1
13-Apr	143	A	C053SS	21:41	51.21	-6.13	5 10 20 30 40 50 60 70 80 90 23 19 17 15 12 10 8 6 5 1
14-Apr	**148**	**J2**	**C058SS**	**05:26**	**50.83**	**-6.67**	**5 10 20 30 40** 45 **50** 60 70 80 90 23 20 19 16 13 11 10 7 6 3 2
14-Apr	151	J4	C059SS	10:43	50.42	-7.23	5 12 22 35 45 52 65 80 100 23 20 17 14 11 8 5 3 2
14-Apr	153	J6	C061SS	16:01	50.01	-7.78	5 10 15 23 28 33 40 60 80 105 23 20 17 14 12 10 8 6 4 1

15-Apr	**156**	**CCS**	**C064SS**	**02:27**	**49.41**	**-8.59**	**5 10 13 16 25 35** 45 70 125 135 20 19 16 14 13 10 9 7 4 2
15-Apr	159	CCS	C066SS	12:43	49.39	-8.59	2 8 14 22 33 42 50 65 75 90 120 132 23 21 19 17 15 13 11 9 7 5 4 2
16-Apr	179	CCS	C069SS	13:05	49.40	-8.61	5 10 15 20 25 35 45 55 60 75 105 130 24 22 20 18 16 14 12 10 8 5 4 2
17-Apr	**199**	**CS2**	**C071SS**	**07:30**	**48.57**	**-9.51**	**5 10 20 30 40 60** 80 100 150 185 22 20 18 13 12 10 8 6 4 2
17-Apr	201	Fe01	C073T	15:45	48.20	-10.05	6 20 40 60 70 90 100 150 200 550 750 1000 1500 24 23 22 21 20 19 18 17 14 12 8 6
18-Apr	209	Fe15	C081T	11:58	48.30	-9.80	6 20 45 65 100 150 200 350 550 700 850 1100 1507 23 22 20 19 18 17 15 12 9 7 4 2
19-Apr	216	Fe04	C086T	07:18	48.37	-9.63	6 20 40 70 100 250 300 400 550 650 750 900 950 24 22 21 19 16 15 14 13 12 8 6 3
19-Apr	219	Fe05	C089T	11:48	48.38	-9.61	6 20 40 70 100 250 450 500 650 741 16 15 14 13 10 9 6 4 1
19-Apr	222	Fe06	C092T	15:30	48.41	-9.53	6 20 40 70 100 225 400 467 17 16 15 11 8 5 2
20-Apr	**224**	**CCS**	**C094SS**	**02:40**	**49.40**	**-8.62**	**5 11 15 20 28 38** 48 70 130 140 20 19 16 14 13 10 8 7 3 2
20-Apr	227	CCS	C097SS	12:29	49.40	-8.62	5 10 14 20 26 34 42 46 55 70 95 130 23 22 20 16 14 12 10 9 7 5 4 1
21-Apr	246	CCS	C101SS	13:02	49.40	-8.62	5 10 15 20 25 35 40 50 75 90 105 132 23 21 19 17 15 13 11 9 7 5 3 1
22-Apr	265	Fe16	C103T	08:34	48.42	-9.94	6 20 35 50 70 100 150 200 400 650 950 1300 1500 24 23 22 21 20 19 18 16 14 11 9 7
22-Apr	267	Fe17	C105T	14:08	48.53	-9.93	6 20 30 50 70 125 250 400 550 750 900 1050 1550 24 23 22 21 20 19 17 16 14 11 9 7
22-Apr	268	Fe18	C106T	19:09	48.58	-9.92	6 20 35 50 70 100 200 400 500 650 950 1100 1510 24 23 22 21 20 19 16 14 12 9 6 2
23-Apr	272	Fe19	C108T	10:07	48.62	-9.83	6 20 55 75 100 125 250 350 500 750 950 1062 20 18 17 16 14 13 12 9 6 4 2
23-Apr	274	Fe20	C110T	14:26	48.63	-9.79	6 20 30 50 70 100 125 175 450 650 758 16 15 14 13 12 10 9 6 3 1
23-Apr	275	Fe21	C111T	18:10	48.63	-9.78	6 20 30 55 70 100 165 200 300 400 503 13 12 11 10 7 6 5 4 3 1
24-Apr	**277**	**CS2**	**C113SS**	**02:42**	**48.57**	**-9.51**	**5 7 13 18 24 30** 40 70 125 175 185 24 20 19 16 15 13 10 8 5 4 2
24-Apr	285	CS2	C116SS	13:49	48.57	-9.51	5 10 15 20 30 50 70 100 192 23 20 17 14 11 8 6 4 2
25-Apr	**293**	**CCS**	**C120SS**	**02:26**	**49.40**	**-8.62**	**5 6 12 18 24 35** 45 70 95 120 132 24 20 19 16 15 12 10 8 5 4 2
25-Apr	301	CCS	C124SS	12:28	49.41	-8.59	5 10 15 20 30 45 60 90 133 24 21 18 15 12 9 6 4 2
27-Apr	**327**	**A**	**C131SS**	**03:25**	**51.21**	**-6.13**	**5 10 15 20 30 40** 50 70 85 95 20 19 16 14 13 10 8 7 3 2
27-Apr	329	J2	C133SS	08:25	50.83	-6.67	5 8 15 18 24 28 70 70 90 19 18 13 11 9 8 5 4 2
27-Apr	330	J4	C134SS	12:51	50.42	-7.23	5 12 16 18 20 262 26 34 50 70 97 22 20 18 16 14 12 9 7 5 3 1
27-Apr	332	J6	C136SS	17:33	50.01	-7.78	5 10 14 18 24 28 32 37 45 65 85 105 23 22 19 18 15 13 12 10 8 6 4 2

28-Apr	**341**	**CCS**	**C140SS**	**08:46**	**49.41**	**-8.58**	5 **15** 25 35 41 46 60 100 135 24 22 20 17 13 12 9 5 2

Collaborative sample analysis by flow cytometry

Dilution grazing experiments

A series of 6 dilution experiments were conducted during the cruise by Sari Giering and Seona Wells (see their cruise report for details). In addition to standard fluorometric analysis of samples, 2 and 4 mL samples were preserved with glutaraldehyde solution (0.5% final concentration) and left to fix in a fridge for a minimum of 1 hour. Samples were then analysed by flow cytometry as described above to quantify phytoplankton. 100% undiluted seawater samples were analysed for 5 minutes. 70% for 8 minutes, 40% for 12 minutes and 20% for 16.5 minutes. All samples were analysed on high flow rate (Approx. 170 µL min^{-1}).

Dissolved organic material incubation experiments.

Samples were analysed to quantify the growth of bacteria in experiments set up by Callum Whyte and Elaine Mitchell at various time points throughout the cruise (see their cruise report for details).

22. Zooplankton biomass & metabolic rates

Sari Giering & Seona Wells (University of Aberdeen)

Scientific motivation

Zooplankton play a significant role in the biogeochemical cycle of the sea as they ingest particulate organic matter and transform it into (1) CO_2 via respiration, (2) N-rich dissolved matter via excretion, and (3) particulate matter via the production of biomass, eggs and C-rich faecal pellets. The N-rich excretion products are likely to remain in the dissolved phase, whereas the C-rich faecal pellets may sink to depth at rates of up to 2700 m per day (review by Turner 2002). This differential recycling, with N staying in the upper ocean and C being exported to depth, has been postulated to enhance decoupling of C and N in shelf regions.

During DY029, we collected mesozooplankton (here zooplankton larger than 63 µm) to assess their abundance, elemental composition and to carry out experiments measuring excretion and grazing for mixed zooplankton communities in different size fractions (63-200 µm, 200-500 µm, >500 µm). We further measured excretion and grazing of *Luidia sarsi* larvae.

Material & Methods

Abundance estimates

Samples for zooplankton biomass and elemental composition were sampled using WP2 nets of two different mesh sizes (63 µm and 200 µm). At each process station, WP2 nets fitted with non-filtering cod-ends and a closing mechanism were deployed 4 times during daytime and 4 times during night-time sampling below and above the thermocline. Zooplankton of the size between 63-200 µm were collected using a 63-µm WP2 net hauled at 0.2 m/s. Zooplankton larger than 200 µm were collected using a 200-µm WP2 net hauled at 0.5 m/s. Collected zooplankton was size-fractioned into 63-200 µm, 200-500 µm, and >500 µm. Each size fraction was split: half was preserve in borax-buffered formaldehyde for identification and counts and half was frozen at -80°C for POC/N/P analyses. Net samples for distribution and abundance will be complemented by vessel-mounted ADCP backscatter data. Samples for microzooplankton abundance and distribution (preserved with Lugol's iodine) were taken from 6 depth from each pre-dawn CTD by Glen Tarran.

Rate-series experiments

Vital rates experiments were aimed to measure excretion and grazing of the same 'mixed community'. To do so, we transferred groups of zooplankton of one size class (63-200 µm, 200-500 µm and >500 µm) in triplicates through sequential experiments determining rates. Zooplankton was first acclimated in unfiltered sea water for 3 hours. Animals were placed into filtered water and excretion of ammonium and nutrients was measured over a period of 3 hours. Animals were then transferred into 2.3-L bottles filled with unfiltered water and incubated for 24 hours to measure ingestion of microplankton. The order is chosen to combine acclimation phases with actual rate measurements. A similar experiment was carried out with gelatinous zooplankton. 12 *L. sarsi* larvae were incubated in filtered water and excretion of ammonium and nutrients was measured over a period of 5 h. The larvae were then transferred into 1.2-L bottles with unfiltered water and incubated for 24 hours on a plankton wheel. Size-fractionated chlorophyll (0.2-2, 2-20, and >20 µm) was measured before and after the incubation to estimate grazing on phytoplankton. All equipment was acid-washed, bottles and carboys were rinsed three times with incubation water prior to filling, and gloves and hair nets were worn at all times.

Sample summary

129 nets were deployed in total. Daytime/night-time distribution was sampled 10 times, vertical night-time distribution was sampled at the off-shore sites Fe11, resulting in a total of 318 samples for biomass (including zooplankton from vital rates experiments) and 264 samples for elemental composition. Six zooplankton vital rates experiments, five gelatinous vital rates experiments and seven dilution experiment were carried out. A total of 380 ammonium and nutrient samples were collected, and analysed on board by Carolyn Harris. 226 samples for microplankton (preserved using Lugol's iodine) were taken from the zooplankton grazing experiments and dilution experiments. Lugol's-preserved samples will be analysed on shore.

References

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23. Microzooplankton grazing

Sari Giering & Seona Wells (University of Aberdeen)

Materials & Methods

We carried out seven dilution experiments to measure microzooplakton grazing (Landry & Hassett 1982). Water was collected from two depths, in the euphotic zone and below the thermocline, using Niskin bottles mounted on a CTD rosette. Water was either gently pre-screened with 63-µm mesh and transferred into carboys or filtered through an in-line filter cartridge (0.2 µm). Dilutions were made up in separate carboys as 100%, 70%, 40% and 20% unfiltered water with the remainder being filtered water. 1.2-L glass bottles were filled in triplicates and incubated for 24 hours at in situ temperature and at the local photoperiod. Samples for time zero of Chlorophyll a (size fractionated: 0.2-2, 2-20, and >20 µm), bacteria (flow cytometry) and nutrients were taken from each dilution. For the shallow dilution series, samples were also taken for coccolithophore abundance and microplankton (preserved using Lugol's iodine). After the incubation period, samples were taken for Chlorophyll a (size fractionated), microplankton counts (shallow only), coccolithophore counts (shallow only) and pico- and nanoplankton community structure and abundance. All equipment was acid-washed, bottles and carboys were rinsed three times with incubation water prior to filling and gloves and hair nets were worn at all times. The experiments were set up in darkness and exposure to light was minimized at all times.

Sample summary

From the grazing and dilution experiments, ~800 samples for Chlorophyll a were taken and analysed on board using a Turner fluorometer. 208 samples for pico- and nanoplankton community structure and abundance were taken and analysed on board by Glen Tarran using flow cytometry. 226 samples for microplankton (preserved using Lugol's iodine) were taken from the zooplankton grazing experiments and dilution experiments. Lugol's-preserved samples will be analysed on shore.

References

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24. Trace metal sampling

Maeve Lohan, Angela Milne, Antony Birchill, Matthew Fishwick (University of Plymouth)

& Dagmara Rusiecka (University of Southampton)

Overview

Sample logs for all Ti-CTD casts and fish sampling are available in the Appendix. Samples were collected for trace metal analysis in both the dissolved and particulate fractions using the dedicated trace metal 10 L OTE bottles mounted on a Ti-frame rosette system.

The trace metal samples collected will be analysed at different institutes for differing parameters:

Total dissolvable, dissolved and soluble Iron – Antony Birchill at the University of Plymouth

Total dissolvable and dissolved Trace Metals (excluding iron) – Dagmara Rusiecka at NOCS and IfM GEOMAR.

Iron(II) – Ship-board analysis by Antony Birchill and Matthew Fishwick, University of Plymouth.

Ligands – Dagmara Rusiecka at NOCS and IfM GEOMAR.

Suspended Particulate Material (SPM) – Angela Milne and Antony Birchill at the University of Plymouth.

A total of 1698 profile seawater samples were collected over the 39 casts. 1084 of these were for Iron Analysis (426 total dissolvable and 425 dissolved and 233 soluble) and 617 were for Trace Metal Analysis (210 total dissolvable, 317 dissolved and 87 ligands). At each station, selected depths were sampled for Suspended Particulate Material resulting in 171 samples. At each deployment of the trace metal rosette, unfiltered samples were collected for macronutrients from all OTE bottles and at selected depths for salinity, oxygen and chlorophyll *a* for sensor calibration.

In addition, selected casts were sampled for flow cytometry (Glen Tarran, Plymouth Marine Laboratory), alkalinity (Alex Poulton, NOC), dissolved organic matter (Claire Davis, University of Liverpool), Fe isoptes (Jessy Klar, NOC), Cr isotopes (Rachel James, NOC), Cu ligands (Hannah Whitby, University of Liverpool), Pigments (James Fox, Essex) and SPM for IP25 (Lukas Smik, University of Plymouth). Separate to the water column profiles, seawater was also collected for a number of incubation experiments (including ^{55}Fe uptake

and zooplankton grazing). These additional samples are detailed in the log sheets (contained in the appendix).

Underway surface samples were collected by pumping surface seawater into a trace metal clean sampling laboratory using a Teflon diaphragm pump (Almatec A-15, Germany) connected by an acid-washed braided PVC tubing to a towed fish positioned at approximately 2 - 3m depth alongside the ship. Both unfiltered and filtered (0.2 μm Sartonbran P membrane filter capsule, Sartorius) seawater samples were collected over 4 transects; Fe1, Fe2, Fe3 and the J line. A total of 128 surface seawater samples were collected at 27 time points. This includes 76 for Fe analysis (27 total dissolvable, 27 dissolved and 22 soluble) and 52 for Trace Metal analysis (15 total dissolvable, 27 dissolved and 10 for ligands). In addition, samples for Cu ligands were collected at 5 time points and SPM for IP25 at 1 time point, whereas samples for nutrient analysis were collected at every time point.

Problems encountered

Over the 39 casts sampled for trace metals, a total of 6 OTE bottles either did not fire or the bottles did not fully close (at Stations O4, Fe01, Fe03, Fe16, Fe20, CCS_6) and therefore these depths were not sampled.

An issue with the conducting cable on the 6th April, during the first Fe transect, resulted in the cable needing to be cut and re-terminated. As sampling for Ra using the SS rosette was able to continue during this period operations still continued and trace metal work re-commenced on the 7th April.

Deployment and use of the clean tow-fish in its new port side position, whilst more complicated to deploy than previously, worked well. If the deployment and recovery process can be eased this new position is preferred in comparison to the closer to the ship location of past cruises. However, I am a little concerned whether the tubing could withstand rougher waters, it is no longer possible to tape the tubing as high up as previously (it used to clear the water line) due to the need to winch/crane the fish into position. This is something that will need to be tested on future cruises. The tow-fish had to be recovered once due to the tubing coming loose and I would therefore recommend using cable ties on the tubing which comes out of the nose for all future deployments. Also, as deployment is now on the port side, it is essential to keep in regular contact with engineering/bridge during fish sampling periods as the sampling pump needs to be turned off during grey water disposal. As fish sampling periods were not overly long this was manageable.

With regards to the clean sampling laboratory, the improvements made to the facility (since last used on DY017 and DY018) have greatly improved its workability in terms of bottle racking, gassing and the ability to sample more efficiently. However, a couple of issues still remain and a couple of new ones have arisen.

- The opening/closing of the outer doors (the ones used to access the changing area) still remains as issue. Windows, or some other means of notification, need to be added so it is known when the

inner laboratory door is open therefore maintaining a clean working environment in the sampling area. Visibility from the changing area through to the deck lab would also prevent opening the door when someone is passing by (this has nearly happened on a couple of occasions).

- The locking/opening mechanism on the door to the inner clean laboratory needs attention, it sometimes requires several hard pushes to open and has even jammed a couple of times.

- The re-spacing of the bottles is great however this has unfortunately meant that the 2 outer bottles (1 and 24) are extremely close to a wall are therefore difficult to rack and, in bottle 24s case, very difficult to sample from (the tap points towards the wall). There are also problems clamping bottle 24 as the arms of the clamp struggle to get past the tap, on occasion the OTE bottle has had to be removed from the rack to remove the clamp.

- Concerning the top of the clamp (the part that goes over the top of the OTE bottle), it would be useful if the hole was made slightly bigger so that the top clamp can pass over the fixing/join of the lanyard.

- The drainage trays have now been lowered which has made it easier to sample for SPM, however it is still not possible to collect SPM from all of the OTE bottles (I had to avoid bottle 24 due to the wall and bottle 12 due to the position of the tap which was located over the gap between the drainage trays), and it would still not be possible to collect SPM from all the OTE bottles at the same time. The positioning of the drainage trays still hinders the ability to get access under each SPM filter holder without moving along to an empty space (i.e. where there is not a filter holder).

25. Total dissolvable, dissolved and soluble iron

Antony Birchill (University of Plymouth)

Objectives

Iron (Fe) is an essential nutrient for primary productivity in the ocean. Due to its low solubility iron can be a limiting factor for the growth of phytoplankton in the open ocean as well as in coastal seas (de Baar et al., 1990; Hutchins and Bruland, 1998; Martin and Fitzwater, 1988). It has become evident that the atmosphere (Duce and Tindale, 1991), rivers (De Baar and de Jong, 2001), hydrothermal activity (Tagliabue et al., 2010 ; Klunder et al.,2011) and advection of shelf derived sediment to the open ocean (Bucciarelli et al., 2001; Lam and Bishop, 2008) are significant transport pathways for iron to the ocean. Fe fluxes from shelf seas to the open ocean are poorly constrained, although estimates indicate they could be 2-10 times higher than atmospheric inputs (Elrod et al. 2004) and thus potentially be a major contributor to the oceanic Fe cycle. Shelf edge biogeochemical processes that result in Fe export to the ocean are not well understood and key questions remain about the magnitude and significance of Fe fluxes from the shelf to the open ocean. We aim to investigate and quantify the supply and transport of iron in the shelf region off the North West of Scotland.

Sampling protocol

On recovery, the 10 L OTE bottles were transferred into a clean sampling laboratory where they were immediately sampled for oxygen, nutrients, salinity and total dissolvable iron before being pressurised to approximately 7 psi with 0.2 µm filtered air using an oil free compressor. After the collection of particulate samples (see section on Particulate Trace Metals), a Sartobran 300 (Sartorius) filter capsule (0.2 µm) was used to collect filtered seawater samples into clean LDPE sample bottles. Bottles and caps were rinsed 3 times with the filtered sample before being filled. All samples, including underway samples, were acidified to 0.024 M (UpA HCl, Romil) and stored, double bagged, for shore based analysis.

Samples collected

A total of 1084 samples were collected for total dissolvable, dissolved and soluble iron as detailed below:

Sample analysis

Samples for dissolved iron will be analysed at the University of Plymouth after 2 months acidification, whereas samples for total dissolvable iron will be left for at least 6 months prior to analyses. Flow Injection with chemiluminescence detection (FI-CL) (Obata et al. 1993; de Jong 1998; Klunder et al. 2011) will be used for all sample analyses using Toyopearl AF-650-M resin for pre-concentration.

References

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Table 28. Sampling details for total dissolvable, dissolved and soluble iron

Station	Samples collected from separate depths ***Dissolvable + Dissolved + Soluble***		Station	Samples collected from separate depths ***Dissolvable + Dissolved + Soluble***
CCS_1	6+6+6		Fe03	18+17+6
CCS_2	6+6+6		Fe04	13+13+6
Fe08	24+24+6		Fe05	9+9+6
Fe09	22+22+6		Fe06	7+7+6
Fe10	20+20+6		CCS_5	6+6+6
Fe11	14+14+6		Fe16	20+20+6
Fe12	11+11+6		Fe17	19+19+6
Fe13	9+9+6		Fe18	19+19+6
Fe14	8+8+6		Fe19	14+14+6
O4	8+8+6		Fe20	11+11+6
O2	8+8+6		Fe21	11+11+6
CCS_3	6+6+6		Fe22	7+7+6
SiteA_1	6+6+6		CS2	7+7+6
J2	6+6+6		CCS_6	5+5+5
J4	6+6+6		SiteA_2	6+6+6
J6	6+6+6		J2(2)	6+6+6
CCS_4	6+6+6		J4(2)	6+6+6
Fe01	22+22+6		J6(2)	6+6+6
Fe02	19+19+6		CCS_7	6+6+6
Fe15	17+17+6			

26. Total dissolvable and dissolved trace metals

Dagmara Rusiecka (University of Southampton)

Objectives

Iron is well established as a limiting element for phytoplankton growth, however the role and cycling of other trace elements are less understood and there is a lack of data on the concentration and distribution of these elements in the global ocean. While elements such as cadmium, zinc and cobalt have a biological role, reflected in their nutrient like profiles, other trace elements can be used as tracers of inputs to the ocean, e.g. aluminium (Al) is an indicator of aerosol deposition (Tria et al., 2007), and manganese (Mn) can indicate sedimentary or hydrothermal inputs (Johnson et al., 1992; Middag et al., 2011). As with Fe, there is a paucity of data concerning the input, and cycling, of trace metals from shelf regions. The questions surrounding the magnitude and export of Fe from the shelf to the open ocean also apply to a suite of trace metals. We aim to investigate and quantify the supply and transport of selected trace metals from the shelf off the North West of Scotland.

Sampling protocol

Following recovery of the Ti-rosette, the OTE bottles were transferred into a clean sampling laboratory where they were immediately sampled for oxygen, nutrients, salinity and total dissolvable trace metals before being pressurised to approximately 7 psi with 0.2 µm filtered air using an oil free compressor. After the collection of particulate samples (see section on Particulate Trace Metals), a Sartobran 300 (Sartorius) filter capsule (0.2 µm) was used to collect filtered seawater samples into clean LDPE sample bottles. Bottles and caps were rinsed 3 times with the filtered sample before being filled. All samples, including those from the underway system, were acidified to 0.016 M (UpA HCl, Romil) and stored, double bagged, for shore based analysis.

Samples collected

Samples for total dissolvable and dissolved trace metals were collected as detailed below, a total of 527 samples were collected for analysis:

Sample analysis

Samples will be analysed for a range of trace metals e.g. Ag, Al, Mn, Cd, Zn, Cu, by inductively coupled mass spectrometry (ICP-MS) at IfM GEOMAR (Milne et al. 2010). For Al analysis, flow injection with fluorescence detection (Resing and Measures, 1994) will be used following the modified method of Brown and Bruland (2008). Dissolved samples will be analysed after 2 months acidification whereas dissolvable samples will be left for at least 6 months before analysis.

References

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Table 29. Sampling details for total dissolvable and dissolved trace metals

Station	Samples collected from separate depths ***Dissolvable + Dissolved***		Station	Samples collected from separate depths ***Dissolvable + Dissolved + Soluble***
CCS_1	3+6		Fe03	8+11
Fe08	12+15		Fe04	7+10
Fe09	12+15		Fe05	5+7
Fe10	10+13		Fe06	4+6
Fe11	7+10		Fe16	11+15
Fe12	6+8		Fe17	10+13
Fe13	5+8		Fe18	10+13
Fe14	4+8		Fe19	7+10
O4	4+8		Fe20	6+8
O2	4+8		Fe21	6+11
SiteA_1	4+6		Fe22	4+7
J2	4+6		CS2	4+7
J4	3+6		SiteA_2	3+6
J6	3+6		J2(2)	3+6
CCS_4	3+6		J4(2)	3+6
Fe01	11+16		J6(2)	3+6
Fe02	9+13		CCS_7	3+6
Fe15	9+11			

27. Iron(II)

Antony Birchill & Matthew Fishwick (University of Plymouth)

Objectives

In shelf sediments microbial oxidation of organic carbon delivered from primary productivity in the overlying shallow water column is the main driver of early diagenesis which produces dFe. For cohesive sediments (~40% of the North Sea floor), Fe(II) is principally generated by dissimilatory reduction of Fe(III), and is subsequently transferred to the water column via diffusion and sediment resuspension. Sedimentary supply of dFe(II) has been reported in low oxygen shelf waters (Lohan & Bruland, 2008) and in more oxic European shelf waters (Ussher et al. 2007). While the benthic cruise is determining Fe(II) in the sediments, our goal was to determine how much Fe(II) is in the bottom water overlying these sediments. In addition Fe(II) is produced in the upper water column from photochemical processes and from biological production. As Fe(II) is a transient species this was determined onboard ship.

Sampling protocol

On recovery of the Ti-rosette, the OTE bottles were transferred into a clean sampling laboratory where they were immediately sampled for Fe(II) from 6 depths. Only 6 depths were chosen due to the transient nature of Fe(II) and the analysis time needed for completion of the measurements. Samples for Fe(II) were the first samples to be collected from the OTE bottles using a technique similar to oxygen sampling (initially filling the sampling bottle while it is upside down and overfilling the bottle in order to reduce oxygen from entering the sample).

Samples collected

It was not possible to analyse Fe(II) on the off-shelf transects, or at all of the on-shelf process stations, due to a lack of personnel on-board the ship. In addition, the failure of a piece of the analysis equipment meant that it was not possible to make any measurements at the last 2 CCS process stations. A total of 18 samples from 3 stations were collected and analysed for Fe(II), these are detailed below:

Table 30. Sampling details for total dissolvable, dissolved and soluble iron

Station	Samples collected from separate depths
CCS_2	6
CCS_4	6
CCS_5	6

Sample analysis

Samples were analysed using flow injection with chemiluminescence detection (Fe-CL) according to procedures outlined in Ussher et al. (2007). Briefly, a 1L sample of seawater was collected from the cast prior to Fe(II) analyses and stored in the dark. This aged seawater was adjusted to pH 5.5 with ammonium acetate and used to calibrated the Fe (II) system using the method of standard additions. Calibrations were done prior to sample collection (to ensure that the system was ready for immediate measurements) and again after the analyses of all samples. Samples were filtered in-line using 0.2 μm luer lock filter.

References

Lohan, M.C. and Bruland, K.W. (2008). Elevated Fe(II) and dissolved Fe in hypoxic shelf waters off Washington and Orgeon: An enhanced source of Fe to coastal upwelling regions. *Environ. Sci. Technol.*, 17, 6462-6468.

Ussher, S.U., Worsfold, P.W., Achterberg, E.P., Laes, A., Blain, S., Laan, P. & deBaar, H.J.W. (2007). Distribution and redo speciation of dissolved iron on the european continental margin. *Limonol. Oceanogr*. 52: 2530-2539.

28. Iron binding ligands

Dagmara Rusiecka (University of Southampton)

Objectives

Understanding the biogeochemistry of Fe requires the ability to measure its oceanic chemical speciation. Fe is present in seawater as chelates with strong metal-binding organic ligands (Bruland & Lohan, 2004) which dramatically influences its' chemical behaviour. These ligands have a stabilising influence, preventing inorganic precipitation (e.g. Liu and Millero, 2002) and increasing the availability of metals for biological uptake. They are therefore an important component in understanding the cycling and distribution of Fe in any system. Ligand samples will therefore be collected at selected stations along the cruise.

Sampling protocol

On recovery of the Ti-rosette, the OTE bottles were transferred into a clean sampling laboratory where they were immediately sampled for oxygen, nutrients, salinity and total dissolvable elements before being pressurised to approximately 7 psi with 0.2 µm filtered air using an oil free compressor. After the collection of particulate samples (see section on Particulate Trace Metals), a Sartobran 300 (Sartorius) filter capsule (0.2 µm) was used to collect filtered seawater samples into clean LDPE sample bottles. Bottles and caps were rinsed 3 times with the filtered sample before being filled. All samples were double bagged and stored unacidified at -20^{o}C until analysis.

Samples collected

A total of 87 speciation samples were collected as detailed below:

Sample analysis

The concentrations and conditional stability of Fe ligands, Fe' (soluble inorganic Fe) and free aqueous Fe will be measured at NOCS/IfM GEOMAR by competitive ligand exchange cathodic stripping voltammetry (CLE-CSV) with the ligand TAC (Croot and Johansson, 2000).

References

Bruland K. W. And M. C. Lohan, 2004. Controls on trace metals in seawater, In the Oceans and Marine Geochemistry Vol 6. Treatise on Geochemistry (eds. H. D. Holland and K. K. Turekian). Elsevier, London, pp. 23-49.

Croot, P. L. & Johansson, M., 2000. Determination of iron speciation by cathodic stripping voltammetry in seawater using the competing ligand 2-(2-thiazolylazo)-*p*cresol (TAC). *Electroanalysis* 12, 565-576

Liu, X. W. & Millero, F. J. 2002. The solubility of iron in seawater. *Marine Chemistry*, 77**,** 43-54.

Table 31. Sampling details for iron binding ligands

Station	Samples collected from separate depths		Station	Samples collected from separate depths
CCS_1	4		Fe01	6
Fe08	6		Fe02	6
Fe09	6		Fe03	5
Fe10	5		Fe04	5
Fe11	5		Fe05	4
Fe12	5		Fe06	4
Fe13	5		CS2	4
Fe14	6 (3x2 duplicates)		CCS_7	3
SiteA_1	3			
J2	3			

29. Particulate trace metals

Angela Milne & Antony Birchill (University of Plymouth)

Objectives

Particulate trace metals may occur in several forms, including stable refractory phases or as coatings on surfaces that can be rapidly recycled. Particulate behaviour is metal specific with, for instance, the majority of particulate Fe occurring in refractory phases while Zn is primarily associated with more labile phases (Hurst & Bruland, 2005). Few studies have concurrently measured trace elements in both the dissolved and particulate phases. Furthermore, labile particulate trace metals which are biologically available could be considerably higher than the dissolved phase (Berger et al., 2008). Assessment of total biologically available trace elements may thus require the determination of both dissolved and labile particulate metal phases (Lam & Bishop, 2008). A step towards a quantitative description of the cycling of trace elements between the dissolved and particulate phases required for their realistic incorporation into biogeochemical ocean models is to measure the standing stock of the particulate fraction. To address this, particulate material will be filtered on selected water samples collected using the trace metal rosette.

Sampling protocol

OTE bottles were transferred from the Ti-rosette into a clean sampling laboratory where they were immediately sampled for oxygen, nutrients, salinity and total dissolvable elements. The OTE bottles to be sampled for particulate material were inverted three times to gently mix the seawater and re-suspend particulates before being pressurised, to approximately 7 psi, with 0.2 µm filtered air using an oil free compressor. Clean filter holders (Swinnex, Millipore) containing acid washed 25 mm (0.2 µm) polyethersulfone filters (PES, Supor, Pall Gellman) were attached to the taps of the OTE bottles and up to a maximum of 7 L of seawater from selected depths was then passed over the filters. Following filtration, the filter holders were removed and placed in a laminar flow bench. Using an all polypropylene syringe attached to the top of the filter holder, residual seawater was forced through the filter using air from within the flow hood. The filter holders were gently opened and the PES filter folded in half using plastic tweezers, the filters were then placed in acid clean 2 mL LDPE vial and frozen at -20^{o}C until analysis. Filtration was completed in approximately three hours.

Samples collected

A total of 171 samples were collected as detailed below:

Table 31. Sampling details for particulate trace metals

Station	Samples collected from separate depths		Station	Samples collected from separate depths
CCS_1	3		Fe01	8
CCS_2	3		Fe02	7
Fe08	5		Fe15	7
Fe09	6		Fe03	7
Fe10	5		Fe04	11 (4x2 duplicates)
Fe11	3		Fe05	9 (3x2 duplicates)
Fe12	3		Fe06	11 (5x2 duplicates)
Fe13	3		Fe16	8
Fe14	2		Fe17	8
O4	2		Fe18	8
O2	3		Fe19	7
CCS_3	4		Fe20	6
SiteA_1	4 (1x2 duplicate)		Fe22	5
J2	3		CS2	10 (5x2 duplicates)
J6	3			
CCS_4	7 (3x2 duplicates)			

Sample analysis

Samples will be analysed for both labile and refractory particulate Fe, Mn, Al, Co, Zn, Cd, Ba, Ni, Cu, Ti and potentially other trace elements using ICP-MS at the University of Plymouth. For labile particulate trace elements the filter is subjected to a weak acid leach (25% acetic acid at pH 2) with a mild reducing agent (0.02 M hydroxylamine hydrochloride) and a heating step (20 min 90-95^{o}C). This approach is fully detailed in Berger et al. (2008). After the labile fraction has been determined the refractory trace elements will be determined following the method of Ohnemus and Lam (Deep Sea Research, in press). Briefly, the filters will be digested following a three step heating/dry-down process, firstly H_2SO_4 and H_2O_2 are used to digest the filter, followed by HNO_3, HCl and HF and finally HNO_3 and H_2O_2 to digest the particulate material. The final solution is dried down and the residue brought back into solution with 2 % HNO_3 for analysis by ICP-MS. The samples are then spiked with an internal reference material such as In for drift correction.

References

Berger, C. J. M., Lippiatt, S. M., Lawrence, M. G.and Bruland, K. W. 2008. Application of a chemical leach technique for estimating labile particulate aluminum, iron, and manganese in the Columbia River plume and coastal waters off Oregon and Washington. *Journal of Geophysical Research-Oceans*, 113.

Hurst, M. P. and Bruland, K. W. 2007. An investigation into the exchange of iron and zinc between soluble, colloidal, and particulate size-fractions in shelf waters using low-abundance isotopes as tracers in shipboard incubation experiments. *Marine Chemistry,* 103**,** 211-226.

Lam, P. J. and Bishop, J. K. B. 2008. The continental margin is a key source of iron to the HNLC North Pacific Ocean. *Geophysical Research Letters,* 35.

30. Radium sampling

Amber Annett (University of Edinburgh)

Objectives

Radium is produced continuously in sediments from the decay of thorium (Th) and thus displays elevated concentrations near the sediment-water interface. Radium is present in the ocean as four naturally-occurring radioactive isotopes: ^{223}Ra, ^{224}Ra, ^{226}Ra and ^{228}Ra, with half-lives (11.4 d, 3.66 d, 1600 y and 5.75 y, respectively) spanning a range of time scales relevant to both vertical fluxes of (micro)nutrients out of sediments into the overlying water column, as well as horizontal advection. As Ra is not particle reactive, the decrease in concentration of each short-lived isotope away from the source (sediments) can be used in conjunction with its half-life to constrain flux rates, and will be coupled to trace metal results to assess the magnitude of any shelf source of Fe and other metals to offshore regions.

The primary objective of the radium (Ra) work done as part of WP3 is to use flux rates from Ra analysis to quantify off-shelf iron (Fe) fluxes from the Celtic Sea shelf to the open ocean. Work on the iron transects on DY018 identified three plumes of ^{224}Ra at different depths, and a key aim of the Ra work on DY029 was to obtain higher-resolution profiles on two transects to investigate spatial variability and differences from measurements in November.

A secondary aim is to use the disequilibrium between dissolved ^{228}Ra and ^{228}Th to investigate particle export above the shelf. The shortest half-life in this system (^{228}Th) is ~1.9 y, thus this approach can integrate particle export over a similar period, although in the case of the Celtic Sea the annual overturning/mixing cycle will result in the Ra-Th disequilibrium reflecting an annually-integrated particle export flux.

Sampling Protocol

Ra sampling requires very large volumes of water, as Ra activities are typically very low away from sediment sources. Samples of 60 – 200 L were collected from the stainless steel Sea-Bird CTD system on-board the RRS Discovery at both process stations and transect stations, and stored in 20 L collapsible plastic containers. These sample bottles were washed with 10% HCl prior to the cruise, and rinsed with Milli-Q between samples.

Each 20 L water sample was weighed using a beam scale, and stored on shelves outside the container in the hangar space. The samples were then passed through a column holding 20 g of MnO_2-coated acrylic fiber, which strongly binds Ra. The fibers were then rinsed with Milli-Q and loaded into a Ra Delayed Coincidence Counter (RaDeCC; Scientific Computer Instruments, USA) system purged with He gas, and

decay of Ra was counted for 6-10 h to quantify ^{223}Ra and ^{224}Ra content. Following decay of these short-lived isotopes, the fibres will be re-analysed using the RaDeCC to determine the activity of the parent isotopes (^{227}Ac and ^{228}Th).

At each depth processed, a subsample was collected into acid-clean 125 mL LDPE bottles for analysis of the long-lived Ra isotopes by mass spectrometry at the University of Edinburgh.

Table 32. CTD samples analysed:

Event	Station	Depth (m)	Vol (L)
DY029-005	CCS	135	111.75
	CCS	100	111.90
	CCS	85	136.61
DY029-007	CCS	65	127.34
	CCS	40	135.49
	CCS	20	117.98
DY029-051	Fe08	2100	124.46
		1750	112.51
		1500	133.34
DY029-052	Fe08	1250	152.96
		950	130.95
		800	149.82
DY029-054	Fe08	600	136.58
		400	151.99
		200	114.72
DY029-059	Fe09	1850	85.59
		1750	113.97
		1500	115.58
DY029-060	Fe09	1250	109.19
		950	136.73
		800	112.55
DY029-061	Fe09	600	145.47
		400	135.26
		200	142.56
DY029-062	Fe10	1400	95.72
		1300	96.30
		1150	116.425
		1000	113.81
DY029-063	Fe10	800	73.56
		600	87.415
		400	56.39
		200	109.35
DY029-068	Fe11	900	111.82
		800	136.46
		700	113.28
DY029-070	Fe11	600	117.61
		500	112.73
		400	98.205
		200	95.7
DY029-076	Fe12	650	114.235
		600	136.28
		450	153.12
DY029-078	Fe12	280	136.325
		150	193.16

		50	136.535
DY029-082	Fe13	370	95.54
		300	96.945
		200	115.33
DY021-083	Fe13	100	112.70
DY029-085	Fe14	240	94.92
		200	94.09
		150	95.56
		100	93.78
DY029-100	O4	150	97.79
		140	117.61
		110	97.18
		80	117.195
DY029-102	O4	60	116.86
		25	109.33
DY029-105	O2	140	107.16
		130	115.805
		100	78.05
		80	110.52
DY029-103	O2	60	108.81
		25	117.62
DY029-145	Site A	93	78.48
		80	97.97
		60	97.71
		35	97.27
		20	96.08
DY029-146	J-2	90	77.89
		70	97.79
		60	77.77
		40	97.29
		25	97.90
DY029-155	J-6	105	75.49
		65	97.22
		33	77.15
		23	96.06
		10	74.10
DY029-200	Fe01	2250	112.73
		1700	115.30
		950	149.36
DY029-202	Fe01	1300	115.39
		850	130.81
		700	133.96
DY029-203	Fe01	550	132.69
		400	154.32
		200	153.64
DY029-204	Fe02	1990	114.88
		1650	116.40
		1550	114.99
DY029-206	Fe02	1300	152.75
		950	116.81
		725	113.97
DY029-207	Fe02	500	131.69
		400	136.50
		200	154.11
DY029-208	Fe15	1450	78.63
		1100	117.50
		900	97.76
		700	117.11

DY029-210	Fe15	575	77.79
		460	102.90
		360	77.65
		200	98.04
DY029-211	Fe03	1300	75.87
		1200	97.43
		1050	94.24
		850	113.05
DY029-213	Fe03	750	117.44
		500	117.48
		200	115.58
DY029-217	Fe04	950	75.96
		750	98.08
		650	96.07
		550	115.01
DY029-218	Fe04	400	114.94
		250	94.79
DY029-220	Fe05	737	115.14
		650	116.93
		500	134.50
DY029-221	Fe05	250	98.00
		100	116.34
DY029-223	Fe06	455	76.53
		350	55.98
		200	111.04
		50	95.41
DY029-290	CS2	208	115.57
		200	116.42
		160	115.38
		100	111.60
DY029-292	CS2	60	136.03
		25	136.30
DY029-322	CCS	135	58.74
		120	97.55
		90	96.12
		54	98.035
		30	78.43
DY029-325	Site A	40	93.875
		56	96.96
		70	96.905
		85	93.15
		95	38.62
		Total:	15821.87

Preliminary results

Process stations:

Short-lived Ra isotopes at the CCS site show a clear seasonal progression between profiles from November, March and April. The March data are similar at all depths, reflecting intense vertical mixing over the winter. The beginning of stratification can be seen in the April profile, with lower surface activities and higher activities of the short-lived Ra isotopes at depth, due to the sedimentary source of Ra. Data from November

(DY018) show the greatest degree of stratification, consistent with a long period of summer stratification. Note that all data presented here are uncorrected for long-lived parent isotopes (^{228}Ra, ^{228}Th, ^{227}Ac) and interference from higher activity isotopes (^{224}Ra). Once the samples have been allowed to decay, repeated analyses are performed to make these corrections; all reported activities will be revised downwards due to these corrections.

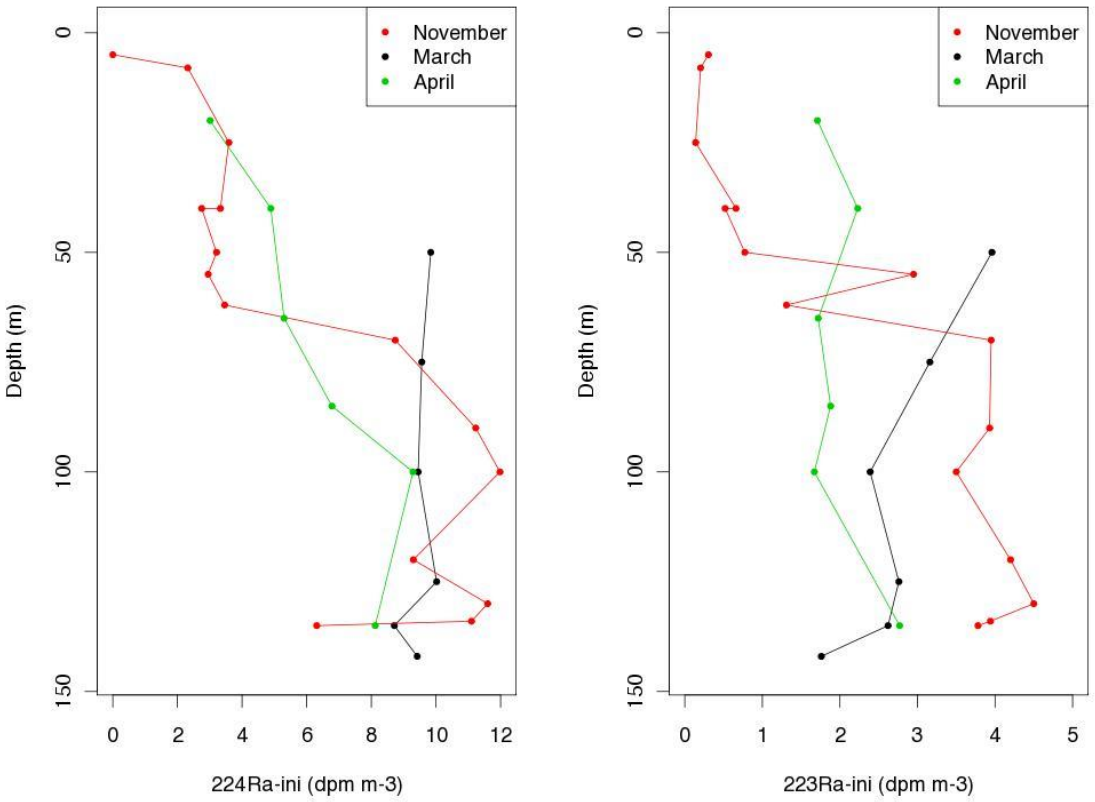

Figure 17. Depth profiles (uncorrected) at the CCS station from November (DY018, red), March (DY021, green) and April (DY029, black).

Transects:

Radium-224 results from the first iron transect (Fe1) are similar to the activities measured at the same stations in November. The greatest discrepancies occur in surface waters, which may reflect different ^{228}Th activities, the parent isotope of ^{224}Ra and unlike Ra an element strongly influenced by particle concentrations. The activites of ^{228}Th and the corrected (excess) ^{224}Ra activities will be determined in Edinburgh following partial decay of the samples.

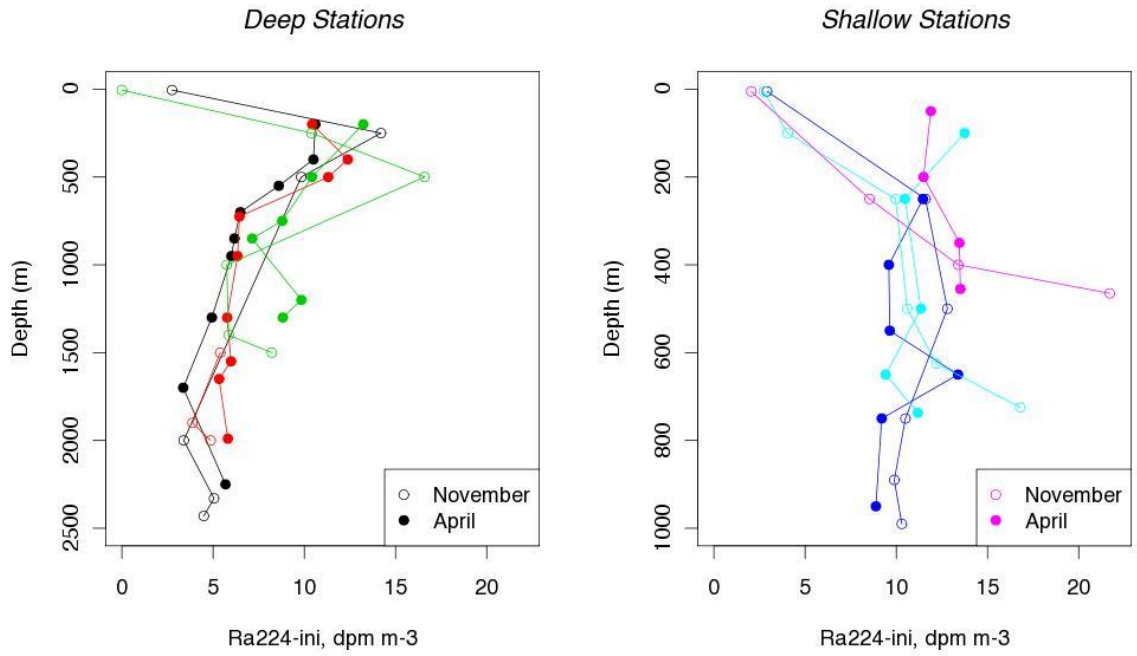

Figure 18. Comparison of uncorrected ^{224}Ra profiles from the Fe1 transect sampled in November (open symbols) and April (closed symbols). Deep stations are shown on the left, shallower stations on the right.

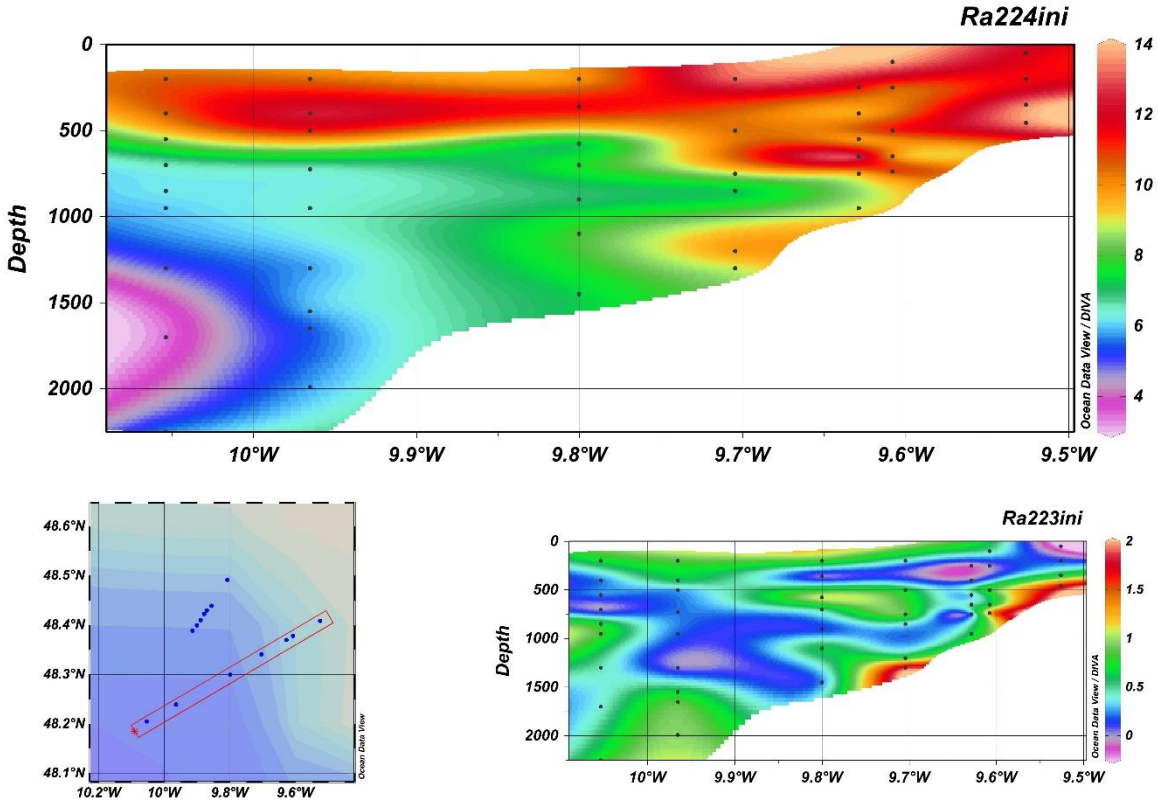

Figure 19. Contour plots of preliminary short-lived Ra data from the Fe1 transect.

The second iron transect was sampled at much higher resolution on the April cruise; in November only one high-resolution depth profile was obtained, with other stations sampled only at 500m. The April data from Fe09 (the high-resolution station) are very similar to previous measurements, and it is likely that ^{228}Th corrections will again show three distinct plumes of water with a signal of recent sediment contact. When combined with data from the other stations sampled on this cruise, the signals seem to be very consistent with higher activities around 400-500m, 1000-1200m and 1800-2000m, with slightly lower maxima at the more off-shelf stations, in keeping with radioactive decay as the water moves away from the shelf source.

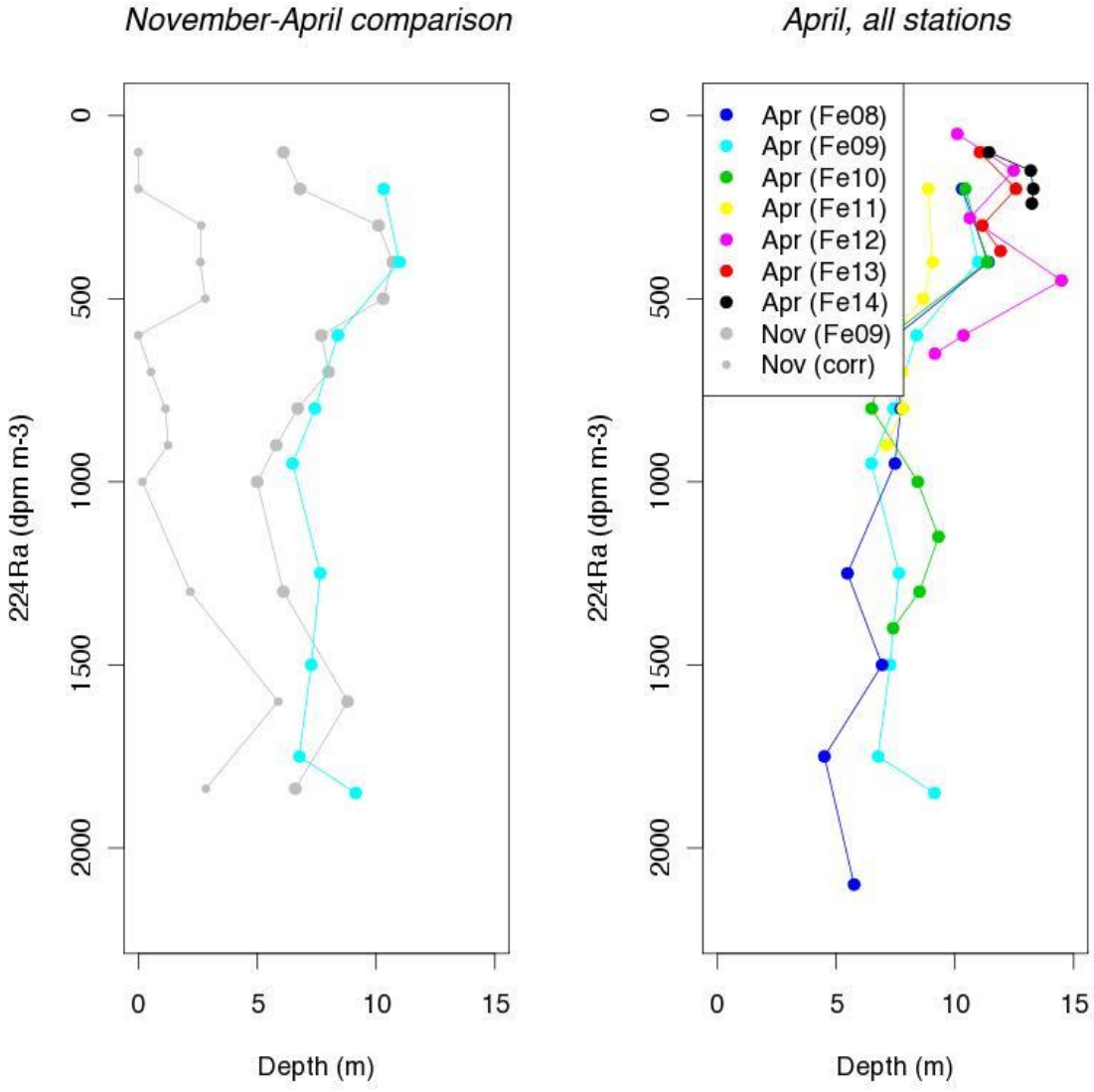

Figure 20. Fe2 transect data, with comparison to initial and corrected ^{224}Ra data from DY018 on the left.

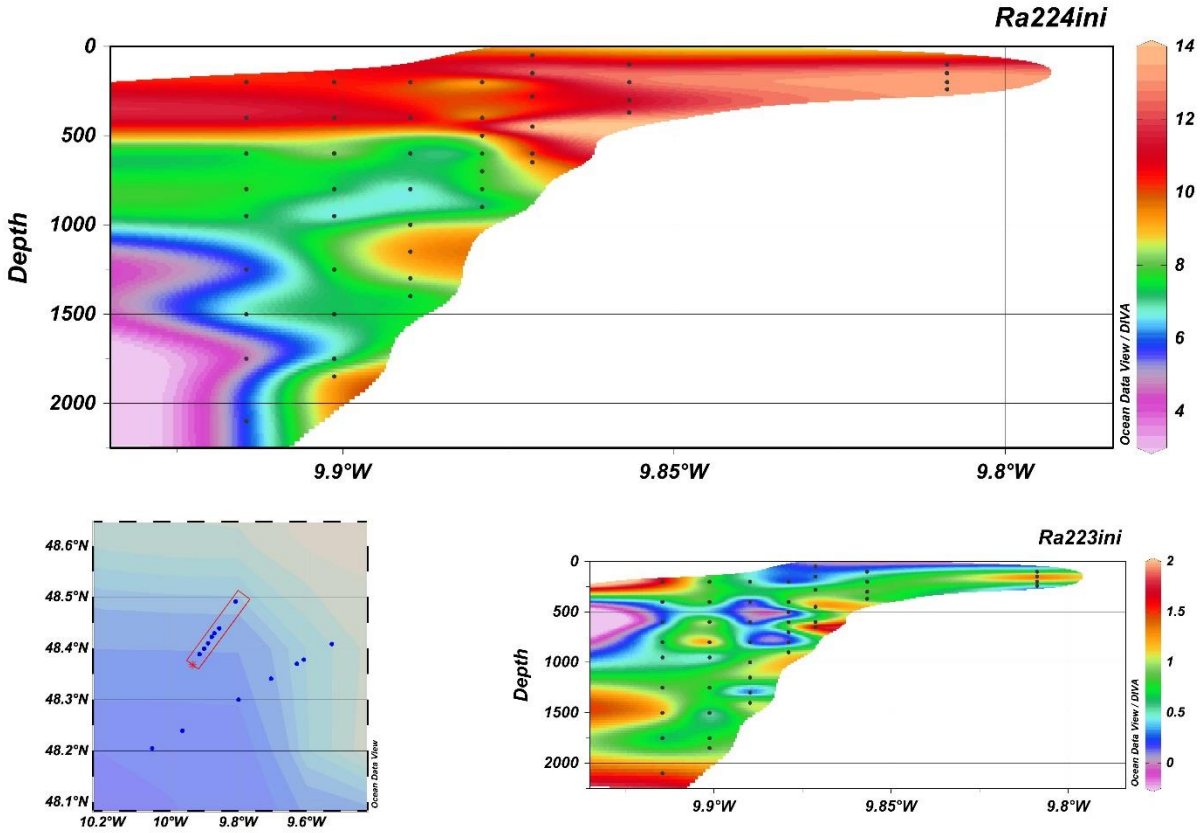

Figure 21. Contour plots of preliminary short-lived Ra data from the Fe2 transect.

Incubation experiments:

Along with benthic work from cruise DY021, samples were collected to investigate the release of Ra over time from different sediments, and compare this to the release and speciation of Fe. For this we carried out an incubation experiment, tracking changes in Ra concentrations over a 36 h period in offshore waters incubated with sediment collected in March from Site H. This contrasts with an incubation where the same sediment was incubated with on-shelf water.

The top 0.5 cm of sediment from several cores were combined into a slurry, and 30 mL of this was added to triplicate carboys containing 25 L of 60 m water. A control was also performed without addition of sediment. The carboys were incubated at ~ 9 ^{o}C, in the dark.

Subsamples of 3 L were collected at each time point using a vacuum, and filtered through 0.2 □m acid-washed polycarbonate filters in a laminar flow hood. For each of the four carboys, samples were collected for nutrients, dissolved and soluble Fe, Fe ligands and trace metals. One carboy each was additionally sampled for Ra isotopes. Time points were 0, 4, 12, 24 and 36 hours after sediment addition.

Results from the incubation experiments display a linear rate of Ra enrichment with time (Figure 22). For both short-lived Ra isotopes, the rate of enrichment is ~two-fold higher from mud than from muddy sand

with in-situ water. Interestingly, the rate of Ra release from muddy sand into offshore water most closely resembles release from mud into shelf water, rather than from the same sediment into shelf water.

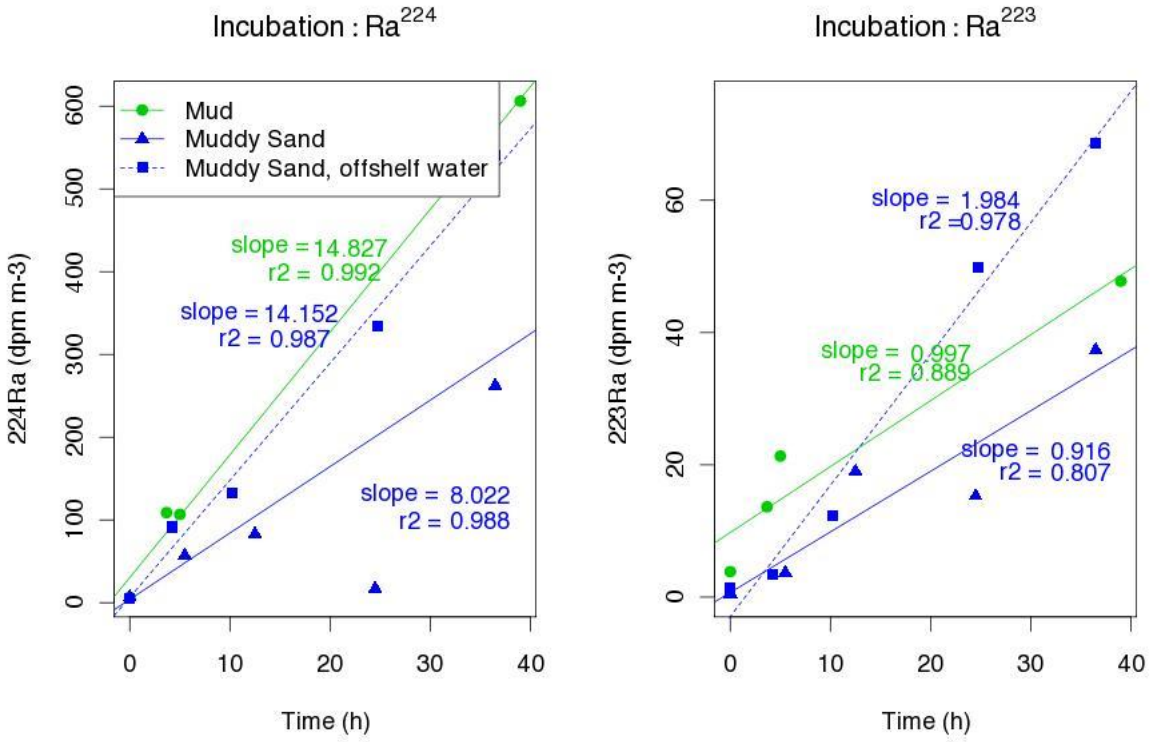

Figure 22. Short-lived Ra isotope concentrations versus time during incubation experiments from DY021 and DY029. The experiment conducted on DY029 is shown as blue squares.

Acknowledgements.

Thank you to the officers, engineers and crew of RRS Discovery. My heartfelt thanks to the many people who helped me with lugging around bottles of water, especially during the transects, and a special thank-you to the NMF technicians and crew for collecting over 15800 L of seawater at all hours of the day (and night).

31. Photosynthetic parameters: Photosynthesis vs Irradiance

Kieran Curran (Plymouth Marine Laboratory)

Background

Phytoplankton play a key role in the biogeochemistry of shelf seas, particularly in carbon and nutrient cycles. They exhibit strong seasonal differences in their community structure, distribution and productivity.

***SSB Studentship project**: Remote sensing algorithms for size-fractionated primary production in UK shelf seas.*

Current remote sensing algorithms for determining depth-integrated size-fractionated productivity are validated using database of samples from primarily oligotrophic, oceanic regions and up-welling zones. These models have not been validated in shallow, productive shelf seas and the application of photo-physiological parameters taken from the aforementioned database to HPLC profiles of diagnostic pigments from shelf seas has shown a significant disparity with measured in-situ values of fixation rates and photo-physiology. Therefore data

Phytoplankton productivity was measured using photosynthesis vs irradiance (PI or PvE) curves for three size fractions (>20 µm, 20-2.0 µm, 2.0-0.2 µm) typically at three depths, (surface, deep/sub-surface chlorophyll maximum DCM/SCM and below DCM). This was done by spiking 15x 70ml samples with 5-10 µCi of 14C sodium bicarbonate and incubating for 1.5 to 2 hours in a linear photosynthetron, cooled using the underway for surface samples and a chiller for deeper samples. Each bottle was then filtered through a sequential rig using 47mm polycarbonate filters.

To enable correction for biomass, 3x 200ml of each water sample was filtered in triplicate into a sequential filter rig then stored in 8ml 90% acetone for 24 hours at 4˚C (following the same protocol used for Western Channel Observatory; SSB protocol GFF samples were refrigerated). Chlorophyll-a fluorescence was then measured using a Turner fluorometer calibrated with a solid standard and blank.

Alongside PvE curves, filtrations for phytoplankton pigments and absorption spectra (PABS) were taken on 25 mm GFF. For some samples size-fractionated pigments and PABS were taken by pre-filtering to get total, <20 µm and <2 µm samples. This should allow investigation of the extent to which diagnostic pigments and absorption spectra can determine the relative abundances of each size class in the absence of size-fractionated measurements and identify any inherent biases with using these methods in the optically-complex and high-biomass shelf seas. Furthermore, having estimates for size-specific absorption spectra is of great benefit to production modelling as groups will have different spectra and thus having different productivity given the ambient light field generated in spectral radiant transfer models.

Fast repetition rate fluorometry (Frrf) samples were taken on many CTD casts by James Fox using a Chelsea Instruments Fast Ocean instrument. Another Fast Ocean measured the underway continuously. PvE and Frrf-generated photophysiological parameters will be compared after data work up. Results from the instrument and total PvE curves at the Western Channel Observatory indicate a good match between the two methods.

Samples of water were taken from the size-fractionated PABS measurements and run on the fast ocean to attempt to generate size-fractionated Frrf data. It was found that pre-filtering in this way had a much less negative effect on the phytoplankton than re-suspending the samples off of a filter. This method will be refined in future cruises to use reverse flow to re-suspend so as not to dry the cells or stress them with changes in the water volume.

Table 33. Stations and depths sampled

Date	Station	CTD	Latitude	Longitude	Depths sampled (m)
04/04/15	012	07ss	49˚ 23.56	08˚ 33.79	5,15,25
05/04/15	030	10ss	48˚ 23.26	08˚ 33.65	5,15,25,45
06/04/15	049	14ss	48˚ 23.31	09˚ 54.87	5,40
08/04/15	059	20ss	48˚ 23.96	09˚ 54.08	5,35
08/04/15	068	29ss	48˚ 25.34	09˚ 52.74	5,40
09/04/15	099	42ss	48˚ 26.36	09˚ 51.41	5,25,35
11/04/15	115	50ss	49˚ 23.81	08˚ 36.03	4,24,47
14/04/15	151	59ss	50˚ 25.21	07˚ 13.69	5,22,35
15/04/15	158	65ss	49˚ 24.39	08˚ 35.97	5,10,14,30
16/04/15	173	68ss	49˚ 23.54	08˚ 35.60	4,12,22,34
17/04/15	199	71ss	48˚ 34.31	09˚ 30.63	5,20,30
19/04/15	220	90ss	48˚ 22.69	09˚ 36.52	5,24
20/04/15	226	96ss	49˚ 24.07	08˚ 37.21	5,27,36
21/04/15	241	100ss	49˚ 24.09	08˚ 37.22	5,25,35
23/04/15	271	107ss	48˚ 36.99	09˚ 50.21	8,30
24/04/15	280	115ss	48˚ 36.23	09˚ 26.69	5,20
25/04/15	299	123ss	49˚ 24.38	08˚ 35.90	5,15,26
26/04/15	324	128ss	49˚ 24.49	08˚ 35.24	5,16,30,42
27/04/15	329	133ss	50˚ 49.68	06˚ 39.94	8,28

32. Phytoplankton physiology: Photosynthetic efficiency and light response parameters (FRRf), spectral absorbance (PABs) and pigment composition (HPLC).

James Fox (University of Essex)

Objectives

To assess the physiological status of phytoplankton over large temporal and spatial scales using fast repetition rate fluorometry (FRRf).

Methods

Fast repetition rate fluorometry - Two FastOcean (Chelsea technologies group Ltd) FRR fluorometers, each fitted with an integrated FastAct bench-top unit (CTG), were used to measure the physiology of phytoplankton found in the surface waters and at depth. Measurements were made for discrete water samples collected from CTD casts (FRRf1) and using a semi-continuously approach with water drawn from the ships non-toxic underway system (FRRf2).

Single turnover FRR acquisitions were made using a protocol of 50 sequences of 100 2μs saturation flashes at 150 ms intervals. FRRf2 was setup to run rapid light curves (RLC) continuously by drawing water from the ships non-toxic underway system. Each RLC took 30 minutes and consisted of 15 two minute light steps ranging from 0 to 1550 μmol photons $m^{-2}s^{-1}$, the sample cuvette was then autonomously flushed with underway for 60 seconds after each light curve before filling with a new sample. Discrete water samples were collected from the CTD and stored in the dark for at least 30 minutes at sea surface temperature to allow the relaxation of quenching. Filtered sea water samples were measured for each sample on FRRf2 and twice daily on FRRf1 to allow for the correction of background fluorescence.

Auxiliary sample collection - Seawater samples were collected from the CTD using 2 L Nalgene bottles and filtered through 25 mm GF/F filters for phytoplankton spectral absorbance (PABs) and pigment composition. Filter volumes ranged from 0.5-1.5 L and samples were immediately frozen in liquid nitrogen before being stored at -80^{o}C until later analysis at the University of Essex.

Size-fractionated collaborative work - Samples for three size fractions (>20 μm, 20-2 μm, <2 μm) were also collected for HPLC and PABs and FRRf together with Kieran Curran (please see his report for full details). Alternative methods were trialled to obtain each size fraction for FRRf, with the re-suspension of cells found of each filter found to have a negative impact on the physiology of the phytoplankton.

CTDs sampled. Niskin and depths can be found in a separately attached log sheet												
STN #	**CAST #**	**NMF ID**	**SITE**	**Description**	**Sample from**	**PIGMENTS**	**PABS**	**FRRf**	**Date**	**Time**	**Latitude**	**Longitude**
006	04	CTD_004_TT	CCS	Fe CTD	CTD (T)	✓	-	✓	03/04/2015	1538	49 23.39 N	008 35.54 W
009	06	CTD_006_SS	CCS	Pre-dawn CTD	CTD (SS)	✓	-	✓	04/04/2015	0205	49 23.371 N	008 35.592 W
012	07	CTD_007SS	CCS	Post-glider calib	CTD (SS)	✓	-	✓	04/04/2015	0709	49 23.561 N	008 33.794 W
015	08	CTD_008SS	CCS	Midday CTD	CTD (SS)	✓	-	✓	04/04/2015	1249	49 23.87 N	008 36.27 W
030	10	CTD_010_SS	CCS	Radium CTD	CTD (SS)	✓	-	✓	05/04/2015	0755	49 23.268 N	008 33.652 W
033	11	CTD_011_SS	CCS	Midday CTD	CTD (SS)	✓	-	✓	05/04/2015	1454	49 24.325 N	008 35.708 W
047	13	CTD_013_SS	CCS	Pre-dawn CTD	CTD (SS)	✓	-	✓	06/04/2015	0214	49 24.31 N	008 35.29 W
049	14	CTD_014_SS	Fe08	Radium CTD	CTD (SS)	✓	-	✓	06/04/2015	1408	48 23.316 N	009 54.872 W
066	27	CTD_027_T	Fe08	Fe CTD	CTD (T)	-	-	✓	08/04/2015	0524	48 23.326 N	009 54.820 W
067	28	CTD_028_T	Fe09	Fe CTD	CTD (T)	-	-	✓	08/04/2015	1050	48 23.97 N	009 54.08 W
068	29	CTD_029_SS	Fe11	Radium CTD	CTD (SS)	✓	-	✓	08/04/2015	1358	48 25.538 N	009 52.74 W
069	30	CTD_030_T	Fe11	Fe CTD	CTD (T)	-	-	✓	08/04/2015	1600	48 25.33 N	009 52.74 W
079	35	CTD_035_T	Fe13	Fe CTD	CTD (T)	-	-	✓	09/04/2015	0723	48 26.248 N	009 51.799 W
082	36	CTD_036_SS	Fe13	Radium CTD	CTD (SS)	✓	-	✓	09/04/2015	0959	48 26.36 N	009 51.41 W
098	41	CTD_041_SS	CS2	Pre-dawn CTD	CTD (SS)	✓	-	✓	10/04/2015	0207	48 34.268 N	009 30.596 W
099	42	CTD_42_SS	CS2	Morning CTD	CTD (SS)	✓	-	✓	10/04/2015	0707	48 34.270 N	009 30.595 W
102	45	CTD_45_SS	O4	Radium CTD	CTD (SS)	✓	✓	✓	10/04/2015	1206	48 51.20 N	009 11.97 W
103	46	CTD_46_SS	O2	Radium CTD	CTD (SS)	✓	✓	✓	10/04/2015	1459	49 7.792 N	008 54.271 W
111	49	CTD_49_SS	CCS	Pre-dawn CTD	CTD (SS)	✓	✓	✓	11/04/2015	0210	49 23.824 N	008 34.894 W
115	50	CTD_050_SS	CCS	Morning CTD	CTD (SS)	✓	✓	✓	11/04/2015	1128	49 23.809 N	008 36.025 W
131	52	CTD_052_TT	CCS	Fe CTD	CTD (T)	-	-	✓	12/04/2015	0547	49 24.834 N	008 35.369 W
143	53	CTD_053_SS	Site A	Evening CTD	CTD (SS)	✓	✓	✓	13/04/2015	2115	51 12.827 N	006 7.725 W
148	58	CTD_057_SS	J2	Morning CTD	CTD (SS)	✓	✓	✓	14/04/2015	0508	50 49.706 N	006 39.977 W
149	59	CTD_059_SS	J4	Midday CTD	CTD (SS)	✓	✓	✓	14/04/2015	1015	50 25.210 N	007 13.691 W

153	61	CTD_061_SS	J6	Afternoon CTD	CTD (SS)	✓	✓	✓	14/04/2015	1508	50 00.787 N	007 46.582 W
156	64	CTD_064_SS	CCS	Pre-dawn CTD	CTD (SS)	✓	✓	✓	15/04/2015	0202	49 24.575 N	008 35.158 W
158	65	CTD_065_SS	CCS	Morning CTD	CTD (SS)	✓	✓	✓	15/04/2015	0822	49 24.389 N	008 35.969 W
159	66	CTD_066_SS	CCS	Midday CTD	CTD (SS)	✓	✓	✓	15/04/2015	1212	49 23.540 N	008 35.605 W
173	68	CTD_068_SS	CCS	Morning CTD	CTD (SS)	✓	✓	✓	16/04/2015	0801	49 23.541 N	008 35.603 W
199	71	CTD_071_SS	CS2	Morning CTD	CTD (SS)	✓	✓	✓	17/04/2015	0659	48 34.313 N	009 30.632 W
209	81	CTD_081_TT	Fe15	Fe CTD	CTD (T)	-	-	✓	18/04/2015	1045	48 18.0 N	009 48.03 W
221	91	CTD_091_SS	Fe05	Radium CTD	CTD (SS)	✓	✓	✓	19/04/2015	1329	48 22.687 N	009 36.517 W
224	94	CTD_094_SS	CCS	Pre-dawn CTD	CTD (SS)	✓	✓	✓	20/04/2015	0214	48 24.030 N	008 37.139 W
226	96	CTD_096_SS	CCS	Morning CTD	CTD (SS)	✓	✓	✓	20/04/2015	0900	49 24.120 N	008 37.139 W
227	97	CTD_097_SS	CCS	Midday CTD	CTD (SS)	✓	✓	✓	20/04/2015	1158	49 24.066 N	008 37.213 W
232	98	CTD_098_SS	CCS	Zooplankton CTD	CTD (SS)	✓	✓	✓	20/04/2015	1540	49 25.308 N	008 37.062 W
233	99	CTD_099_SS	CCS	Evening CTD	CTD (SS)	✓	✓	✓	20/04/2015	1859	49 24.352 N	008 37.146 W
241	100	CTD_100_SS	CCS	Morning CTD	CTD (SS)	✓	✓	✓	21/04/2015	0806	49 24.099 N	008 37.221 W
271	107	CTD_107_SS	Fe19	Morning CTD	CTD (SS)	-	-	✓	23/04/2015	0754	48 36.996 N	009 50.021 W
273	109	CTD_109_SS	Fe20	Midday CTD	CTD (SS)	-	-	✓	23/04/2015	1205	48 37.515 N	009 47.578 W
277	113	CTD_113_SS	CS2	Pre-dawn CTD	CTD (SS)	✓	✓	✓	24/04/2015	0206	48 34.262 N	009 30.577 W
280	115	CTD_115_SS	CS2	Morning CTD	CTD (SS)	✓	✓	✓	24/04/2015	0841	48 36.232 N	009 26.686 W
285	116	CTD_116_SS	CS2	Midday CTD	CTD (SS)	✓	✓	✓	24/04/2015	1322	48 34.181 N	009 30.565 W
293	120	CTD_120_SS	CS2	Pre-dawn CTD	CTD (SS)	✓	✓	✓	25/04/2015	0200	49 24.091 N	008 37.166 W
301	124	CTD_124_SS	CCS	Midday CTD	CTD (SS)	✓	✓	✓	25/04/2015	1202	48 24.568 N	008 35.477 W
313	125	CTD_125_SS	CCS	Zooplankton CTD	CTD (SS)	✓	✓	✓	25/04/2015	1622	49 24.499 N	008 35.233 W
324	128	CTD_128_SS	CCS	Morning CTD	CTD (SS)	✓	✓	✓	26/04/2015	0646	49 24.489 N	008 35.238 W
327	131	CTD_131_SS	Site A	Pre-dawn CTD	CTD (SS)	✓	✓	✓	27/04/2015	0301	51 12.786 N	006 7.801 W
329	133	CTD_133_SS	J2	Morning CTD	CTD (SS)	✓	✓	✓	27/04/2015	0803	50 49.681 N	006 39.935 W
330	134	CTD_134_SS	J4	Midday CTD	CTD (SS)	✓	✓	✓	27/04/2015	1221	50 25.199 N	007 13.657 W

332	136	CTD_136_SS	J6	Afternoon CTD	CTD (SS)	✓	✓	✓	27/04/2015	1711	50 0.787 N	007 46.583 W
341	140	CTD_140_SS	CCS	Morning CTD	CTD (SS)	✓	✓	✓	28/04/2015	0821	49 24.354 N	008 34.848 W

33. Marine Snow Catcher

Alex Poulton (NOC), Isabel (Chata) Seguro (UEA) & Stephanie Wilson (Bangor)

Background

The Marine Snow Catcher (MSC) is a ~100 L closing water bottle used to collect and settle sinking particulate material. During DY029 it was deployed at process stations to collect sinking material for subsequent rate measurements (respiration, nitrogen cycling and bacterial production – see individual cruise reports for details) and for photography (see Table 35).

Table 34. Details of the MSC deployments

Date	Time (GMT)	Site	Event no.	Depth (m)	Notes
05/04/15	2216	CCS	42	70	Winch problems, aborted
12/04/15	1150	CCS	133	10	Hardy
12/04/15	1207	CCS	134	10	Laural
12/04/15	1236	CCS	135	10	Tom, misfire
12/04/15	1250	CCS	136	10	Tom
12/04/15	1304	CCS	137	10	Jerry
12/04/15	1529	CCS	138	70	Jerry
12/04/15	1556	CCS	139	70	Hardy
12/04/15	1603	CCS	140	70	Laural
12/04/15	1618	CCS	141	70	Tom
16/04/15	1430	CCS	181	10	Laural
16/04/15	1445	CCS	182	10	Tom
16/04/15	1459	CCS	183	10	Hardy
16/04/15	1511	CCS	184	10	Jerry, misfire
16/04/15	1522	CCS	185	10	Jerry
16/04/15	1748	CCS	187	70	Laural
16/04/15	1808	CCS	188	70	Jerry
16/04/15	1823	CCS	189	70	Hardy
16/04/15	1838	CCS	190	70	Tom, misfire
16/04/15	1851	CCS	191	70	Tom
21/04/15	1426	CCS	248	10	Hardy
21/04/15	1440	CCS	249	10	Tom, misfire
21/04/15	1449	CCS	250	10	Tom
21/04/15	1500	CCS	251	10	Jerry
21/04/15	1512	CCS	252	10	Laural
21/04/15	1821	CCS	255	70	Laural, misfire
21/04/15	1835	CCS	256	70	Laural, misfire (broken)
21/04/15	1852	CCS	257	70	Hardy
21/04/15	1909	CCS	258	70	Jerry
21/04/15	1924	CCS	259	70	Tom

24/04/15	1241	CS2	283	80	Tom
24/04/15	1252	CS2	284	10	Jerry
25/04/15	1317	CCS	302	10	Hardy
25/04/15	1328	CCS	303	10	Tom
25/04/15	1337	CCS	304	10	Jerry
25/04/15	1526	CCS	310	70	Hardy
25/04/15	1546	CCS	311	70	Jerry
25/04/15	1558	CCS	312	70	Tom

Table 35. Details of the images taken from the base of the MSC

Date	Event no.	Site	Details	Start	End	Images
12/04/15	134	CCS	'Laurel', 10 m (Shallow)	2016	2047	31
	137	CCS	'Jerry', 10 m (Shallow)	2048	2078	30
	140	CCS	'Laurel', 70 m (Deep)	2079	2109	30
16/04/15	181	CCS	'Laurel', 10 m (Shallow)	2111	2143	32
	185	CCS	'Jerry', 10 m (Shallow)	2144	2173	29
	187	CCS	'Laurel', 70 m (Deep)	2179	2211	32
21/04/15	252	CCS	'Laurel', 10 m (Shallow)	2212	2242	30
	258	CCS	'Jerry', 70 m (Deep)	2243	2274	31
24/04/15	283	CS2	'Tom', 80 m (Deep)	2275	2304	29
	284	CS2	'Jerry', 15 m (Shallow)	2305	2340	35

Appendix A: Technical detail report

TITANIUM CTD

The Titanium CTD performed well with only one bottle fire failure on CTD_135T bottle number 1. In subsequent dips bottles 2 onwards were used in their corresponding rosette position.

CTD_015T was aborted due to MF CTD termination failed. Water ingress in cable - 200m cable chopped off. Mechanical and electrical splice redone ~ 2300

Trace Metal Niskin bottle number 23 is reported as leaking from broken back and was removed after CTD_086T. Also bottle 1 needs servicing due to leakage and bottle 8 is leaking where lanyard guide is screwed in.

CTD103T sensor cap left on turbidity sensor.

There were several occasions when the scrolling on the metal free winch delayed the upwards cast. Scrolling was adjusted at the bottom with a view to doing the upcast with no further stops for scrolling adjustments.

Bottles on TMF casts were done “on the fly” with the winch speed reduced to 0.3m/s.

S/S CTD

The Stainless Steel rosette head was removed and cleaned several times to try and rectify issues with firing, which started on CTD_041SS and continued randomly for the rest of the cruise. The bottles were moved round one position so the lanyard angle was changed, but had no effect.

CTD_013SS Offset noted in conductivity cell.

CTD_018SS CTD electrical splice failed – re-terminated at 0100.

CTD_019SS hit bottom, no clear readout from Altimeter and only showed due to instrument readings and CLAM display showing zero load. After recovery Conductivity sensor s/n 04C 3054 replaced with 04C 3873. New config file - "DY029_ss_NMEA_070415.xmlcon".

CTD_032SS Oxygen values odd on downcast but normal on up cast. No reason concluded as unit clean.

CTD_076SS had firing issues with bottles. Program was restarted to gain control of bottles again, thus there is a second file CTD_076Awas generated for the up cast. Mega test on cable only came to 0.52Ω. Cable Re-terminated electrically. Termination has lasted for 11 days and 42 casts. Water ingress from tail end of termination. Cables cleaned and cut back. Cable reading >999MΩ before termination remade. New tail used on termination and cable reading >999MΩ after termination completed. Mechanical termination checked and found to be all ok.

AUTOSAL

A Guildline 8400B, s/n 71126, was installed in the Salinometer Room as the main instrument for salinity analysis. A second Guildline 8400B, s/n 71185, was installed in the Salinometer Room as a spare instrument. The Autosal set point was 24C, and samples were processed according to WOCE cruise guidelines: The salinometer was standardized at the beginning of the first set of samples, and checked with an additional standard analysed prior to setting the RS. Once standardized the Autosal was not adjusted for the duration of sampling, unless the set point was changed. Additional standards were analysed every 24 samples to monitor & record drift.

LADCP

The LADCP battery packs were regularly charged and vented. The charge/communications cable was switched due to charging issues with TRDI Workhorse 300kHz Sentinel LADCP, s/n 15288 Plus LADCP battery pack pressure case s/n WH010T

Appendix B: Configuration files

Titanium CTD frame:

Date: 03/12/2015

Instrument configuration file: C:\Program Files\Sea-Bird\SeasaveV7\DY029\DY029_tita_NMEA.xmlcon

Configuration report for SBE 911plus/917plus CTD

Frequency channels suppressed: 0

Voltage words suppressed:	0
Computer interface:	RS-232C
Deck unit:	SBE11plus Firmware Version >= 5.0
Scans to average:	1
NMEA position data added:	Yes
NMEA depth data added:	No
NMEA time added:	Yes
NMEA device connected to:	PC
Surface PAR voltage added :	No
Scan time added:	Yes

1) Frequency 0, Temperature

Serial number:	03P-4593
Calibrated on:	3 July 2014
G:	4.35405284e-003
H:	6.44561015e-004
I:	2.17709996e-005
J:	1.75890257e-006
F0:	1000.000
Slope:	1.00000000
Offset:	0.0000

2) Frequency 1, Conductivity

Serial number:	04C-2164
Calibrated on:	6 May 2014
G:	-1.02203562e+001
H:	1.40877221e+000
I:	-2.45278999e-003
J:	2.41005660e-004
CTcor:	3.2500e-006
CPcor:	-9.57000000e-008
Slope:	1.00000000
Offset:	0.00000

3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 129735
Calibrated on : 12 March 2014
C1 : -6.064446e+004
C2 : 6.966022e-001
C3 : 1.971200e-002
D1 : 2.882500e-002
D2 : 0.000000e+000
T1 : 3.029590e+001
T2 : -6.713679e-005
T3 : 4.165400e-006
T4 : 0.000000e+000
T5 : 0.000000e+000
Slope : 1.00000000
Offset : 0.00000
AD590M : 1.279181e-002
AD590B : -8.821250e+000

4) Frequency 3, Temperature, 2

Serial number : 03P-5494
Calibrated on : 6 May 2014
G : 4.32421678e-003
H : 6.25972479e-004
I : 1.94252613e-005

J : 1.47692004e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2

Serial number : 04C-4140
Calibrated on : 6 May 2014
G : -9.84144365e+000
H : 1.48564552e+000
I : -2.50353162e-003
J : 2.75975478e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

6) A/D voltage 0, Oxygen, SBE 43

Serial number : 43-0862
Calibrated on : 4 July 2014
Equation : Sea-Bird
Soc : 4.69200e-001
Offset : -5.03400e-001
A : -3.27820e-003
B : 1.33040e-004
C : -2.09790e-006
E : 3.60000e-002
Tau20 : 1.71000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

7) A/D voltage 1, Free

8) A/D voltage 2, PAR/Irradiance, Biospherical/Licor

Serial number : PAR 02
Calibrated on : 7 May 2013
M : 0.47913900
B : 1.05925300
Calibration constant : 100000000000.00000000
Multiplier : 0.99960000
Offset : 0.00000000

9) A/D voltage 3, PAR/Irradiance, Biospherical/Licor, 2

Serial number : PAR 04
Calibrated on : 21 November 2013
M : 0.43427300
B : 1.61542400
Calibration constant : 100000000000.00000000
Multiplier : 0.99950000
Offset : 0.00000000

10) A/D voltage 4, Altimeter

Serial number : 62679
Calibrated on : 27 March 2014
Scale factor : 15.000
Offset : 0.000

11) A/D voltage 5, Turbidity Meter, WET Labs, ECO-BB

Serial number : BBRTD-758R
Calibrated on : 3 June 2013
ScaleFactor : 0.002903
Dark output : 0.043100

12) A/D voltage 6, Transmissometer, Chelsea/Seatech

Serial number : 161049

Calibrated on : 21 January 2015

M : 23.8589

B : -0.2622

Path length : 0.250

13) A/D voltage 7, Fluorometer, Chelsea Aqua 3

Serial number : 088244

Calibrated on : 6 August 2014

VB : 0.236800

V1 : 2.151000

Vacetone : 0.305900

Scale factor : 1.000000

Slope : 1.000000

Offset : 0.000000

Scan length : 45

Stainless CTD frame:

Date: 03/12/2015

Instrument configuration file: C:\Program Files\Sea-Bird\SeasaveV7\DY029\DY029_ss_NMEA.xmlcon

Configuration report for SBE 911plus/917plus CTD

Frequency channels suppressed : 0

Voltage words suppressed : 0

Computer interface : RS-232C

Deck unit : SBE11plus Firmware Version >= 5.0

Scans to average : 1

NMEA position data added : Yes

NMEA depth data added : No

NMEA time added : Yes

NMEA device connected to : PC
Surface PAR voltage added : No
Scan time added : Yes

1) Frequency 0, Temperature

Serial number : 03P-4712
Calibrated on : 3 July 2014
G : 4.40410075e-003
H : 6.33322034e-004
I : 1.91374411e-005
J : 1.16331879e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity

Serial number : 04C-2858
Calibrated on : 8 July 2014
G : -1.02328910e+001
H : 1.43809516e+000
I : 6.45529649e-004
J : 2.63930782e-005
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 79501
Calibrated on : 6 January 2015
C1 : -6.052595e+004
C2 : -1.619787e+000
C3 : 1.743190e-002
D1 : 2.819600e-002

D2 : 0.000000e+000
T1 : 3.011561e+001
T2 : -5.788717e-004
T3 : 3.417040e-006
T4 : 4.126500e-009
T5 : 0.000000e+000
Slope : 0.99985000
Offset : -1.66130
AD590M : 1.293660e-002
AD590B : -9.522570e+000

4) Frequency 3, Temperature, 2

Serial number : 03P-5660
Calibrated on : 3 July 2014
G : 4.33127875e-003
H : 6.25105787e-004
I : 1.89482101e-005
J : 1.36909866e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2

Serial number :	04C-3054	04C-3873
Calibrated on :	8 July 2014	8 July 2014
G :	-1.01903780e+001	-1.01853363e+001
H :	1.40118158e+000	1.35554213e+000
I :	2.26596848e-004	-6.18936473e-004
J :	5.30583452e-005	1.14927218e-004

CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

6) A/D voltage 0, Oxygen, SBE 43

Serial number : 43-2575
Calibrated on : 10 April 2014
Equation : Sea-Bird
Soc : 4.45400e-001
Offset : -4.68400e-001
A : -3.27450e-003
B : 2.06980e-004
C : -2.85420e-006
E : 3.60000e-002
Tau20 : 1.47000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

7) A/D voltage 1, Free

8) A/D voltage 2, Turbidity Meter, WET Labs, ECO-BB

Serial number : BBRTD-1055
Calibrated on : 13 March 2013
ScaleFactor : 0.002365
Dark output : 0.061000

9) A/D voltage 3, Altimeter

Serial number : 59493
Calibrated on : 25 March 2013
Scale factor : 15.000
Offset : 0.000

10) A/D voltage 4, Fluorometer, Chelsea Aqua 3

Serial number : 88-2615-124
Calibrated on : 21 January 2015

VB : 0.463400

V1 : 2.044300

Vacetone : 0.474400

Scale factor : 1.000000

Slope : 1.000000

Offset : 0.000000

11) A/D voltage 5, Transmissometer, Chelsea/Seatech

Serial number : 161048

Calibrated on : 24 July 2012

M : 23.5172

B : -0.0861

Path length : 0.250

12) A/D voltage 6, PAR/Irradiance, Biospherical/Licor

Serial number : 70510

Calibrated on : 6 January 2015

M : 1.00000000

B : 0.00000000

Calibration constant : 20200000000.00000000

Multiplier : 1.00000000

Offset : -0.05051050

13) A/D voltage 7, PAR/Irradiance, Biospherical/Licor, 2

Serial number : 70520

Calibrated on : 6 January 2015

M : 1.00000000

B : 0.00000000

Calibration constant : 19500000000.00000000

Multiplier : 1.00000000

Offset : -0.05251338

Scan length : 45