National Oceanography Centre

Cruise Report No. 55

RRS *Discovery* Cruise DY086
12 NOVEMBER – 19 DECEMBER 2017

Controls over Ocean Mesopelagic Carbon Storage (COMICS)

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2017

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DOCUMENT DATA SHEET

AUTHOR GIERING, S. L. C., et al	PUBLICATION DATE 2019

TITLE
RRS *Discovery* Cruise DY086, 12 November – 19 December 2017. Controls over Ocean Mesopelagic Carbon Storage (COMICS)

REFERENCE
Southampton, UK: National Oceanography Centre, Southampton, 265pp. (National Oceanography Centre Cruise Report, No. 55)

ABSTRACT
This cruise was the first of two cruises focussed on the functioning of the mesopelagic zone, the region between approximately 100 and 500 m depth. Both cruises are funded by the NERC large grant "Controls over Ocean Mesopelagic Carbon Storage" (COMICS). The general objective of this cruise was to test the hypothesis that variability in surface community structure drives variability in the flux of material through the mesopelagic. A particular focus was to evaluate the role of large diatom blooms which are hypothesised to have very shallow mineralisation length scales. The highly seasonal nature and rapid changes in the community structure of such events requires multiple observations across the bloom progression. This first cruise, COMICS1, sampled the highly productive region downstream of South Georgia in the vicinity of British Antarctic Survey station P3 (52.40 S, 40.06 W). Our sampling strategy was to fully characterize the ecosystems in the epipelagic and upper mesopelagic zone during repeated visits of the same site. We had originally planned to sample a second station further South (P2) but abandoned this plan owing to the inability to find a suitable deployment region for the PELAGRA sediment traps and the presence of several large icebergs. Instead, we focussed our efforts on station P3, which was considered biologically more interesting. At P3, we arrived in the middle of a diatom bloom allowing us to follow in detail the decline of the phytoplankton bloom over the coming weeks. Each visit took ~7 days and we conducted 3 full cycles (P3A, P3B and P3C) during 15 Nov – 22 Nov, 29 Nov – 5 Dec, and 9 Dec – 15 Dec. In total, 345 events were completed in 32 days of science.

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Contents

1. Overview

1.1 List of personnel

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Filipa Carvalho	Physical oceanography	National Oceanography Centre
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Nick Rundle	Engineer	National Oceanography Centre
Tom Roberts	Engineer	National Oceanography Centre

1.2 Objectives

Richard Sanders[+]

[+](National Oceanography Centre)

This cruise was the first of a pair of cruises focussed on the functioning of the mesopelagic zone, the region between approximately 100 and 500m. It was one of two cruses funded by the NERC large grant COMICS. The general objective was to test the hypothesis that variability in surface community structure drives variability in the flux of material through the mesopelagic. A particular focus was to evaluate the role of large diatom blooms which are hypothesised to have very shallow mineralisation length scales. The highly seasonal nature of such events means that making multiple observations across the bloom was required as instantaneously it is not necessarily the case that they system will be at steady state. We had two basic cruise strategies to test this hypothesis:

1. To make observations at 2 sites in the region, one to the S of S Georgia in a low biomass transient eddy that forms reliably in the region and one to the N in a slack water region where substantial biomass accumulates. The original plan was to visit each three times for a period of 5 days so as to compile a time series of processes at each site.
2. A fall back plan of make observations over a repeated period at one of those sites (the northerly one) as community structure changed.

We began the cruise aiming to deliver strategy 1. It rapidly became apparent for a variety of reasons that this cruise plan was undeliverable and we ended up delivering 2. The reasons for this were as follows:

1. The first station took about 9 days, meaning that only 3 were likely to occur.
2. Our attempt to undertake the second station (itself only characterised by two µg Chl L^{-1}) was truncated by bad weather, an inability to find a suitable deployment region for Pelagra and the presence of several large icebergs.

Consequently the cruise eventually made a good set of observations at the northerly site on three occasions separated from each other by periods of roughly a week. The first gap was due to the southerly excursion, the associated inclement weather, a need to calibrate the echosounder, and a medical visit to Grytviken. The second gap was due to a large storm, which necessitated sheltering in Rosita Bay at the western end of South Georgia for two days. A day by day narrative of the cruise follows.

1.3 Narrative

Richard Sanders[+]

[+](Ocean Biogeochemistry and Ecosystems)

Sunday 5th November. The majority of the science party flew out from Brize Norton to Port Stanley via the Cape Verde Islands.

Monday 6th November. Science party arrived in Port Stanley and checked into Malvina House Hotel. Attended talks at Stanley Museum to celebrate launch of the South Atlantic Environmental Research Institute.
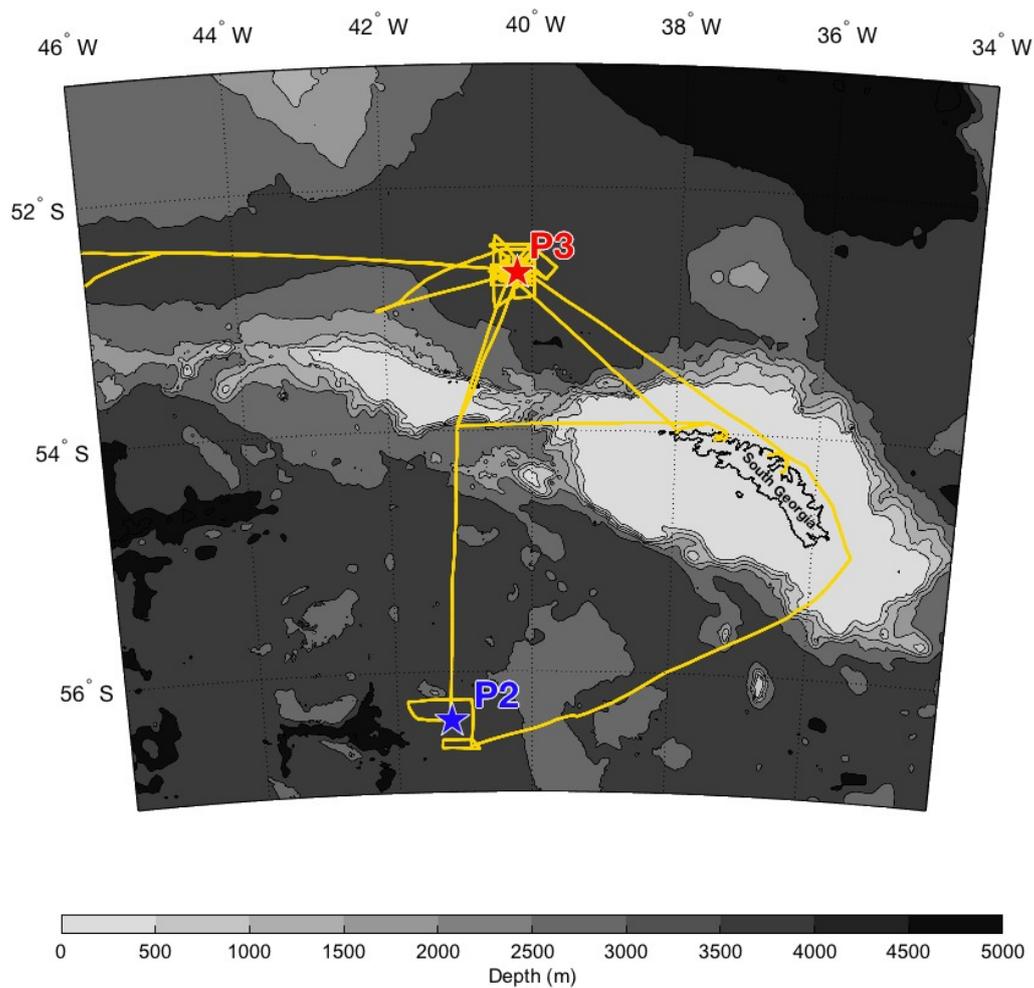
Figure 1.1: Cruise track and the two DY086 sampling sites.

Figure 1.2: Reception at Government House, Stanley given by the governor of the Falkland Islands to celebrate the launch of the South Atlantic Environmental Research Institute (SAERI).

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Tuesday 7th November. First day on ship, started unloading containers after lunch. A second series of talks at the museum was followed by a reception at Government House. Unfortunately we discovered that the termination on the fibre optic cable required to make the BAS nets work undertaken by the ROV team in the UK had been cut off on AMT.

Weds 8th November. We began unpacking seriously. We were unable to find key connectors required to link the BAS net system to the fibre optic cable and that the backup ones were not suitable for use in the oil filled pressure case. We also discovered that the splicer required to connect the nets to the cable wasn't on board. We called NOC and asked the OBE group administrator to fly out with spares. A reception was held in Discovery for various Falkland Island guests.

Thursday 9th November. NOC decided to send out a ROV engineer to perform the termination, with the expectation that they would arrive on Saturday. The missing connectors were discovered in the BAS freight.

Friday 10th November. All the wires were got out and the mechanical terminations done. Permission to use 3rd engine was granted.

Saturday 11th November. The flight from Punta Arenas to the Falklands was delayed by a day and the decision made to wait. A new fibre optic lead made up – and the oil resistance investigated. Seem to be OK, transmission test failed but possibly OK to use.

Sunday 12th November. Discovery sailed at Sailed at 7 am to stand off in Berkeley Sound and wait for engineer. The ROV Engineer arrived at 3 pm equipped with a termination kit and left at 8 pm having instructed Nick Rundle in how to undertake the termination. We sailed then and then made 12 knots overnight.

Monday 13th November. Discovery was on passage. The termination made the day before failed – further experimentation ensued until a functional termination was made. This failed in the pressure case prior to filing with oil.

Tuesday 14th November. On passage, the fibre optic termination was strengthened mechanically using welding rod to reduce the radius it curved round. This succeeded in allowing it to work in the pressure case. The pressure case was therefore filled with oil.

Wednesday 15th November. We arrived on station at 9.30 am and began deploying PELAGRAs, Argo floats and finally the two GOCART gliders. One glider suffered some damage on deployment and was therefore recovered. The main over the side work of the station then got underway, including snow catchers and a CTD.

Thursday 16th November. The MOCNESS was trialled unsuccessfully and a series of over the side deployments including the TM CTD were undertaken before the toroid buoy required for the RESPIRE array was trialled. Finally the RMT was trialled and then deployed for a proper haul. MT late in day.

Friday 17th November. A long day of SAPS, Marine Snow Catchers and PELAGRA deployments and recoveries was undertaken.

Saturday 18th November. The long trailed storm finally arrived in the evening. We had hoped to work the entire day but eventually conditions became unworkable. Before this however the RESPIRE array was deployed alongside 5 PELAGRAs deployed, the latest at 11 pm.

Sunday 19th November. Commenced survey at 4 am. On survey in heavy weather all day.

Monday 20th November. We started work at 6 am with marine snowcatchers, then recovered an errant PELAGRA, which had surfaced and redeployed. Various other over the side deployments were undertaken.

Tuesday 21st November. RESPIRE was recovered and the MAMMOTH net broken out in lieu of the MOCNESS which has not worked to this point due to a series of technical failures.

Wednesday 22nd November. Recovered last PELAGRA at around 10 and then did final MAMMOTH net before declaring the first station over after a weeks work. We transited to the Southern Station, with a CTD at an Argo float site on the way.

Thursday 23rd November. The transit to the Southern station continued with the weather being poor on arrival. On arrival we undertook a CTD deployment and a series of Marine Snow Catchers.

Friday 24th November. We began to survey the area to determine a good site for PELAGRA deployments and relocated to a new central location for this station.

Sat 25th November. More over the side work continued as we prepared for PELAGRA deployments. The weather was OK so Marine Snow Catcher and net deployments were undertaken prior to cancelling the PELAGRA deployments in the face of inclement weather and the existence of persistent southerly flow into icebergs. We decided to head east to find new deployment site with northerly flow in the eddy. We found a site but were unable to turn in the big seas and therefore continued steaming east.

Sun 26th November. We steamed east in big seas up to the SE end of South Georgia. We then continued along the N Coast of S Georgia aiming to be at Stromness for acoustic calibrations the next day.

Mon 27th November. We arrived in Stromness Harbour to commence acoustic calibrations.

Figure 1.3: Tour around Stromness. From left to right: Rachel R, Steph H, Sari G, Victoria H. Anna B, Dan A, Phyllis L, and Richard L.

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Tuesday 28th November. The ship moved around to Grytviken to allow one of the ships party to attend the Doctors. The science party went on tours of the bay in the Fast Rescue Boat and the ships lifeboats were tested. Eventually we sailed at 4 pm.

Weds 29th November. We decided to conduct the second major station in the same location as the first, partly due to weather, partly due to the requirement to pick up a glider gliders and partly due being close to this location. We arrived on station at 10 am, and undertook a trace metal CTD before deploying Snow Catchers, PELAGRAs, the RMT and the final glider.

Thursday 30th November. We deployed the drifting array RESPIRE and a series of marine snow catchers, the Red Camera Frame and the Mammoth net.

Friday 1st December. A long day with lots of over the side deployments culminated in the recovery of four PELAGRAs by about midnight. The Trace Metal CTD cable failed on deployment and MOCNESS was trialled.

Saturday 2nd December. We deployed PELAGRAs and then started the acoustic survey prior to recovering a glider. Thereafter we undertook station work all day.

Sunday 3rd December. We recovered respire and undertook a series of acoustic surveys and over the side deployments.

Monday 4th December. We recovered multiple PELAGRAs and undertook Nets and SAPS.

Tuesday 5th December. We deployed PELAGRAs before steaming for the Argo float station to collect water for experiments by Claire Evans.

Wednesday 6th December. A CTD station was undertaken for Claire Evans in the early hours in the blue water immediately south of Shag Rocks. Discovery then steamed east to South Georgia arriving at Rosita Harbour, Bay of Isles, in the late afternoon/ early evening at which point she went onto DP.

Figure 1.4: CTD ready for deployment in Stromness Harbour. Such work would not be possible without the invaluable support by NMF. In photo: John W.

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Thursday 7th December. Discovery was on DP in Rosita Bay in strong winds. In the evening a Saucy Gull party was held.

Friday 8th December. Discovery came of DP at 1 pm and steamed out of the Bay of Isles passing Salisbury plain on the way out. We looked into Elsehul and the northern side of Bird Island before.

Saturday 9th December. Discovery reached Station at 7 am. Station work resumed including Bongos in the pm and the recovery of all 5 Pelagras by 9.30 pm. The RMT was deployed in the night.

Sunday 10th December. Station work began with a CTD for rates. The RMT was then deployed in the afternoon, and a set of Pelagras deployed in the evening to recover on Thursday am. The night time was occupied by the MOCNESS net.

Monday 11th December. Station work all day starting with SAPS, inc Trace Metal CTD, double Nets, deployed the REPIRE array then went on to a CTD for Thorium.

Tuesday 12th December. A process CTD was undertaken and then the ship started the acoustic survey, aiming to finish by around noon for over the side work. Over the side work finished around 7 pm and the ship then started on the underway acoustics survey. This became unworkable in the early hours.

Wednesday 13th December. Discovery continued steaming west into heavy weather in bright sunshine. We turned at 8 pm and then made our way back to the RESPIRE array.

Thursday 14th December. We stood off the RESPIRE array until recovery was feasible at 8.30 am. We then proceeded to PELAGRA recoveries with four transmitting their positions and being recovered easily and the fifth not transmitting and only being recovered due to a huge stroke of good fortune. Discovery then set off on a repeat of the acoustic survey which had been abandoned on Wednesday.

Friday 15th December. We finished the overnight survey and then undertook 2 CTDs, the first to check calibrations on all the PELAGRA sensors and the second to collect an organic matter profile, deep polonium samples and to calibrate the Argo floats. Discovery left the final station at 9.30 for the steam back to Port Stanley.

Saturday 16th December. On passage

Sunday 17th December. On passage

Mon 18th December. On passage

Tuesday 19th December. On passage

Wednesday 20th December. Alongside

Thursday 21st December. Alongside

Friday 22nd December. Flight

1.4 Acknowledgements

Figure 1.5: Part of the COMICS team enjoying the stunning scenery of South Georgia. From left to right: Richard S, Steph H, Mark S, Alex P, Dan M, and Anna B.

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1.5 Events

Figure 1.6: Postcards commemorating the Discovery Investigations. This expedition (DY086) took place around 100 years after the Discovery committee was set up and later commissioned a series of investigations in the same area, around South Georgia. These investigations were onboard the original RRS Discovery, first used by Captain Scott, and laid the foundations of modern biological oceanography.

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Event	Station	Deployment	Date	Time (GMT)	Lat (S)	Lon (W)	Comment
1	Test	CTD001	14-Nov	18:37	52 29.5	43 47.0	Trace metal. Winch stopped at 800m
2	P3A	Pelagra001	15-Nov	13:11	52 42.0	40 06.4	Test Pelagra deployments P7
3	P3A	Pelagra002	15-Nov	13:25	52 42.0	40 06.4	Pelagra P9
4	P3A	Pelagra003	15-Nov	13:52	52 42.0	40 06.4	Pelagra P6
5	P3A	Pelagra004	15-Nov	13:54	52 42.0	40 06.4	Pelagra P4
6	P3A	Pelagra005	15-Nov	14:09	52 42.3	40 06.4	Pelagra P2
7	P3A	Argo001	15-Nov	14:22	52 42.3	40 06.4	Argo Float deployed
8	P3A	Argo002	15-Nov	14:24	52 42.3	40 06.4	
9	P3A	Argo003	15-Nov	14:26	52 42.3	40 06.4	
10	P3A	Argo004	15-Nov	14:26	52 42.3	40 06.4	
11	P3A	Argo005	15-Nov	14:27	52 42.3	40 06.4	
12	P3A	Argo006	15-Nov	14:30	52 42.5	40 06.3	
13	P3A	Glider001	15-Nov	15:09	52 42.5	40 06.3	Pancake deployed
14	P3A	CTD002	15-Nov	16:45	52 42.5	40 06.3	Stainless
15	P3A	Glider002	15-Nov	19:05	52 42.5	40 06.5	Churchill deployed
16	P3A	Glider002	15-Nov	19:47	52 41.83	40 06.85	Churchill recovered
17	P3A	PelagraRecover	15-Nov	20:02	52 41.74	40 07.06	Pelagra P4 recovered
18	P3A	PelagraRecover	15-Nov	20:12	52 41.64	40 07.17	Pelagra P2 recovered
19	P3A	PelagraRecover	15-Nov	20:25	52 41.52	40 07.46	Pelagra P6 recovered
20	P3A	MSC001	15-Nov	21:09	52 41.50	40 07.46	Marine Snow Catcher MSC1 deployed
21	P3A	MSC002	15-Nov	21:30	52 41.50	40 07.46	Marine Snow Catcher MSC2 deployed
22	P3A	MSC003	15-Nov	21:56	52 41.49	40 07.46	Marine Snow Catcher MSC3 deployed
23	P3A	MSC004	15-Nov	22:09	52 41.49	40 07.46	Marine Snow Catcher MSC4 deployed
24	P3A	MSC005	15-Nov	22:24	52 41.49	40 07.46	Marine Snow Catcher MSC5 deployed
25	P3A	MOCNESS001	16-Nov	00:40	52 41.49	40 07.46	MOCNESS deployed to 500m
26	P3A	CTD003	16-Nov	04:56	52 41.40	40 07.50	1000m stainless steel
27	P3A	Bongo001	16-Nov	06:35	52 41.40	40 07.50	400m
28	P3A	Bongo002	16-Nov	07:12	52 41.40	40 07.50	
29	P3A	MSC006	16-Nov	07:57	52 41.40	40 07.50	60m

Event	Station	Deployment	Date	Time (GMT)	Lat (S)	Lon (W)	Comment
30	P3A	MSC007	16-Nov	08:10	52 41.40	40 07.50	100m
31	P3A	MSC008	16-Nov	08:28	52 41.40	40 07.50	150m - misfired
32	P3A	MSC009	16-Nov	08:48	52 41.40	40 07.50	150m - misfired
33	P3A	MSC010	16-Nov	09:12	52 41.40	40 07.50	150m
34	P3A	RCF001	16-Nov	10:09	52 41.40	40 07.50	250m
35	P3A	CTD004	16-Nov	12:20	52 41.40	40 07.50	Trace metal
36	P3A	RCF002	16-Nov	14:00	52 41.40	40 07.50	500m
37	P3A	PelagraRecover	16-Nov	18:30	52 44.2	40 13.1	Pelagra P7 recovered
38	P3A	PelagraRecover	16-Nov	18:48	52 44.2	40 13.1	Pelagra P9 recovered
39	P3A	RESPIRE001	16-Nov	20:14	52 44.2	40 13.1	Toroid buoy deployed and recovered
40	P3A	RMT001	16-Nov	22:56	52 44.2	40 13.1	RMT deployed (trial) - end @ -52 44.25, -40 16.44
41	P3A	RMT002	17-Nov	00:20	52 44.25	40 16.44	
42	P3A	CTD005	17-Nov	05:12	52 43.5	40 09.2	2000m
43	P3A	RCF003	17-Nov	09:30	52 41.4	40 07.6	
44	P3A	Pelagra006	17-Nov	10:08	52 41.44	40 07.58	Pelagra P6
45	P3A	Pelagra007	17-Nov	10:20	52 41.50	40 07.68	Pelagra P4
46	P3A	Pelagra008	17-Nov	10:37	52 41.53	40 07.82	Pelagra P2
47	P3A	PelagraRecover	17-Nov	11:00	52 41.39	40 08.05	Pelagra P6
48	P3A	MSC011	17-Nov	11:18	52 41.39	40 08.05	No RBR Concerto data
49	P3A	MSC012	17-Nov	12:51	52 41.39	40 08.05	
50	P3A	MSC013	17-Nov	13:11	52 41.39	40 08.05	
51	P3A	MSC014	17-Nov	13:30	52 41.39	40 08.05	
52	P3A	Pelagra009	17-Nov	14:08	52 41.39	40 08.05	
53	P3A	PelagraRecover	17-Nov	14:39	52 41.39	40 08.05	Pelagra P4
54	P3A	PelagraRecover	17-Nov	15:00	52 41.39	40 08.05	Pelagra P2
55	P3A	RCF004	17-Nov	15:36	52 41.5	40 08.0	
56	P3A	Pelagra010	17-Nov	16:38	52 41.5	40 08.0	Pelagra P4
57	P3A	RMT003	17-Nov	17:20	52 41.5	40 08.1	
58	P3A	SAPS001	17-Nov	22:12	52 42.0	40 06.4	recovered at 01:34

Event	Station	Deployment	Date	Time (GMT)	Lat (S)	Lon (W)	Comment
59	P3A	PelagraRecover	18-Nov	02:40	52 42.19	40 09.0	Pelagra P9
60	P3A	PelagraRecover	18-Nov	03:22	52 41.9	40 10.2	Pelagra P4
61	P3A	MSC015	18-Nov	03:42	52 41.9	40 10.2	
62	P3A	MSC016	18-Nov	03:55	52 41.9	40 10.2	
63	P3A	CTD006	18-Nov	04:36	52 41.9	40 10.2	Stainless
64	P3A	Bongo003	18-Nov	06:16	52 41.9	40 10.2	
65	P3A	Bongo004	18-Nov	08:09	52 41.9	40 10.2	
66	P3A	MSC017	18-Nov	08:25	52 41.9	40 10.2	
67	P3A	MSC018	18-Nov	08:50	52 41.9	40 10.2	
68	P3A	MSC019	18-Nov	09:19	52 41.9	40 10.2	
69	P3A	MSC020	18-Nov	09:32	52 41.9	40 10.2	
70	P3A	MSC021	18-Nov	10:03	52 41.9	40 10.2	
71	P3A	MSC022	18-Nov	10:15	52 41.9	40 10.2	
72	P3A	CTD007	18-Nov	11:42	52 41.9	40 10.1	TMC
73	P3A	MSC023	18-Nov	14:46	52 41.9	40 10.1	
74	P3A	MSC024	18-Nov	15:06	52 41.9	40 10.1	
75	P3A	MSC025	18-Nov	15:26	52 41.9	40 10.1	
76	P3A	CTD008	18-Nov	16:13	52 41.9	40 10.1	deployment suspended due to adverse weather
77	P3A	RESPIRE002	18-Nov	19:45	52 41.9	40 10.1	
78	P3A	Pelagra011	18-Nov	23:17	52 41.8	40 10.0	Pelagra P7
79	P3A	Pelagra012	18-Nov	23:26	52 41.8	40 10.0	Pelagra P9
80	P3A	Pelagra013	18-Nov	23:40	52 41.8	40 10.0	Pelagra P6
81	P3A	Pelagra014	18-Nov	23:52	52 41.8	40 10.0	Pelagra P4
82	P3A	Pelagra015	19-Nov	02:10	52 41.24	40 9.9	Pelagra P2
83	P3A	MSC026	20-Nov	08:52	52 45.0	40 12.0	
84	P3A	MSC027	20-Nov	09:06	52 45.0	40 12.0	
85	P3A	MSC028	20-Nov	09:35	52 45.0	40 12.0	
86	P3A	MSC029	20-Nov	09:52	52 45.0	40 12.0	
87	P3A	MSC030	20-Nov	10:28	52 45.0	40 12.0	

Event	Station	Deployment	Date	Time (GMT)	Lat (S)	Lon (W)	Comment
88	P3A	PelagraRecover	20-Nov	11:40	52 49.2	40 11.0	Pelagra P2
89	P3A	Bongo005	20-Nov	12:52	52 44.95	40 11.96	
90	P3A	MSC031	20-Nov	13:45	52 44.95	40 11.96	
91	P3A	MSC032	20-Nov	14:23	52 44.95	40 11.96	
92	P3A	Pelagra016	20-Nov	15:06	52 44.95	40 11.96	Pelagra P2
93	P3A	MSC033	20-Nov	15:23	52 44.9	40 11.9	
94	P3A	SAPS002	20-Nov	16:16	52 44.9	40 11.9	
95	P3A	MOCNESS002	20-Nov	19:40	52 22.92	40 11.94	
96	P3A	MSC034	20-Nov	23:01	52 46.52	40 20.96	
97	P3A	MSC035	20-Nov	23:25	52 46.52	40 20.96	
98	P3A	RCF005	20-Nov	23:50	52 46.52	40 20.96	
99	P3A	RCF006	21-Nov	00:44	52 46.52	40 20.96	
100	P3A	PelagraRecover	21-Nov	04:19	52 43.9	40 13.1	
101	P3A	CTD009	21-Nov	05:20	52 43.9	40 13.1	
102	P3A	RESPIRERecover	21-Nov	08:00	52 46.5	40 15.6	
103	P3A	MSC036	21-Nov	09:44	52 45.09	40 12.25	
104	P3A	MSC037	21-Nov	10:07	52 45.09	40 12.25	
105	P3A	MSC038	21-Nov	10:48	52 45.09	40 12.25	
106	P3A	MSC039	21-Nov	11:14	52 45.08	40 12.25	
107	P3A	Pelagra017	21-Nov	12:38	52 45.08	40 12.25	
108	P3A	CTD010	21-Nov	14:00	52 42.09	40 08.39	glider calibration cast
109	P3A	MSC040	21-Nov	17:11	52 42.09	40 08.39	1000m
110	P3A	Mammoth001	21-Nov	19:30	52 45.15	40 12.2	
111	P3A	Mammoth002	21-Nov	23:15	52 45.15	40 12.2	
112	P3A	PelagraRecover	22-Nov	02:33	52 45.0	40 11.7	Pelagra P2
113	P3A	PelagraRecover	22-Nov	05:31	52 43.1	40 23.7	
114	P3A	PelagraRecover	22-Nov	06:22	52 40.8	40 27.4	
115	P3A	PelagraRecover	22-Nov	07:50	52 34.35	40 18.96	
116	P3A	PelagraRecover	22-Nov	14:00	52 38.3	40 18.4	

Event	Station	Deployment	Date	Time (GMT)	Lat (S)	Lon (W)	Comment
117	P3A	Mammoth003	22-Nov	15:54	52 45.1	40 12.2	
118	Argo	CTD011	23-Nov	04:55	53 58.1	41 2.2	Argo calibration CTD
119	Argo	MSC041	23-Nov	07:36	53 58.1	41 2.2	
120	P2A	RCF007	24-Nov	01:35	56 24.0	41 13.0	
121	P2A	RCF008	24-Nov	02:19	56 24.0	41 13.0	
122	P2A	CTD012	24-Nov	04:00	56 24.0	41 13.0	
123	P2A	MSC042	24-Nov	07:00	56 24.0	41 13.0	
124	P2A	MSC043	24-Nov	07:24	56 24.0	41 13.0	
125	P2A	MSC044	24-Nov	07:42	56 24.0	41 13.0	
126	P2A	MSC045	24-Nov	07:57	56 24.0	41 13.0	
127	P2A	MSC046	24-Nov	08:36	56 24.0	41 13.0	
128	P2A	MSC047	24-Nov	08:50	56 24.0	41 13.0	
129	P2A	MSC048	24-Nov	09:10	56 24.0	41 13.0	
130	P2A	MSC049	24-Nov	09:14	56 24.0	41 13.0	
131	P2A	MSC050	25-Nov	07:24	56 38.0	40 55.0	
132	P2A	MSC051	25-Nov	07:40	56 38.0	40 55.0	
133	P2A	MSC052	25-Nov	08:16	56 38.0	40 55.0	
134	P2A	MSC053	25-Nov	08:44	56 38.0	40 55.0	
135	P2A	Bongo006	25-Nov	09:21	56 38.0	40 55.0	
136	P2A	Bongo007	25-Nov	10:02	56 38.0	40 55.0	
137	P2A	MSC054	25-Nov	10:56	56 38.0	40 55.0	
138	P2A	MSC055	25-Nov	11:20	56 38.0	40 55.0	
139	P2A	MSC056	25-Nov	11:37	56 38.0	40 55.0	
140	P2A	MSC057	25-Nov	12:10	56 38.0	40 55.0	
141	P2A	MSC058	25-Nov	12:25	56 38.0	40 55.0	
142	P2A	MSC059	25-Nov	12:40	56 38.0	40 55.0	
143	P2A	MSC060	25-Nov	12:57	56 38.0	40 55.0	
144	P2A	CTD013	25-Nov	13:49	56 38.0	40 55.0	
145	P2A	RCF009	25-Nov	16:15	56 38.0	40 55.0	

Event	Station	Deployment	Date	Time (GMT)	Lat (S)	Lon (W)	Comment
146	P2A	RCF010	25-Nov	17:16	56 38.0	40 55.0	
147	P2A	Bongo008	25-Nov	19:20	56 38.0	40 55.0	
148	P2A	Bongo009	25-Nov	20:29	56 38.0	40 55.0	
149	Stromness	CTD014	27-Nov	12:16	54 04.9	36 41.7	
150	Stromness	Sophie's Balls	27-Nov	16:30	54 04.9	36 41.7	Ended 03:42
151	P3B	CTD015	29-Nov	13:30	52 41.42	40 07.52	Trace metal
152	P3B	Glider003	29-Nov	16:53	52 41.42	40 07.52	Churchill deployed
153	P3B	RMT004	29-Nov	17:30	52 41.4	40 07.8	finished at 52 39.31S, 40 15.81W
154	P3B	MSC061	29-Nov	21:44	52 39.31	40 15.81	
155	P3B	MSC062	29-Nov	22:06	52 39.31	40 15.81	
156	P3B	MSC063	29-Nov	22:24	52 39.31	40 15.81	
157	P3B	Pelagra018	29-Nov	23:17	52 39.31	40 15.81	
158	P3B	Pelagra019	29-Nov	23:34	52 39.31	40 15.81	
159	P3B	Pelagra020	29-Nov	23:40	52 39.31	40 15.81	
160	P3B	Pelagra021	29-Nov	23:53	52 39.31	40 15.81	
161	P3B	Pelagra022	30-Nov	00:08	52 39.31	40 15.9	
162	P3B	RMT005	30-Nov	01:20	52 41.48	40 07.4	
163	P3B	PelagraRecover	30-Nov	05:36	52 39.4	40 16.6	
164	P3B	CTD016	30-Nov	07:00	52 42.6	40 04.6	
165	P3B	Pelagra023	30-Nov	08:46	52 42.6	40 04.6	
166	P3B	CTD017	30-Nov	10:14	52 42.53	40 04.6	
167	P3B	MSC064	30-Nov	11:27	52 42.53	40 04.6	
168	P3B	MSC065	30-Nov	12:00	52 42.53	40 04.6	
169	P3B	MSC066	30-Nov	12:33	52 42.53	40 04.6	
170	P3B	MSC067	30-Nov	13:02	52 42.5	40 04.6	
171	P3B	RESPIRE003	30-Nov	13:48	52 42.4	40 05.1	Fully deployed at 14:25
172	P3B	RCF011	30-Nov	15:09	52 42.27	40 06.14	
173	P3B	RCF012	30-Nov	16:16	52 42.27	40 06.14	
174	P3B	Bongo010	30-Nov	17:38	52 42.3	40 06.1	

Event	Station	Deployment	Date	Time (GMT)	Lat (S)	Lon (W)	Comment
175	P3B	Mammoth004	30-Nov	18:34	52 42.3	40 06.1	
176	P3B	MSC068	30-Nov	21:12	52 42.3	40 06.1	
177	P3B	MSC069	30-Nov	21:25	52 42.3	40 06.1	
178	P3B	MSC070	30-Nov	21:34	52 42.3	40 06.1	
179	P3B	MSC071	30-Nov	22:02	52 42.3	40 06.1	
180	P3B	MSC072	30-Nov	22:23	52 42.28	40 06.15	
181	P3B	Mammoth005	30-Nov	23:35	52 42.3	40 06.2	
182	P3B	PelagraRecover	01-Dec	03:49	52 40.8	40 14.3	
183	P3B	SAPS003	01-Dec	05:18	52 42.3	40 06.2	
184	P3B	CTD018	01-Dec	09:14	52 42.3	40 06.2	Claire's shallow CTD
185	P3B	MSC073	01-Dec	10:53	52 42.28	40 06.1	
186	P3B	MSC074	01-Dec	11:14	52 42.28	40 06.1	
187	P3B	MSC075	01-Dec	11:34	52 42.28	40 06.1	
188	P3B	MSC076	01-Dec	11:55	52 42.28	40 06.1	
189	P3B	Bongo011	01-Dec	15:05	52 42.3	40 06.1	
190	P3B	Bongo012	01-Dec	15:35	52 42.3	40 06.1	
191	P3B	Bongo013	01-Dec	16:32	52 42.3	40 06.1	
192	P3B	MOCNESS003	01-Dec	17:43	52 42.5	40 00.5	Ended 19:18
193	P3B	MSC077	01-Dec	20:58	52 42.33	40 06.08	
194	P3B	MSC078	01-Dec	21:12	52 42.33	40 06.08	
195	P3B	MSC079	01-Dec	21:25	52 42.33	40 06.08	
196	P3B	MSC080	01-Dec	21:44	52 42.33	40 06.08	
197	P3B	PelagraRecover	01-Dec	22:57	52 45.00	40 07.5	
198	P3B	PelagraRecover	02-Dec	00:30	52 37.83	40 18.57	
199	P3B	PelagraRecover	02-Dec	01:30	52 36.47	40 19.9	
200	P3B	PelagraRecover	02-Dec	02:34	52 35.61	40 17.43	
201	P3B	Bongo014	02-Dec	03:03	52 35.6	40 17.9	
202	P3B	Bongo015	02-Dec	03:55	52 35.6	40 17.9	
203	P3B	GliderRecovery	02-Dec	11:47	52 41.77	40 15.1	

Event	Station	Deployment	Date	Time (GMT)	Lat (S)	Lon (W)	Comment
204	P3B	CTD019	02-Dec	12:51	52 41.74	40 15.17	TMC (1000 m)
205	P3B	RCF013	02-Dec	14:27	52 41.74	40 15.17	
206	P3B	MSC081	02-Dec	15:30	52 41.74	40 15.2	
207	P3B	MSC082	02-Dec	15:52	52 41.74	40 15.2	
208	P3B	MSC083	02-Dec	16:10	52 41.74	40 15.2	
209	P3B	MSC084	02-Dec	16:21	52 41.74	40 15.2	
210	P3B	MOCNESS004	02-Dec	17:00	52 41.7	40 15.3	
211	P3B	CTD020	02-Dec	21:00	52 41.7	40 15.08	Thorium
212	P3B	Pelagra024	02-Dec	23:08	52 41.7	40 15.08	Pelagra P7
213	P3B	Pelagra025	02-Dec	23:27	52 41.7	40 15.08	Pelagra P9
214	P3B	Pelagra026	02-Dec	23:36	52 41.7	40 15.08	Pelagra P6
215	P3B	Pelagra027	02-Dec	23:54	52 41.7	40 15.08	Pelagra P4
216	P3B	Pelagra028	03-Dec	00:07	52 41.64	40 15.3	Pelagra P2
217	P3B	MOCNESS005	03-Dec	00:30	52 41.64	40 15.3	recovered @ 03:23
218	P3B	CTD021	03-Dec	05:48	52 46.2	40 03.1	1000m stainless steel
219	P3B	Bongo016	03-Dec	07:20	52 46.2	40 03.1	
220	P3B	Bongo017	03-Dec	07:41	52 46.2	40 03.1	
221	P3B	MSC085	03-Dec	09:02	52 46.4	40 03.1	
222	P3B	MSC086	03-Dec	09:12	52 46.4	40 03.1	
223	P3B	MSC087	03-Dec	09:26	52 46.4	40 03.1	
224	P3B	MSC088	03-Dec	09:40	52 46.4	40 03.1	
225	P3B	RESPIRERecover	03-Dec	11:47	52 46.4	40 03.1	
226	P3B	Acoustic Survey	03-Dec	12:22	52 48.5	40 00.32	
227	P3B	RCF014	03-Dec	20:25	52 31.0	40 0.21	
228	P3B	RCF015	03-Dec	21:22	52 31.0	40 0.21	
229	P3B	Acoustic Survey	03-Dec	22:30	52 31.0	40 0.21	
230	P3B	CTD022	04-Dec	07:30	52 41.25	40 20.66	Claire's deep CTD
231	P3B	MSC089	04-Dec	11:26	52 41.25	40 20.66	
232	P3B	MSC090	04-Dec	11:41	52 41.25	40 20.66	

Event	Station	Deployment	Date	Time (GMT)	Lat (S)	Lon (W)	Comment
233	P3B	MSC091	04-Dec	11:50	52 41.25	40 20.66	
234	P3B	MOCNESS006	04-Dec	12:38	52 41.254	40 20.87	Ended 16:06
235	P3B	MSC092	04-Dec	17:19	52 41.3	40 20.7	
236	P3B	MSC093	04-Dec	17:31	52 41.3	40 20.7	
237	P3B	MSC094	04-Dec	17:45	52 41.3	40 20.7	
238	P3B	MSC095	04-Dec	17:51	52 41.3	40 20.7	
239	P3B	MSC096	04-Dec	18:05	52 41.3	40 20.7	
240	P3B	MSC097	04-Dec	18:13	52 41.3	40 20.7	
241	P3B	RCF016	04-Dec	18:28	52 41.3	40 20.7	500 m
242	P3B	PelagraRecover	04-Dec	20:25	52 41.33	40 20.65	P7
243	P3B	PelagraRecover	04-Dec	20:53	52 42.08	40 20.26	P9
244	P3B	PelagraRecover	04-Dec	21:21	52 42.22	40 19.65	P6
245	P3B	PelagraRecover	04-Dec	21:45	52 42.7	40 19.16	P4
246	P3B	PelagraRecover	04-Dec	22:25	52 43.24	40 19.57	P2
247	P3B	RCF017	04-Dec	22:32	52 43.24	40 19.57	
248	P3B	MSC098	05-Dec	00:08	52 43.24	40 19.57	
249	P3B	Bongo018	05-Dec	02:20	52 43.24	40 19.57	
250	P3B	Bongo019	05-Dec	02:47	52 43.24	40 19.57	
251	P3B	Bongo020	05-Dec	03:15	52 43.3	40 19.6	
252	P3B	CTD023	05-Dec	05:04	52 43.3	40 19.6	
253	P3B	SAPS004	05-Dec	07:41	52 43.3	40 19.6	Ended 10:40
254	P3B	CTD024	05-Dec	11:38	52 43.3	40 19.6	Trace metal
255	P3B	MSC099	05-Dec	15:48	52 43.3	40 19.6	
256	P3B	MSC100	05-Dec	16:33	52 43.3	40 19.6	
257	P3B	MSC101	05-Dec	16:40	52 43.3	40 19.6	
258	P3B	RCF018	05-Dec	16:56	52 43.3	40 19.6	
259	P3B	RCF019	05-Dec	17:38	52 43.3	40 19.6	
260	P3B	Pelagra029	05-Dec	19:15	52 43.3	40 19.6	
261	P3B	Pelagra030	05-Dec	19:24	52 43.4	40 19.5	

Event	Station	Deployment	Date	Time (GMT)	Lat (S)	Lon (W)	Comment
262	P3B	Pelagra031	05-Dec	19:40	52 43.4	40 19.3	
263	P3B	Pelagra032	05-Dec	19:50	52 43.4	40 19.2	
264	P3B	Pelagra033	05-Dec	20:08	52 43.4	40 19.0	
265	Argo Float	CTD025	06-Dec	06:54	53 57.7	41 02.5	150m
266	P3C	MSC102	09-Dec	10:12	52 43.2	40 19.7	
267	P3C	MSC103	09-Dec	10:33	52 43.2	40 19.7	
268	P3C	MSC104	09-Dec	11:10	52 43.2	40 19.7	
269	P3C	MSC105	09-Dec	11:25	52 43.2	40 19.7	
270	P3C	MSC106	09-Dec	11:45	52 43.2	40 19.7	
271	P3C	Bongo021	09-Dec	12:05	52 43.2	40 19.7	
272	P3C	Bongo022	09-Dec	12:40	52 43.2	40 19.7	
273	P3C	Bongo023	09-Dec	13:35	52 43.2	40 19.7	
274	P3C	RCF020	09-Dec	14:25	52 43.2	40 19.7	
275	P3C	CTD026	09-Dec	15:43	52 43.3	40 19.7	Trace metal
276	P3C	Bongo024	09-Dec	17:35	52 43.3	40 19.7	
277	P3C	Bongo025	09-Dec	18:05	52 43.3	40 19.7	
278	P3C	Bongo026	09-Dec	18:40	52 43.3	40 19.7	
279	P3C	Bongo027	09-Dec	19:16	52 43.3	40 19.7	
280	P3C	Bongo028	09-Dec	20:05	52 43.3	40 19.7	
281	P3C	PelagraRecover	09-Dec	21:21	52 45.0	40 24.9	
282	P3C	PelagraRecover	09-Dec	22:02	52 45.1	40 25.86	
283	P3C	PelagraRecover	09-Dec	23:10	52 41.6	40 34.4	
284	P3C	PelagraRecover	09-Dec	23:36	52 41.27	40 32.4	
285	P3C	PelagraRecover	10-Dec	00:38	52 44.99	40 24.06	
286	P3C	RMT006	10-Dec	01:07	52 45.02	40 29.04	Ended 04:18
287	P3C	CTD027	10-Dec	05:10	52 41.7	40 19.4	Stainless 1000m
288	P3C	SAPS005	10-Dec	07:02	52 41.7	40 19.4	Ended 10:24
289	P3C	MSC107	10-Dec	11:10	52 41.7	40 19.4	
290	P3C	MSC108	10-Dec	11:40	52 41.7	40 19.4	

Event	Station	Deployment	Date	Time (GMT)	Lat (S)	Lon (W)	Comment
291	P3C	MSC109	10-Dec	12:13	52 41.7	40 19.4	
292	P3C	MSC110	10-Dec	12:50	52 41.7	40 19.4	
293	P3C	RCF021	10-Dec	13:14	52 41.7	40 19.4	
294	P3C	RCF022	10-Dec	13:54	52 41.7	40 19.0	
295	P3C	RMT007	10-Dec	15:25	52 41.5	40 18.9	
296	P3C	MSC111	10-Dec	19:24	52 40.02	40 15.74	
297	P3C	MSC112	10-Dec	19:38	52 40.02	40 15.74	
298	P3C	MSC113	10-Dec	19:51	52 40.02	40 15.74	
299	P3C	MSC114	10-Dec	20:04	52 40.02	40 15.74	
300	P3C	Pelagra034	10-Dec	21:06	52 40.02	40 15.74	
301	P3C	Pelagra035	10-Dec	21:18	52 39.98	40 15.66	
302	P3C	Pelagra036	10-Dec	21:35	52 39.96	40 15.62	
303	P3C	Pelagra037	10-Dec	21:50	52 39.94	40 15.56	
304	P3C	Pelagra038	10-Dec	22:05	52 39.91	40 15.48	
305	P3C	MOCNESS007	10-Dec	23:00	52 39.91	40 15.48	823m Ended @02:05, 52 36.15, 40 07.6
306	P3C	Mammoth006	11-Dec	03:18	52 36.6	40 07.6	
307	P3C	CTD028	11-Dec	07:38	52 43.0	40 14.3	Manu calibration CTD
308	P3C	MSC115	11-Dec	09:28	52 43.0	40 14.3	
309	P3C	MSC116	11-Dec	09:42	52 43.0	40 14.3	
310	P3C	MSC117	11-Dec	09:55	52 43.0	40 14.3	
311	P3C	MSC118	11-Dec	10:02	52 43.0	40 14.3	
312	P3C	CTD029	11-Dec	11:30	52 43.0	40 14.3	Trace metal
313	P3C	RCF023	11-Dec	13:30	52 43.0	40 14.3	
314	P3C	RCF024	11-Dec	15:20	52 42.99	40 14.32	
315	P3C	MOCNESS008	11-Dec	15:34	52 43.0	40 14.5	Ended 18:33 @ 52 44.8, 40 24.1
316	P3C	Mammoth007	11-Dec	19:24	52 43.0	40 14.5	
317	P3C	RESPIRE004	11-Dec	21:56	52 43.0	40 14.5	
318	P3C	CTD030	12-Dec	00:00	52 45.36	40 24.71	
319	P3C	CTD031	12-Dec	04:07	52 42.1	40 15.3	

Event	Station	Deployment	Date	Time (GMT)	Lat (S)	Lon (W)	Comment
320	P3C	Acoustic Survey	12-Dec	06:57	52 46.2	40 25.2	end of survey @ 15:10 (52 31.0 S; 40 0.3 W)
321	P3C	Bongo029	12-Dec	16:49	52 38.6	40 12.7	
322	P3C	Bongo030	12-Dec	17:12	52 38.6	40 12.7	
323	P3C	Bongo031	12-Dec	18:04	52 38.6	40 12.7	
324	P3C	MSC119	12-Dec	18:37	52 38.7	40 12.6	
325	P3C	MSC120	12-Dec	18:49	52 38.6	40 12.6	
326	P3C	MSC121	12-Dec	18:59	52 38.6	40 12.6	
327	P3C	MSC122	12-Dec	19:09	52 38.6	40 12.6	
328	P3C	MSC123	12-Dec	19:24	52 38.7	40 12.6	
329	P3C	MSC124	12-Dec	19:35	52 38.7	40 12.6	
330	P3C	RCF025	12-Dec	19:48	52 38.8	40 12.6	
331	P3C	RCF026	12-Dec	20:20	52 38.8	40 12.6	
332	P3C	RESPIRERecover	14-Dec	11:12	52 42.61	40 13.85	
333	P3C	RESPIRERecover	14-Dec				** Bridge gave the recovery 2 event numbers **
334	P3C	PelagraRecover	14-Dec	13:28	52 40.18	40 20.73	P2
335	P3C	PelagraRecover	14-Dec	13:54	52 39.47	40 21.83	P6
336	P3C	PelagraRecover	14-Dec	15:03	52 38.9	40 23.1	P9
337	P3C	PelagraRecover	14-Dec	15:49	52 36.6	40 24.3	P7
338	P3C	PelagraRecover	14-Dec	19:46	52 40.9	40 19.0	P4
339	P3C	Survey	14-Dec	22:25	52 29.0	40 01.0	Ended 04:49, 52 45.5 39 48.5
340	P3C	CTD032	15-Dec	06:20	52 42.1	39 57.0	Calibration cast (Lampitt)
341	P3C	CTD033	15-Dec	07:15	52 42.1	39 57.0	Deep cast (Claire)
342	P3C	MSC125	15-Dec	10:50	52 42.1	39 57.0	
343	P3C	MSC126	15-Dec	11:24	52 42.09	39 56.99	
344	P3C	MSC127	15-Dec	11:41	52 42.09	39 56.99	
345	P3C	MSC128	15-Dec	11:55	52 42.09	39 56.99	

2. Specific reports

2.1 Satellite data

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*(National Oceanography Centre)

2.1.1 Overview

Satellite data was provided as a bulletin by the NERC Earth Observation Data Acquisition and Analysis Service (NEODAAS) on a daily basis.

Data provided included weekly composites and daily images (when coverage was available) of ocean colour, sea surface temperature (SST) and mean sea level anomaly (MSLA) in netcdf format and a png (low resolution). Additionally, a full_area dataset was also provided. The following datasets were available:

1. From VIIRS, MODIS and OLCI:
   - Chlorophyll daily (chlor_a)
   - Chlorophyll weekly (chlor_a).
2. From VIIRS and MODIS
   - Chlorophyll present in cells between 0.2 micrometres and 2 micrometres daily (c02to2)
   - Chlorophyll present in cells between 2 micrometres and 20 micrometres daily (c2to20)
   - Chlorophyll present in cells between 20 micrometres and 200 micrometres daily (c20to200)
   - NASA standard PIC (from November 11th)
3. From MW+IR and MUR:
   - Sea surface temperature daily
4. MSLA product distributed by CMEMS.
   - MSLA and geostrophic currents

2.1.2 Data availability during the cruise

Data was downloaded daily via FTP from ftp://neodaas19:hiH2ap1Iuje6tohshai8Y@ftp.rsg.pml.ac.uk/2017/mmmdd, where 'mmm' is the month (the first 3 letters) and 'dd' is the day (2 digits).

Data was plotted daily. PNGs were generated daily and available in the public drive. Image overlays were also exported as a Google Earth product (KMZ). This helped planning cruise stations locations by having different products overlaid together with the ship track, previous stations and instruments in the water.

2.1.3 Matlab routines

Importing data

Several functions were written to import the netcdf file to a struct variable in Matlab:

1. *satchlL2nc2struct.m*: for all ocean colour satellites
2. *satmslanc2struct.m*: for mean sea level anomaly data (MSLA)
3. *satmursstnc2struc.m*: for Sea Surface Temperature (SST) from MUR
4. *satmwirsstnc2struct.m*: for SST from MWIR

Plots

PNG images were generated in Matlab using the following routines:

1. *COMICS_satellite_image2png_standard.m* creates png images of geostrophic currents (overlaid on top of bathymetry), total chlorophyll from all 3 satellites, MSLA, SST all with curly geostrophic current vectors overlaid on top of the pcolor map. It also allows to plot the standard area or the extended 'full_area'. Earlier scripts were *COMICS_satellite_images2kmz.m*, *COMICS_latest_CHL_currents_overlaid.m*.
2. *COMICS_1_stations*.m: adds important station points (and labels) for COMICS1 cruise such as P3, argo float, P2 and LP (low productivity site).
3. *COMICS_satellite_averages.m* plots shown in this section of the report

KMZ (Google Earth) overlays were generated in Matlab using the following routines:

1. *COMICS_currents2kmz.m* creates coloured (intensity) current vectors overlays
2. *neodaas_CHL2kmz.m* creates total chlorophyll maps overlays

Ancillary data

Some ancillary data was also added to the KMZs to aid cruise planning.

1. *COMICS_cruise2kmz.m* creates KMZs with:
   (a) Argo floats tracks and surfacings
   (b) ship track and current ship position
   (c) CTD locations
   (d) MSC locations
   (e) Pelagra deployment/recovery sites and track of the drift
   (f) Glider tracks and last surfacing

Additional scripts were written to import that data:

1. *import COMICS_event_log.m* necessary to import data to run *COMICS_cruise2kmz.m*.

2.1.4 Satellite imagery for the three main stations

Overall currents at P3 were very slow. This matches well what we saw on the other instruments (gliders, ADCP) and drifting trajectories of drifting instruments. A small increase in the water temperature at the surface was also observed throughout the cruise duration. Overall, there was a sharp decrease in chlorophyll at the sampling site (P3).

Google Maps overlays

KMZs integrating all available datasets were created throughout the cruise to facilitate cruise planning. Figure 2.5 is an example of VIIRS total chlorophyll image from Dec 10th (in the background), with geostrophic current vectors, CTD and Marine Snow Catchers (MSC) locations, Pelagra and RESPIRE deployments and recoveries (magenta and cyan, respectively), acoustic surveys plans (red lines), ship track (green line), Argo floats tracks and surfacings (yellow), glider surveys (orange).
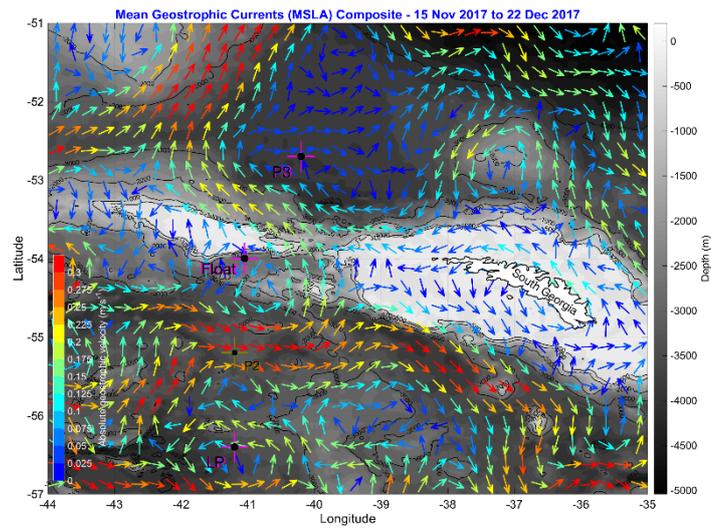
(a) P3A
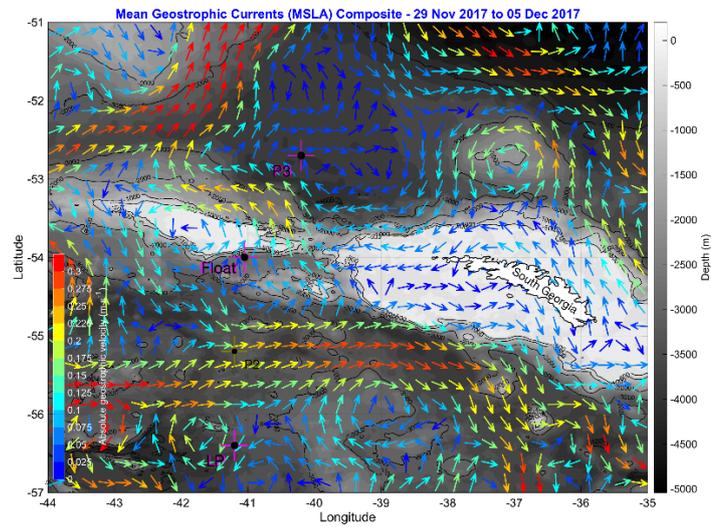
(b) P3B
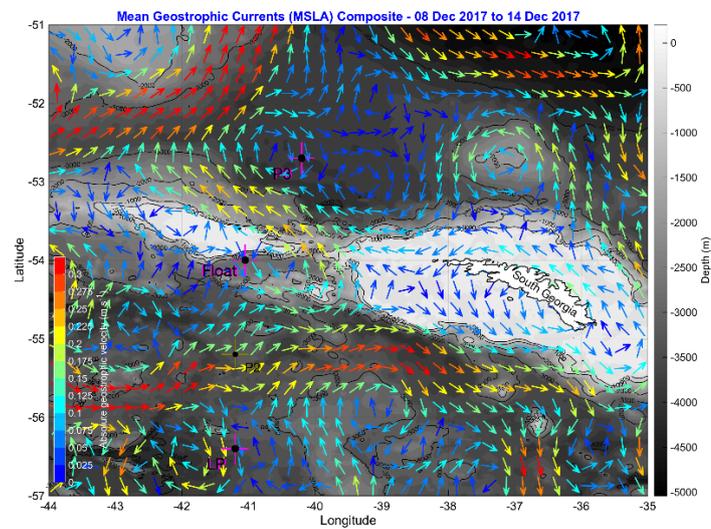
(c) P3C

Figure 2.1: Mean Geostrophic Currents from Mean Sea Level Anomaly (MLSA)
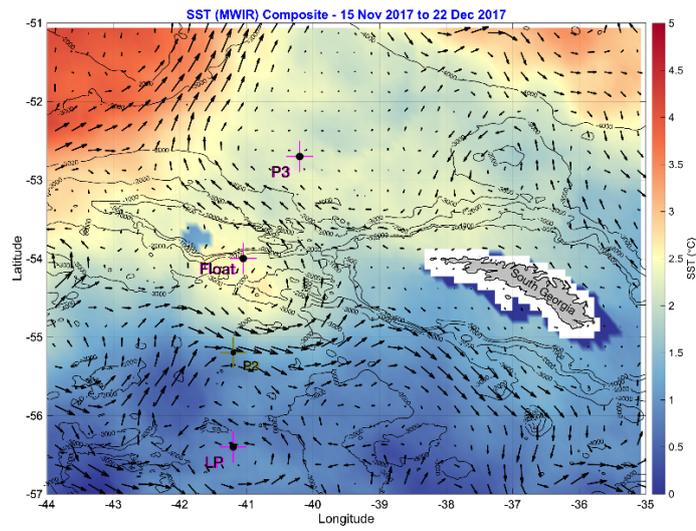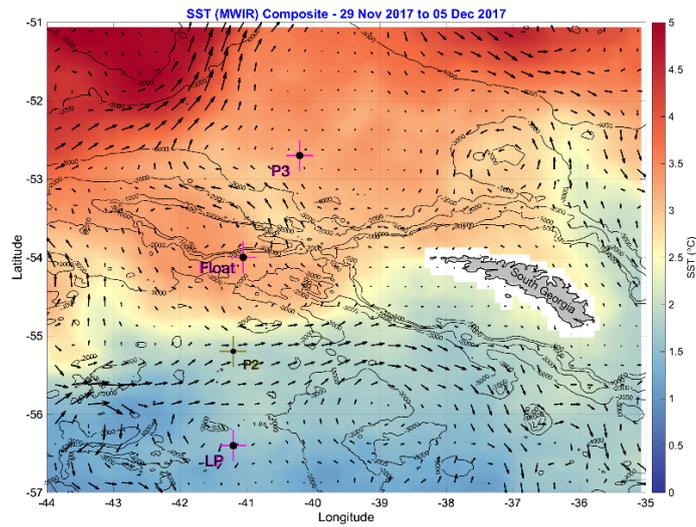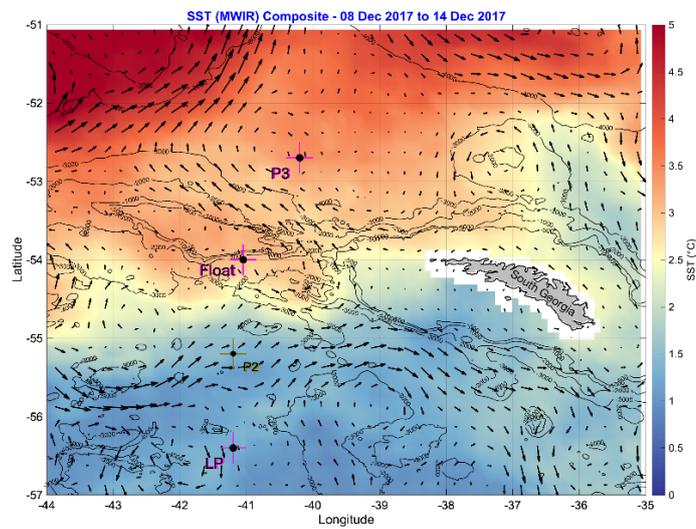
(a) P3A

(b) P3B

(c) P3C

Figure 2.2: Sea Surface Temperature (SST) from MWIR with mean geostrophic currents overlaid)
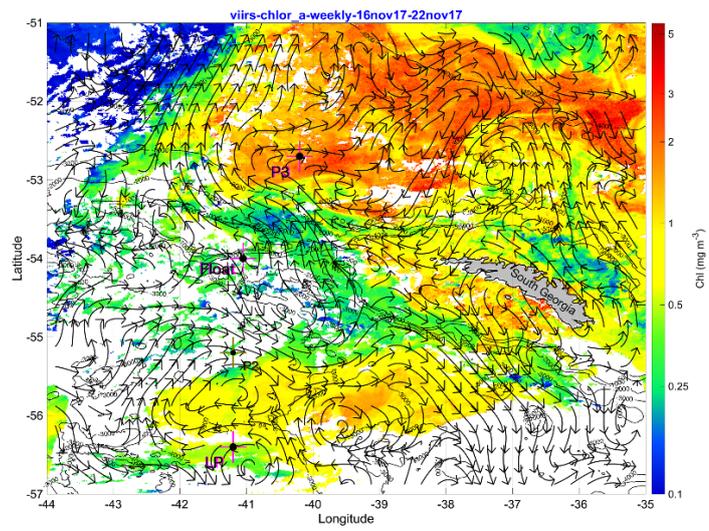
(a) P3A
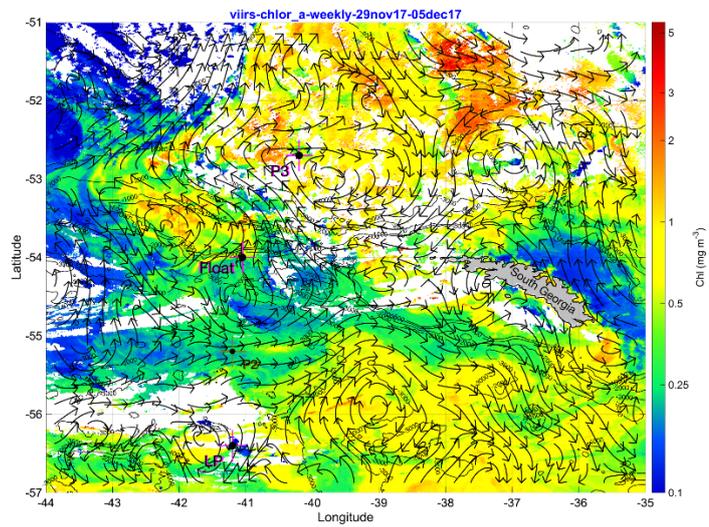
(b) P3B
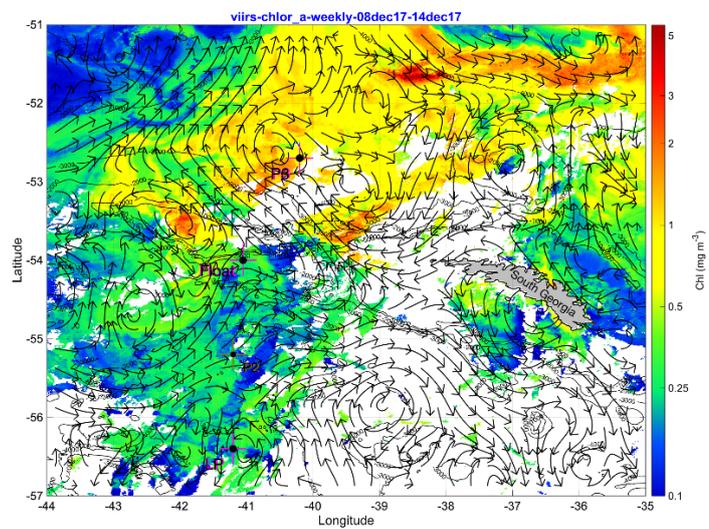
(c) P3C

Figure 2.3: Total Chlorophyll from VIIRS
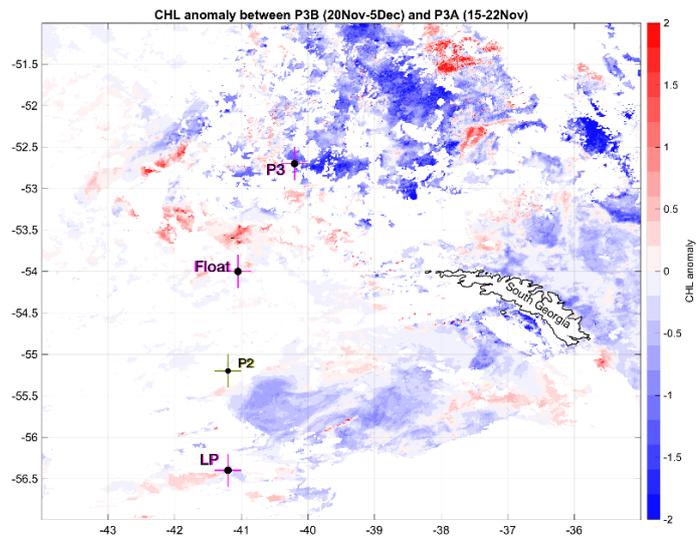
(a) P3A vs P3B
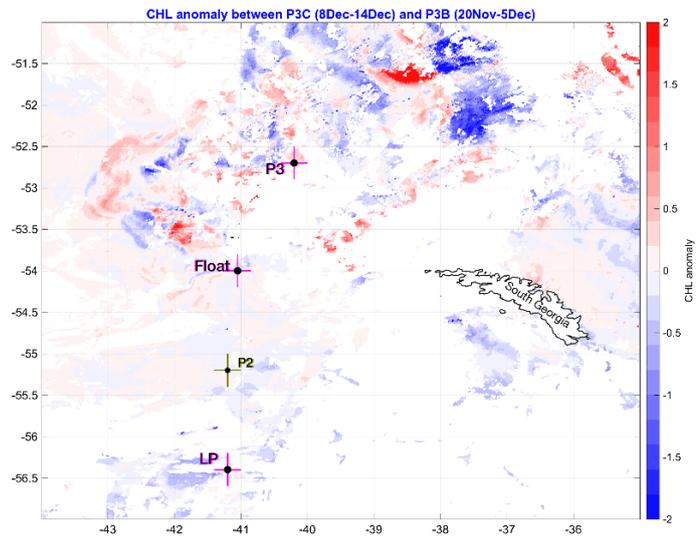
(b) P3A vs P3C
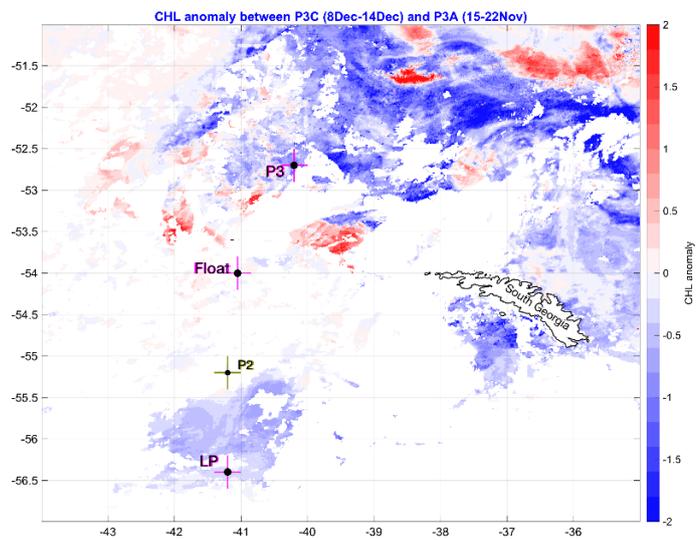
(c) P3A vs P3C

Figure 2.4: Chlorophyll anomaly between station (re)visits

Figure 2.5: VIIRS total chlorophyll image from Dec 10th (in the background), with geostrophic current vectors, CTD and Marine Snow Catchers (MSC) locations, Pelagra and RESPIRE deployments and recoveries (magenta and cyan, respectively), acoustic surveys plans (red lines), ship track (green line), Argo floats tracks and surfacings (yellow), glider surveys (orange)

2.2 Glider operations

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2.2.1 Objectives

Glider operations on DY086 consisted of supporting the ERC funded grant GOCART (Gauging
Ocean organic Carbon fluxes using Autonomous Robotic Technologies) project.

Three gliders were used to characterize the temporal variability of organic carbon flux and the
remineralisation depth during the spring bloom in a highly productive region near South Georgia:

- 2 Teledyne Webb Research Slocum gliders from MARS, National Oceanography Centre
  (NOC): Unit-398 (Churchill, a.k.a. 'Waffle') and Unit-404 (Pancake)
- 1 Kongsberg Seaglider from the Southern Ocean Carbon and Climate Observatory (SOCCO),
  Cape Town: SG-542 (a.k.a. 'Sea Biscuit') deployed before the start of the cruise by the
  SOCCO team.

Mission details can be found at https://mars.noc.ac.uk/missions/go-cart-s-georgia and http://iop.apl.washington.edu/s
for the Slocum gliders and Seaglider, respectively.

2.2.2 Deployment description

Gliders were tasked to survey a triangle with its southernmost vertex 2 km north of the British
Antarctic Survey's P3 mooring (Figure 1). The proximity to the mooring allows good calibration
between the glider sensors and the mooring CTD and oxygen optode. The ADCP and current meter
on the mooring will help to constrain some of the advection uncertainties and provide some current
information at depth as the gliders only report 1000 m depth-averaged currents.

The location and orientation of the triangle was chosen based on the predominantly northward
surface currents in the region (climatology for November and December 2003-2016 using OSCAR
currents). Gliders reported predominantly north-western depth averaged currents throughout the
deployment. By having gliders fly in opposite directions, we maximized the number of inter-
calibrations between gliders (they crossed paths roughly once every 1.5-2 days).

Table 2.1: Coordinates of glider waypoints and P3 mooring.

	GOCART 1	GOCART 2	GOCART 3	P3 mooring
Latitude	52°47.670' S	52°42.059' S	52°42.059' S	52° 48.750' S
Longitude	40°09.864' W	40°04.501' W	40°15.221' W	40° 9.861' W

2.2.3 Sensor Packages

Gliders were fitted with a custom made Wetlabs Environmental Characterization (ECO) Triplet
puck Eco Puck, measuring backscatter at 532 and 700 nm together with the standard chlorophyll
fluorescence. A standalone Eco Puck was also acquired and used on the CTD rosette during the
cruise to provide good calibrations between the gliders, cruise CTD and in situ POC samples.

The following table (Table 2.3) summarises the serial numbers, last calibration date, measured
variables and additional notes for each sensor on each glider.
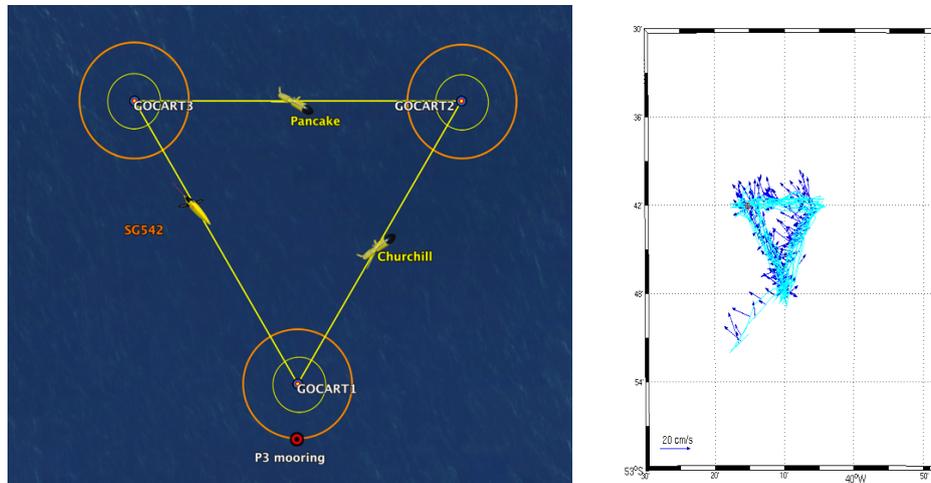
Figure 2.6: (left) flight track (yellow) for all three gliders. Waypoints are shown in the vertices of the triangle with a range (circle) of 2km and 1km for the Seaglider (orange) and Slocum gliders (yellow), respectively. P3 mooring is shown in red. (right) depth averaged currents reported by SG-542 throughout the 44-day deployment.

Table 2.2: Glider deployment characteristics. Note SG-542 was not deployed on this cruise.

Glider	Deployment	Recovery	WPT direction
Pancake	2017-11-15 15:09 GMT LAT: 52° 42.5' S LON: 40° 06.3' W	N/A	3-2-1 (clockwise)
Churchill (deployment 1)	2017-11-15 19:05 GMT LAT: 52° 42.5' S LON: 40° 06.5' W	2017-11-15 19:47 GMT LAT: 52° 41.83' S LON: 40° 06.85' W	N/A
Churchill (deployment 2)	2017-11-29 16:53 GMT LAT: 52° 41.42' S LON: 40° 07.52' W	N/A	1-2-3 (anti-clockwise)
SG-542	2017-10-19 14:20 GMT LAT: 52° 47.34' S LON: 40° 09.54' W	2017-12-02 11:47 GMT LAT: 52° 41.77' S LON: 40° 15.1' W	1-2-3 (anti-clockwise)

Table 2.3: Sensor Packages on the three gliders

PANCAKE

Sensor	S/N	Last cal	Variables measured	Notes
SeaBird CTD	9105	24/07/17	Conductivity, Temperature, Depth	
Wetlabs Eco Puck	1609	31/07/17	Backscatter at 532, 700 nm; chlorophyll fluorescence	
Oxygen Optode	104	25/02/17	Dissolved oxygen	
Satlantic PAR	461	12/12/15	Photosynthetic Active Radiation	

CHURCHILL

Sensor	S/N	Last cal	Variables measured	Notes
SeaBird CTD	9106	25/07/17	Conductivity, Temperature, Depth	issues with conductivity started on Dec 4th
Wetlabs Eco Puck	1612	14/08/17	Backscatter at 532, 700 nm; chlorophyll fluorescence	
Aanderaa Oxygen Optode	144	25/02/17	Dissolved oxygen	

SG-542

Sensor	S/N	Last cal	Variables measured	Notes
SeaBird CTD			Conductivity, Temperature, Depth	
Wetlabs Eco Puck			Backscatter at 532, 700 nm; chlorophyll fluorescence	
Oxygen Optode			Dissolved oxygen	
Satlantic PAR			Photosysthetic Active Radiation	

Figure 2.7: (left) Churchill and Pancake before deployment on November 15th. (right) Churchill during functional checkouts near King Edward point before redeployment (November 27th).

2.2.4 Deployment operations

Functional checks were conducted on both Slocum gliders while in port in Stanley on November 9th using the Slocum_prelaunch_checkout_v1.0.xls sheet. Same checks were performed again the day before deployment. An updated checkout sheet version (same name) was supplied for Churchill's redeployment checkout with more commands to check. Both gliders passed their functional checks with flying colours.

Both Slocum gliders were scheduled to be deployed on November 15th as soon as we got to P3. Steve Woodward was the point of contact handling the deployment back on MARS base. Last functional checks (e.g. running status.mi) were done a couple of hours prior to deployment as per Steve's instructions.

Deployment rig was set up following the instructions supplied by MARS staff. For both gliders, the weight bar was placed under the starboard wing (CTD is on the port side on both gliders), black taped section of the rope was placed under the glider for better grip and white pvc tubes were placed on the port side (Figure 3 top). Gliders were facing the stern of the ship during deployment with the weight bar on the ship's side. The crane used for the first 2 deployments was the knuckle boom on the starboard aft of the ship. Communications with MARS were via WhatsApp – this worked very well, and we would recommend that MARS use this route wherever possible for future deployments/recoveries.

PANCAKE

Pancake went first since Churchill was having some iridium communication issues. During the deployment, glider was lifted from deck and lowered onto the water. A pole was used to prevent the glider from spinning. When the glider hit the water, the sea catch was released, but it seems as only the aft rope was released, causing the glider to get tangled onto the rig ropes. After a while in the water, the glider freed itself from the rig. No damage was observed on the glider.

CHURCHILL

Churchill wasn't so lucky. . . the digifin was broken during deployment and the glider had to be recovered. While the glider was being lowered into the water, a big swell reached Churchill which was around 3 meters above the water. The ropes on the rig lost tension and got tangled around the tail. The swell went away and the glider was left dangling in mid-air. The rotation of the rig

Figure 2.8: Pancake's entanglement during deployment

around itself caused the glider to eventually become free and it fell into the water from a height. The deployment was recorded from the bridge and after reviewing it several times carefully (and painfully), no visual damage to the digifin, CTD nor starboard wing can be observed while the glider was in the air. It seems that the digifin was broken on contact with the water when the glider fell from ~3 meters, tail first. Churchill was immediately recovered again by asking MARS to trigger release of the nose cone and Churchill was lifted back to deck with the P-frame.

2.2.5 Glider refit and redeployment

Churchill's digifin was broken when hitting the water from a height. Luckily, a glider (named Boomer) belonging to Woods Hole Oceanographic Institution (WHOI) was recovered on the previous cruise (DY085) and permission from the PI (Louis St Laurent) was given to use Boomer's digifin on Churchill.

After inspecting the similarities between the 2 digifins (notice a slot at the bottom of the digifin, 2.10 top right photo), it was determined that the fins were potentially compatible. Using an imperial hex key 0.05", the fin was easily replaced. After 'wiggle on' for 15 minutes without errors, we concluded the digifin was working properly. If the rudder was at its widest angle when the command 'wiggle off' was given, it would not come back to the mid-point. After moving to the mid-point after a 'ballast' command, MARS reassured us that was okay. During functional checkouts, right before the second deployment we noticed Churchill's digifin was showing some degree of asymmetry at the widest angle the rudder would go. It was capable of going around 30 degrees when turning the rudder to the left side and only 25 degrees when turning the rudder to the right.

The nose recovery system was activated for Churchill's recovery and needed replacing. Following instructions provided by MARS and with support from NMF techs Nick Rundle and Tom Roberts, nose recovery system was reassembled and the glider was ready to be redeployed.

2.2.6 Future deployment recommendations

Churchill's second deployment went a lot smoother. Using the P-frame (starboard gantry) seemed to work a lot better as the anti-pendulum roller provides more control and prevents the glider from
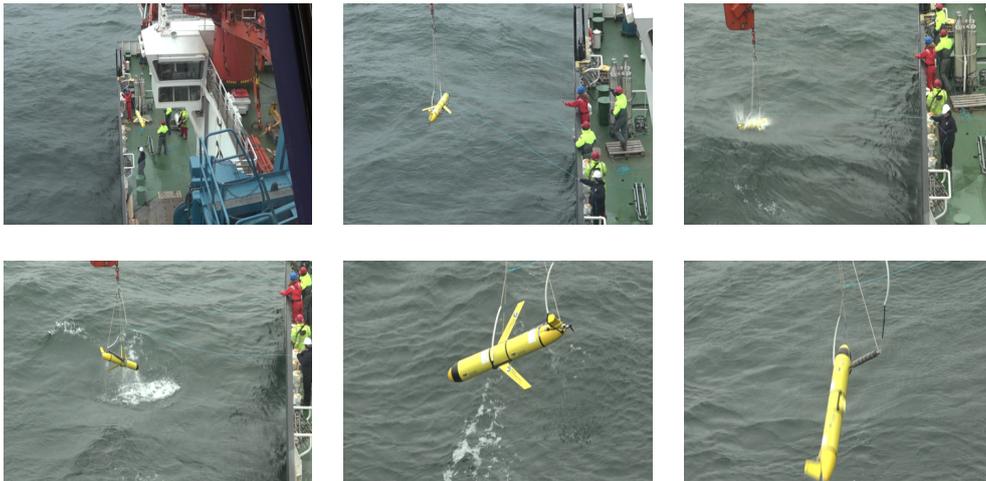
Figure 2.9: Sequence of snapshots from a video during Churchill's first deployment.

Figure 2.10: (top left) Churchill and Boomer on the bench before refitting. (top right) detail on the small crease found on newer models of G2 digifins that makes them interchangeable. (bottom left and centre) before and after refitting rudder on Churchill. (bottom right) nose recovering system reinstalled.
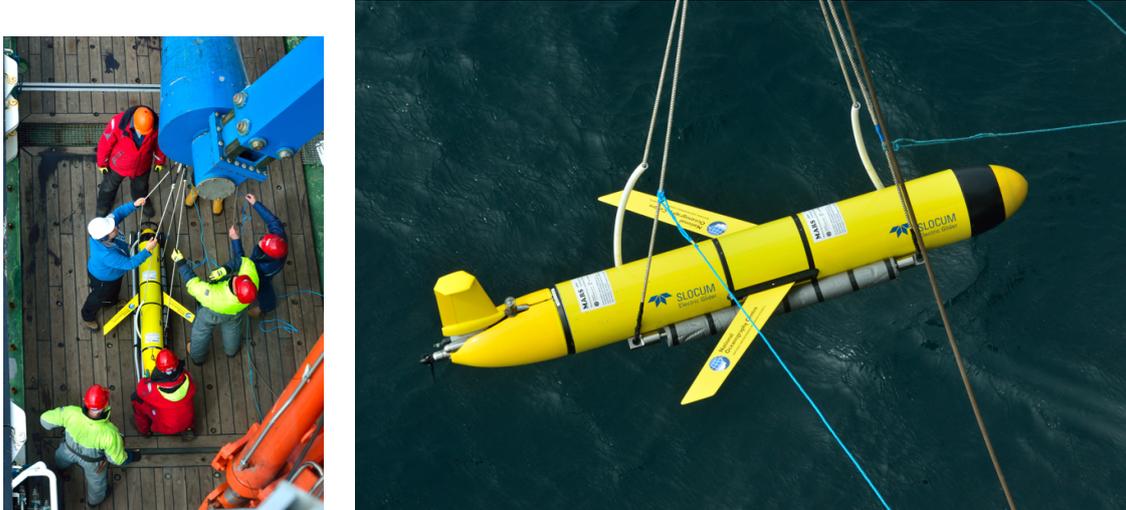
Figure 2.11: Churchill's redeployment. The P-frame (starboard gantry) was used for more control during descent (photo credit: Rob Ovenden).

moving sideways. Also, its location in the middle of the ship provides a more stable environment for deployment. Using 2 tag lines helps the deployment greatly by stabilizing the glider and preventing spinning. The final (and decisive) advice is that once the glider hits the water, commit to it and pull the sea catch (as fast and for as many times as necessary) until the mechanism activates and the glider is released.

We also recommend that a full spares kit be sent with each glider deployment. We were only able to repair Churchill, and thus save the GOCART mission, by pure chance i.e. that a compatible Slocum glider had been recovered on a previous cruise and left onboard for DY086.

2.2.7 Calibration casts

Calibration casts were conducted at deployment and during the cruise in coordination with the MARS piloting team. For mid-cruise calibrations, gliders were tasked to station keep at the same vertex a few hours before the cast, initially performing shallow dives. When the ship's CTD was ready to be deployed, glider was sent on a deep (1000 m) dive. Bottles were fired at several depths throughout the water column and water samples were collected for oxygen, total chlorophyll concentration, POC and DIC.

2.2.8 Problems Encountered

Churchill's air bladder

On two occasions prior to deployment while Churchill was in the hanger and while on the bench, Churchill's air bladder was found inflated. The first time was the day of the first deployment. While we were removing the oxygen optode cap, the cowling needed to be removed. We were incapable of doing so until we turn the glider on and commanded 'ballast'. The second time happened after the deployment when the glider was put on the bench to refit the digifin. On both occasions, the glider was properly turned off. MARS and Teledyne suspected the battery harness, but after a quick 30-minute test, that hypothesis was abandoned. Churchill was kept on the bench for over a week, within freewave range and a terminal window connected to it to evaluate whether a short circuit was somehow turning the glider on. After a week on the bench and a couple of days outside in the hangar (to test the effect of cold temperatures), the air bladder remained deflated. After consideration from home base, the go ahead was given to redeploy Churchill.

Table 2.4: Detail of the calibration casts between the Slocum gliders and the ship's CTD

	Calibration 1	Calibration 2	Calibration 3	Calibration 4
Date	2017-11-15	2017-11-21	2017-11-29	2017-12-12
Time	16:45 GMT	14:00 GMT	07:00 GMT	04:07 GMT
Latitude	52 42.5' S	52 42.09' S	52 42.6' S	52 42.1' S
Longitude	40 06.3' W	∘ 08.39' W	40∘ 04.6' W	40 15.3' W
Event number	014	108	164	319
CTD cast	CDT002	CTD010	CTD016	CTD031
Gliders involved	Pancake	Pancake	Pancake and Churchill	Pancake and Churchill
Notes	Pancake's deployment cast	-	Churchill's deployment cast	

Churchill's conductivity data

On December 4th and after almost a week of providing good data, Churchill started reporting bad conductivity. The resulting salinity is ∼12 psu, but the offset is not constant with depth. The reasons are still unknown. A set of very steep shallow dives were conducted to try to release something that may have got stuck in the conductivity cell (potentially a jelly fish since they have been abundant catches in the zooplankton nets), unsuccessfully. For this short test, autoballast was set to off, maximum buoyancy, angle of 34 degrees, 100 m depth and 3 yos.

Damage sustained during first deployment/recovery (and not spotted prior to second deployment) is still possible, although after reviewing the existing footage, it seems like the glider's port side was not compromised. No thorough visual inspection was conducted prior to 2nd deployment. Although the option existed to recover Churchill and re-deploy again during DY086, we decided that the risk was greater than the reward as salinity isn't our primary data stream, the glider itself hasn't been compromised and we can still use Pancake's CTD data.

Communication (Iridium) issues

Starting on December 8th, Churchill started having issues holding its iridium calls long enough to transmit data. A storm was present at the gliders' location at the time (Discovery had to go and hide behind South Georgia for a couple of days), so we attributed the missed calls to the choppiness of the water due to the storm. Pancake showed a brief struggle at some times, but overall was not much affected by the storm.

Communications issues have since been intermittent.

2.2.9 Seaglider recovery

Seaglider SG-542 was recovered successfully on 2nd of December after 44 days at sea, 450 profiles collected and 750.08 km flown.

Recovery was coordinated with the South African team who tasked the glider to carry out shallow dives a few hours before the ship arrived on location. When the ship was a mile out of the last known position, the glider was set to recovery mode. Glider was easily spotted from the bridge and recovery efforts began shortly.

An improvised pole with a hoop and inside out cable ties securing the rope onto the hoop was used to pick up the glider from the water (constructed by NMF tech Owain Shepherd). Once on deck, glider was rinsed with freshwater, wings were removed, sensor caps were put on and the glider was set to travel mode as per instructions supplied by the SOCCO team. ZOC software was used to talk to the glider. Settings used - connection type: serial/direct; Emulation VT100; baud
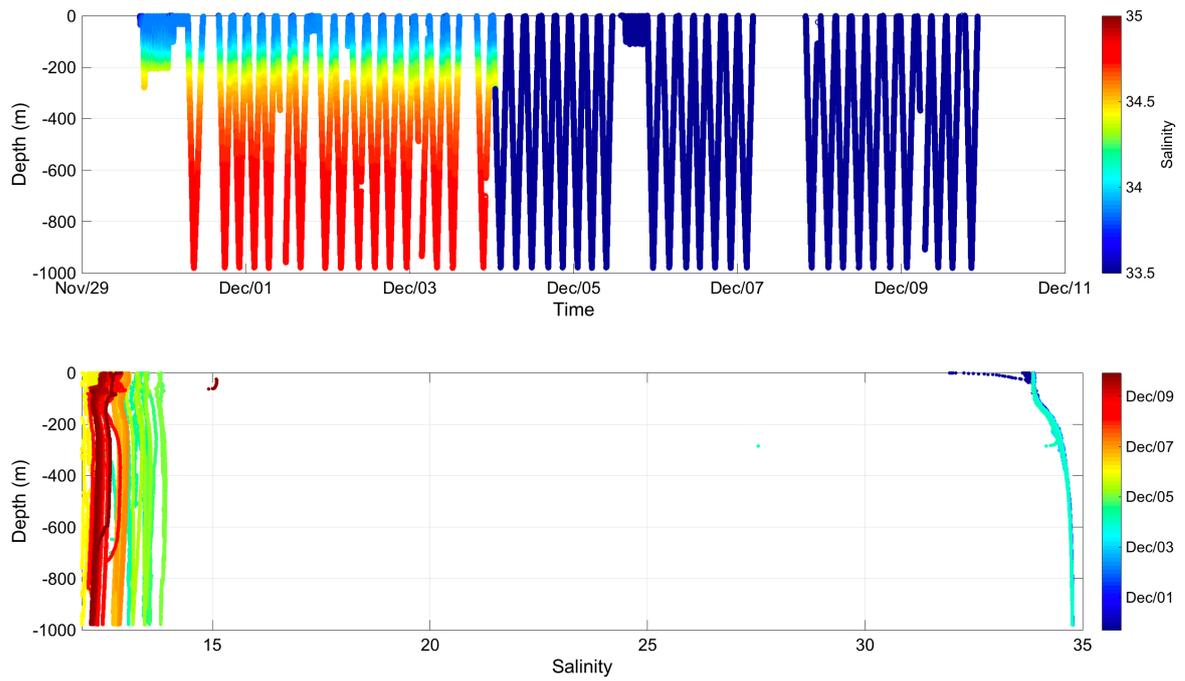
Figure 2.12: Scatter plots showing conductivity issues affecting salinity. (top) glider cross-section with salinity in colour. (bottom) individual glider profiles coloured by time

rate: 9600; 8N1; RTS signal on; DTR signal on.

Glider was then put in its crate, the cradle was dismantled and put inside as well.

Figure 2.13: Snapshots from the Seaglider recovery, showing the detail of the improvised hoop to recover the glider.

2.3   Argo floats

Six Argo Floats were deployed on COMICS as a contribution to the Orchestra project with samples being taken for calibration purposes to be analysed by the University of Exeter as part of the SONATA project funded by ROSES. The characteristics of each float is summarised in Table 2.5.

Table 2.5: Characteristics of floats deployed during DY086

Webb Serial #	Depth dB	Sensor Type	SBE Sensor Serial #	pH Sensor Serial#	Optode #	Antenna #
8138	2000	SBE41CP(PH) - AJ100	9423	0190	2654	10373
8139	2000	SBE41CP(PH) - AJ100	9424	0189	2678	10374
8140	2000	SBE41CP(PH) - AJ100	9426	0199	2681	10376
8141	2000	SBE41CP(PH) - AJ100	9427	0200	2683	10377
8142	2000	SBE41CP(PH) - AJ100	9422	0203	2688	10378
8143	2000	SBE41CP(PH) - AJ100	9425	0184	2723	10379

2.3.1   Calibration samples

Approximately 275 DIC samples were taken on to support the calibration of the float sensors in the early part of their lifetime during which a drifty in pH data is expected.

Table 2.6: DIC samples collected from CTD profiles

CTD Cast	Date	Time	Lat	Long	Event			
002	15 Nov	16.45	52 42.5	40 06.3	14			
Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth
1	305	2010	9	304	504	17	314	76
2	298	2011	10	306	504	18	315	51
3	299	1760	11	307	355	19	316	41
4	300	1507	12	308	255	20	317	31
5	301	1257	13	310	202	21	341	22
6	301	1006	14	311	152	22	319	16
7	302	1005	15	312	127	23	320	11
8	303	753	16	313	102	24	321	6

CTD Cast	Date	Time	Lat	Long	Event			
003	16 Nov	04.56	52 41.4	40 07.5	26			
Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth
1	250	1000	6	254	250	16	258	60
2	251	750	8	255	160	19	259	40
3	252	500	11	256	110	21	260	20
5	253	350	13	257	70	23	261	6

CTD Cast	Date	Time	Lat	Long	Event			
05	17 Nov	05:12	52 43.5	40 09.2	42			
Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth
1	621	2000	11	640	500	19	631	70
3	622	1750	12	641	350	20	626	60
4	624	1500	14	633	250	22	637	40

| 6 | 620 | 1250 | 15 | 623 | 160 | 23 | 639 | 60 |
| 7 | 635 | 1000 | 17 | 625 | 110 | 24 | 629 | 6 |

CTD Cast	Date	Time	Lat	Long	Event			
06	18 Nov	04:36	52 41.9	40 10.2	63			
Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth
1	330	1000	8	335	160	21	340	20
2	334	750	11	339	110	23	344	6
3	338	500	14	332	70	24	333	6
5	342	350	16	343	60			
7	331	250	19	336	40			

CTD Cast	Date	Time	Lat	Long	Event			
9	21 Nov	05:20	52 43.9	40 13.1	101			
Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth
1	267	1000	6	266	250	16	522	70
2	264	750	8	529	170	19	273	45
3	270	500	11	272	120	21	516	20
5	265	350	14	527	80	23	518	6

CTD Cast	Date	Time	Lat	Long	Event			
10	21 Nov	14:00	52 42.09	40 08.39	108			
Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth
2	521	502	11	525	128	21	546	17
4	532	356	14	526	78	23	520	13
6	528	254	16	530	52	24	519	6
8	524	203	18	514	31			
10	515	152	20	533	21			

CTD Cast	Date	Time	Lat	Long	Event			
11	23 Nov	04:55	53 58.1	41 2.2	118			
Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth
1	799	1000	9	783	300	17	788	75
3	795	750	11	789	200	19	787	50
5	805	500	14	801	150	21	800	20
8	790	400	15	802	100	23	796	10

CTD Cast	Date	Time	Lat	Long	Event			
12	24 Nov	04:00	56 24.0	41 13.0	122			
Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth
1	785		6	798		16	782	
2	784		8	797		19	794	
3	791		11	804		21	793	
5	792		13	803		23	786	

CTD Cast	Date	Time	Lat	Long	Event			
16	30 Nov	07:00	52 42.6	40 04.6	164			

Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth
1	806	1005	3	822	503	16	818	60
1	815	1005	5	808	354	19	810	38
2	820	752	6	817	252	21	811	20
2	816	752	11	819	111	23	812	6
3	809	503	13	807	71			

CTD Cast	Date	Time	Lat	Long	Event			
20	2/12	21:14	52 41.738	40 15.146				
Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth
1	453	1000	11	447	150	19	457	30
3	454	500	13	450	125	21	455	15
5	451	350	15	445	100	23	449	10
7	456	250	16	461	75			
9	460	200	17	459	50			

CTD Cast	Date	Time	Lat	Long	Event			
21	5 Dec	05.48	52 46.2	40 03.1	218			
Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth
1	483	1007	6	468	253	16	475	52
2	486	755	8	466	162	19	488	42
3	476	504	10	479	112	21	485	22
5	471	355	13	470	72	23	467	7

CTD Cast	Date	Time	Lat	Long	Event			
22	4/12	08:03	52 41.25	40 20.642				
Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth
2	489	3521	12	472	254	20	458	83
5	605	2012	14	448	205	21	442	63
8	609	755	15	610	163	22	452	65
11	612	456	16	599	127	24	443	6

CTD Cast	Date	Time	Lat	Long	Event			
23	5 Dec	5.04	52 43.254	40 19.556				
Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth
1	703	1005	6	706	251	16	712	50
2	701	753	8	714	161	19	708	25
3	702	503	11	709	111	21	703	15
5	700	353	13	704	71	23	707	6

CTD Cast	Date	Time	Lat	Long	Event			
027	10/12	05:10	52 41.707	40 19.418				
Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth
1	710	1004	5	695	353	21	20	697
2	711	752	10	696	165	24	5	699
3	713	503	16	698	60			

CTD Cast	Date	Time	Lat	Long	Event			
031	12/12	04:08	52 42.131	40 15.238				
Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth
1	393	1003	6	411	252	16	59	650
2	399	752	9	813	160	19	40	406
3	410	502	12	660	110	21	19	649
5	414	350	13	403	70			

CTD Cast	Date	Time	Lat	Long	Event			
033	15/12	07.19	52 42.108	39 56.98				
Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth
1	3733	3700	10	2008	2000	18	253	250
3	3520	3500	12	1508	1500	20	152	150
5	3016	3000	14	1005	1000	22	51	51
7	2512	2500	16	503	500	24	7	6

CTD Cast	Date	Time	Lat	Long	Event			
033	15/12	07.19	52 42.108	39 56.98				
Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth	Niskin	DIC Bottle	Depth
1	NOC1	3700	10	NOC5	2000	17	NOC8	253
3	NOC2	3500	12	NOC6	1500	20	NOC9	150
5	NOC3	3000	14	NOC7	1000	22	NOC10	51
7	NOC4	2500	15	NOC13	503	24	NOC11	6

Table 2.7: DIC samples collected from the underway sampling system

Sample Number	Date	Time	Lat	Long	DIC bottle
1	13/11	15.27	51 58.9424	52 25.0425	321
2	13/11	19.11	52 03.01074	51 13.21734	201
3	13/11	23.08	52 7.43052	50 0.39132	323
4	14/11	03.02	52 11.62434	48 47.77548	325
5	318	07:02	52 16.201	47 29.523	326
6	318	11.47	52 22.36	45 49.42	327
7	14/11	15.12	52 26.04396	44 40.31994	328
8	15/11	07:00	52 36.72	41 29.25	329
9	19/11	07.22	52 34.87	39 58.1	337
10	19/11	09:00	52 44.6	39 58.1	630
11	19/11	10.38	52 53.85	39 58.08	643
12	19/11	12.38	52 53.37	40 12.53	642
13	19/11	14.45	52 43.6558	40 14.6152	632
14	19/11	17.27	52 34.0323	40 14.9204	634
15	19/11	22.24	52 34.5417	40 31.04244	262
16	20/11	00.17	52 44.3196	40 31.0962	271
17	20/11	01.56	52 54.25484	41 31.06914	269
18	24/11	09.48	56 24.09	41 12.99	444
19	24/11	13.05	56 23.99	41 25.89	446
20	24/11	16.32	56 19.989	41 47.409	572

Sample Number	Date	Time	Lat	Long	DIC bottle
21	24/11	19.13	56 13.89	41 30.17	574
22	24/11	21.39	56 14.040	40 53.759	573
23	25/11	00.55	56 38.770	40 50.187	576
24	02/12	06.28	52 28.48458	40 28.93074	469
25	02/12	07.27	52 28.49310	40 13.31238	473
26	02/12	08:18	52 28.54020	40 0.37394	474
27	02/12	09.31	52 38.55	40 01.187	480
28	03/12	12:22	52 48.478	40 0.2143	596
29	03/12	13.24	52 48.576	10 10.78	603
30	03/12	14.24	52 48.4978	40 20.940	604
31	03/12	15.26	52 48.486	40 31.786	611
32	03/12	16.26	52 41.77158	40 33.06692	618
33	03/12	17.27	52 38.4978	40 24.923	617
34	03/12	18.25	52 38.500	40 11.566	597
35	03/12	19.28	52 36.93	40 0.241	619
36	04/12	00.00	52 31.0	40 17.48	606
37	04/12	01.00	52 33.74	40 25.21	614
38	04/12	02.00	52 38.602	40 19.36	615
39	04/12	03.00	52 38.6	40 3.95	616
40	04/12	04.01	52 44.517	40 0.2211	598
41	04/12	05.00	52 46.198	40 9.04	602
42	04/12	06.03	52 46.199	40 20.376	608
43	12/12	22.46	52 31.815	39 58.620	416
44	12/12	23.58	52 30.947	40 6.683	285
45	13/12	00.57	52 30 .942	40 14.687	291
46	14/12	02.09	52 30.875	40 24.028	292
47	14/12	20.48	52 39.127	40 16.2	824
48	14/12	21.31	52 34.64	40 9.367	279
49	14/12	22.22	52 28.88	40 1.5	402
50	14/12	23.10	52 34.01	39 51.17	407
51	15/12	00.03	52 39.81	39 48.4	656
52	15/12	00.57	52 45.39	39 48.63	286
53	15/12	02:21	52 38.61	40 1.89	415
54	15/12	03:13	52 34.99	40 8.78	823
55	15/12	04.05	52 40.67	39 57.82	352
56	15/12	04.49	52 45.51	39 48.46	348

2.4 Scientific ship systems (NMF)

Martin Bridger*

*(National Oceanography Centre)

2.4.1 Overview

Cruise	Departure	Arrival	Technicians
DY086	10/11/17 FKPSY	21/12/17 FKPSY	Martin Bridger

Scientific Ship Systems (SSS) is responsible for managing the ship's network infrastructure, data acquisition, compilation and delivery, the email system and a range of ship-fitted instruments and sensors. Unless stated otherwise, all times in this report are UTC.

2.4.2 Scientific computer systems

Cruise disk location: '*DY086\Cruise_Documentatio\Data_Description_Documents*'

Acquisition

Network drives were setup on the on-board file server; firstly a read-only drive of the ships instruments data and a second scratch drive for the scientific party. Both were combined at the end of the cruise and copied to disks for the PSO and BODC. Data was logged by the Techsas 5.11 data acquisition system. The system creates NetCDF and ASCII output data files. The format of the data files is given per instrument in the "Data Description" directory.

The ship-fitted instruments that were logged are listed in the below file (includes BODC/Level-C notes):

'*DY086_BODC_ship_fitted_information_sheet_DY.docx*'

Cruise disk location: '*DY086\Cruise_Documentation*'

Data was additionally logged into the legacy RVS Level-C format.

Main acquisition period

Techsas logging for 'DY086' commenced whilst alongside in FKPSY (Falklands) on 09/11/17. Legacy 'Level-C' logging started on 16/11/2017 (J320). All logging was concluded 19/12/2017 (J353) at arrival in FKPSY.

Events/data losses

No data loss occurred.

Internet provision

Satellite communications were provided with both the Vsat and FBB systems. The Vsat had been upgraded to around 2048 kbps down and 1024 kbps up unlimited data (and provides 3 on board phone lines to cabins/work areas) and the FBB initially had a maximum un-guaranteed speed of 256 kbps with a 20 GB monthly plan.

Email provision

Email communications were provided via the AMS system (approx. 27 users), whitelisting institute webmail pages and with individuals IMAP clients.

2.4.3 Instrumentation

Position and attitude

GPS and attitude measurement systems were run throughout the cruise.

- The **Applanix POSMV** 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 available to be sent to all systems and is repeated around the vessel. The position fixes attitude and gyro data are logged to the Techsas system. This was also the navigation source for the EK60, indicated by the TalkerID 'GP'.
- The **Kongsberg Seapath 300** system is the vessel's secondary GPS system. It provides an input to the gravity meter due to the POSMV not having vessel course available in its RMC NMEA message. Position fixes and attitude data are logged to the Techsas system.
- The **CNav 3050 GPS** system is a differential correction service. It provides the Applanix POSMV system with RTCM DGPS corrections (greater than 1 m accuracy). The position fixes data are logged to the Techsas system.
- The **Fugro Seastar 9205 GPS** system is a differential correction service. It provides the Seapath system with RTCM DGPS corrections and is also logged to the Techsas system.

Meteorology and sea surface monitoring package

The NMF Surfmet system was run throughout the cruise, excepting times for cleaning, entering and leaving port and whilst alongside. Please see the separate information sheet for details of the sensors used and whether calibrations values have been applied:

'*DY084_Surfmet_sensor_calibrations.docx*'

Cruise disk location: ***DY086\Ship_Fitted_Scientific_Systems\Surfmet***

Instrument calibration sheets are also included in the directory.

Underway TSG sampling

Samples from the ships underway system were collected throughout the cruise by the scientific party. Salinity was also logged from the underway Seabird 45 sensor at the time the bottle sample was taken.

Nutrients sensor

A nutrients sensor (Alison Schaap, NOC) was installed in the underway sampling lab prior to departure from GBSOU and was monitored to ensure there was satisfactory flow in/out of the instrument during the cruise duration. Power was removed when the underway was switched off – primarily during the Azores port call and during sensor cleaning events. This system will continue to be used on the subsequent DY086 cruise.

Kongsberg EA640 10 & 12 kHz Single-beam

The EA640 single-beam echo-sounder was run throughout the cruise on the K-Sync synchronisation unit (as master) with a ping interval of around 8 seconds. Both the 10 and 12 kHz transducers were used. The system used a constant sound velocity of 1500 m s^{-1} throughout the water column to allow it to be corrected for sound velocity in post processing if required. Salinity (35 PSU) and Temperature (10°C) and Conditions (salt water) were also left at their initial constant values for the cruise duration. Kongsberg *.raw files (100 MB maximum file size) and *.xyz files are logged and depths were logged to Techsas and Level-C.

ADCP OS 75 kHz & 150 kHz

75 kHz and 150 kHz ADCPs were set up in GBSOU with Stephanie Henson using standard NMF configuration files. The data alongside was verified by the scientists prior to departure with the requirement to keep ADCP resolution at ≤ 4 seconds during the cruise and to switch from bottom-tracking configuration as soon as the depth permits (e.g beyond approx. 800 m).

Below shows the events for the ADCPs, including when the bottom tracking (BT) was on and off. A ping rate of 2 and 3 seconds was maintained for most of the cruise for the 150 kHz and 75 kHz respectively:

Date	Time	Event	Notes
13/11/2017	11:36	Switched off BT for 75 & 150	Leaving Falklands Plateau
18/12/2017	13:00	Changed to bottom tracking	Approaching Falklands

Cruise disk location: *'DY086\Ship_Fitted_Scientific_Systems\Acoustics\OS75kHz\'* and *'..\OS150kHz'*

EK60

The EK60 was run for the duration of the cruise (it was calibrated during a planned visit to South Georgia). Prior to the cruise the transducer settings in the software were verified against the manufacturers (SIMRAD) transducer measurements sheets.

The system is mounted on the drop keel. This remained flush (to the vessel baseline) for the duration of the cruise, and so a depth of 6.60 m was applied to the system for all transducers. This value is the depth of the transducer face relative to the water surface (ref. 164692/D Simrad EK60 Manual). Figure 2.14 shows the depth and power levels that were used for the cruise.

Cruise disk location: *'DY086\Ship_Fitted_Scientific_Systems\Acoustics\EK60'*
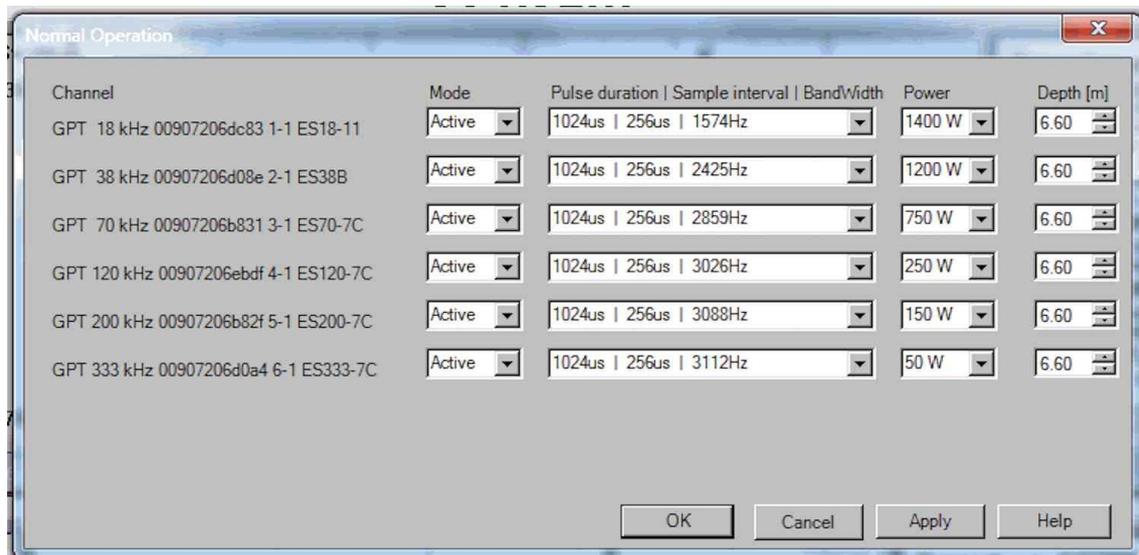
Figure 2.14: Depth and power levels of EK60

CTD2Met

Following on from DY084/5, the 'CTD2MET' program system to automatically send low resolution CTD cast data to the Met Office in 'near-real time' was used. The data is automatically ingested into

global ocean forecast models and feedback was received from the Met Office confirming the positive impact of the new data. Details of this activity can be found in *'DY084-Report-CTD2MET.pdf'* located in the 'Cruise Documentation' directory. Permission to use this during DY086 was also obtained prior to its continuation.

AirSeall gravity meter

Gravity meter (S-084) was tied in at GBSOU prior to the beginning of the cruise. The instrument was operational during the cruise - running directly from the vessel's 110VAC supply available in the Gravity room. There is no UPS backup as this had failed before the cruise commenced. This data is not included in DY086 cruise archive.

Wamos wave radar

The Wamos wave radar was run during the cruise but the system is currently not calibrated and appears to under-read Significant wave height (Hs) when compared to bridge observations. Summary data files (including Hs and significant wave period, Ts) were transferred to the cruise data disk. On 26/11/17, the wave radar failed with hardware failure, so was switched off for the rest of the cruise.

Cruise disk location: *'DY086\Ship_Fitted_Scientific_Systems\Met\Wamos\'*

2.5 BODC ship-fitted systems

Martin Bridger*

*(National Oceanography Centre)

2.5.1 Overview

The logging status of ship-fitted instrumentation and suites are listed in table 2.8.

Table 2.8: Ship-fitted instrumentation and suites during DY086

Manufacturer	Model	Function/data types	Logged?	Comments
Meinberg	M300	GPS network time server (NTP)	N	Not logged but feeds times to other systems
Applanix	POS MV320 V5	DGPS and attitude	Y	Secondary DGPS
C-Nav	3050	DGPS and DGNSS	Y	Primary DGPS
Kongsberg Seatex	Seapath 330	DGPS and attitude	Y	No attitude logged, only position
iXSea	PHINSIII	Inertial Navigation System	N	
Sonardyne	Fusion USBL	USBL	N	
Sperry Marine		Ship gyrocompasses x 3	Y	
Kongsberg Maritime	Simrad EA640	Single beam echo sounder (hull)	Y	
Kongsberg Maritime	Simrad EM122	Multibeam echo sounder (deep)	N	
Kongsberg Maritime	Simrad EM710	Multibeam echo sounder (shallow)	N	2-3 days only (30/10-1/11)
Kongsberg Maritime	Simrad SBP120	Sub bottom profiler	N	
Kongsberg Maritime	Simrad EK60	Scientific echo sounder (fisheries)	Y	
NMFSS	CLAM	CLAM system winch log	Y	
NMFSS	Surfmet	Meteorology suite	Y	
NMFSS	Surfmet	Surface hydrography suite	Y	
		Skipper log (ship's velocity)	Y	
OceanWaveS GmbH	WaMoS II	Wave Radar	N	Summary Data only
Teledyne RD Instruments	Ocean Observer 75 kHz	VM-ADCP	Y	
Teledyne RD Instruments	Ocean Observer 150 kHz	VM-ADCP	Y	
Microg Lacoste	Air-Sea System II	Gravity	Y	DY084 continuation

2.5.2 Bestnav hierarchical ordering

The order of navigational systems in the bestnav process for positional fix were as follows. Units of dist_run: nautical miles.

Rank	Order of positional fixes	Comment
1	Seapath 330	spathpos
2	PosMV V5	posmvpos
3	Cnav 3050	gps_cnav

2.5.3 Relmov source

The navigational systems that are used in the relmov process for ship's motion were as follows.

Navigational source	Comment
Gyro	gyro_s
LOG	log_dysk

2.5.4 RVS data processing

The RVS Level-C processing programs that were run were as follows. **Please state if sound velocity probes used for depth correction instead of *prodep*.

Programme	Was it run?	Comment
bestnav	Y	
prodep**	N	SVP obtained from CTD casts
protsg	N	
relmov	Y	
satnav	N	
windcalc	N	

2.6 Lab equipment, containers and winches

Owen Shepherd*
*(Ocean Engineering Group, National Oceanography Centre)

2.6.1 Lab equipment
Liquid scintillation analyser

System U/S for duration of cruise DY086 due to comms issue.

Liquid nitrogen generator (orange frame)

Not used on cruise DY086 due to sufficient production from other LN2 generator (Blue Frame) to meet science requirements.

Liquid nitrogen generator (blue frame)

Normal system operation experienced throughout cruise DY086.

Scotsman icemaker

System situated in Deck Laboratory was brought on-line at the request of science party. Ice produced was only used for scientific purposes and a warning sign was posted stating that ice was unfit for human consumption. If in future this system is to be a regular expedition requirement it would be beneficial to have a dedicated potable water supply and a drain line for system. The current installation of system utilising one of the laboratory sinks for potable water supply and drain is impractical and hinders use of sink.

Milli-Q Integral 15 Systems

Normal system operation experienced throughout cruise DY086. Consumables used were recorded and equipment custodian notified via e-mail.

Scientific sample freezers

Normal system operation experienced throughout cruise DY086.

Fume cupboards

Normal system operation experienced throughout cruise DY086.

2.6.2 Containers
RN laboratory container

Normal system operation experienced throughout cruise DY086.

Laboratory container

Normal system operation experienced throughout cruise DY086.

2.6.3 Winches
Lebus umbilical lift winch system (metal-free)

Sporadic inexplicable stopping of the winch system has been experienced throughout cruise DY086 when control system is in auto. There has been no correlation observed between winch stoppages and haul or veer speeds, cable length paid out, or time system has been in operation. Returning auto potentiometer to the stop position and then back to desired haul or veer speed has been the solution utilised to get winch system operating again and CTD operations resumed. This is clearly a controls issue that will require further investigation if control issues are to be identified and interrogated. In order to achieve this it will be necessary to conduct suitably designed winch trials serials. Previous trials have not recorded suitable or sufficient operational data to even begin to diagnose causes of sporadic winch system controls failure.

Observations:

- Controls system is of a basic design and utilises an unsuitable +18 V, +12 V, +6 V control signal in order to haul, stop and veer.
- Impedance of 50 m control cable is likely to be affecting transmission of control voltages to Faber pump regulator.
- Induced voltages within control cable through insufficient shielding may be having an adverse effect on control signal received by the Faber pump regulator.
- Current control system cannot be integrated into ship fitted CLAM system without significant redesign to a digital controller system.
- CCTV cables are unsuitable for harsh weather environment.
- Sauer Danfoss Series 90 axial piston pump proportional solenoid valve may be receiving occasional spurious signals from the Faber pump regulator, possibly due to control cable impedance or excessive temperatures.
- It would be beneficial to ascertain as to whether the Faber pump regulator is suitable as a control signal generator for the Sauer Danfoss Series 90 axial piston pump proportional solenoid valve.
- Line tension indication has been factory calibrated to display the correct tension on the mid layers. Therefore the tension variation across all layers is +/- 20% from the mid layer. Additional error is due to fleeting angle to first sheave on parallelogram frame. This was never taken into consideration in the winch system manufacturing specification; consequently a direct pull approach was adopted by winch system manufacturer.
- If existing winch control system is to remain in operation it would be beneficial to route all wiring internally through the ship. This will significantly lengthen service life of control cables and reduce chance of sustaining damage.
- Existing auto potentiometer is not defective. Simple resistance measurements using a Fluke multi-meter have proven that this is not the cause of sporadic winch stoppages as had been previously suggested during winch trials.
- Wireless E-stop was not utilised due to issues of signal loss when being carried by operator on the STBD working deck. System is designed so that in the event of signal loss system treats situation as an E-stop operation. It was deemed a potential safety issue should this occur when CTD is being launched or recovered. Wireless E-stop was therefore left connected to charger in winch container and no further issues occurred.
- Scanreco remote control box suffered from intermittent signal loss due to receiver unit being hidden by ship's structure as well as it being fitted within winch container. Operation on STBD side was achieved by operator standing in a set spot on deck and not moving from there.
- Load cell and speed indication cable is unsuitable for harsh weather environment, routed over the deck on the hangar top it is only a matter of time before it degrades and or is damaged.
- Micro switch on main power distribution panel cover in winch container caused a brief issue when the mounting bracket to which it was fitted became bent out of shape. This micro switch is unnecessary and not required to be part of a safe E-stop circuit. It is suggested that switch is linked out of circuit on both winch systems in order to prevent reoccurring issues.
- Ship's crew do not feel comfortable using this winch system despite being fully trained to operate it. This is due to poor control from any operating location. Many expressed a concern for safety of those recovering and deploying CTD system.
- Metal-free sheave fitted to Bull-Horn was not free to move to counteract pitch and roll of ship in any sea state. Subsequently cable jumped the sheave on one occasion even though system was being hauled at a very slow rate.

North Sea winch

Normal system operation experienced throughout cruise DY086. Existing paint system in poor state and heavy corrosion evident over much of winch system.

Romica multi-purpose winch

Winch system was utilised on DY086 for the deployment of the Red Camera Frame, Bongo Nets and Snow Catcher System on multiple occasions. System operated without significant issue however it was necessary to manually adjust auto-scrolling periodically. This will be an ongoing issue with this winch system due to there being no 8-mm diameter shells fitted to winch drum and scrolling auto-stops are not fully calibrated for 8-mm diameter wire.

2.7 SurfMet sensors

Martin Bridger*
*(National Oceanography Centre)

2.7.1 Overview

This section lists the details for the meteorological platform (Figure 2.15), fitted sensors (Table 2.9) and non-fitted spare sensors (Table 2.10).

Pumped seawater flow rates (mL min^{-1}): 1,500
Anemometer orientation on bow (deg): 0
Seawater intake depth (m): 5.5
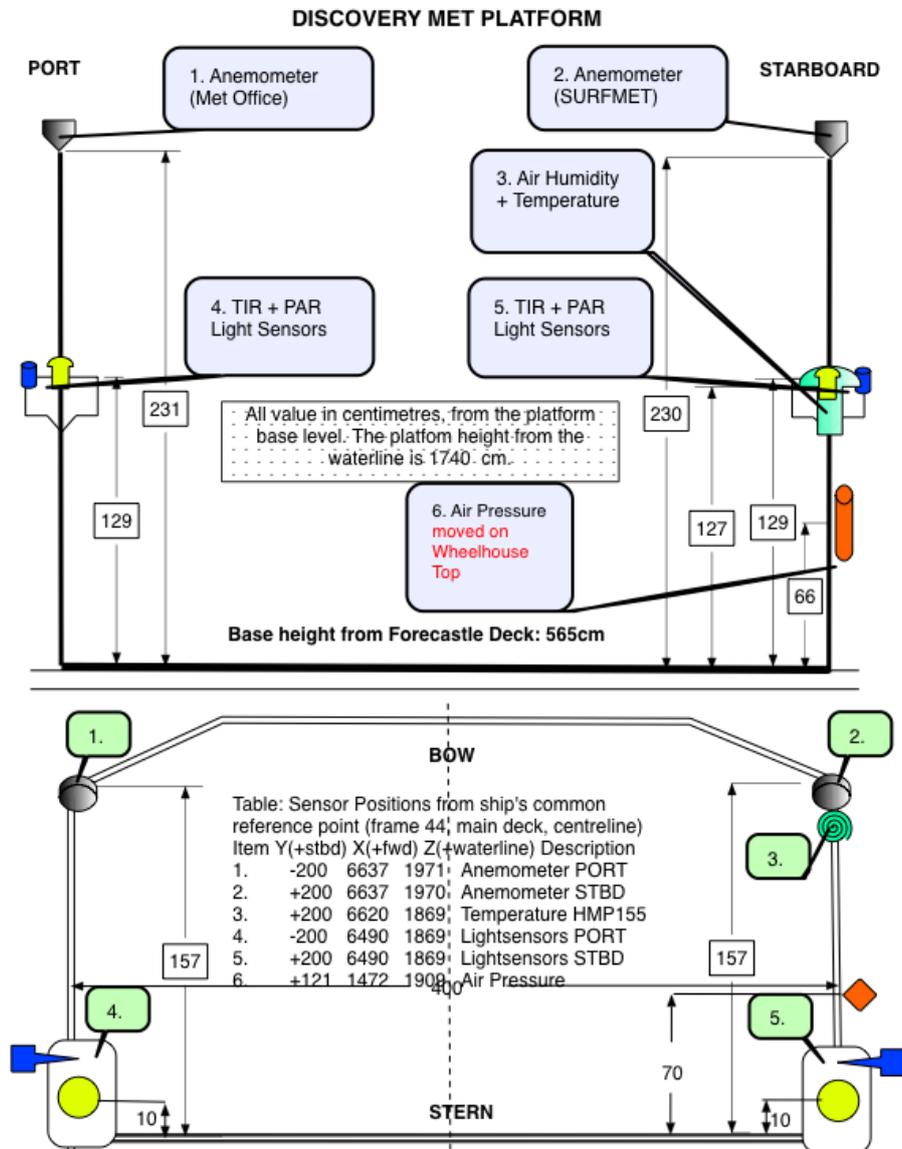
Figure 2.15: Meteorology platform (Foremast)

Table 2.9: Fitted Sensors. Date as DD/MM/YYYY.

Manufacturer	Sensor	Serial No.	Comments	Calibrated?	Last calibration
Surface SV	AML Micro X-Series	11404/206072	Drop keel SV	Yes	18/08/2017
Skye	PAR SKE510	28557	(Starboard)	No	08/08/2017 (2 yr)
Skye	PAR SKE510	38884	(Port)	No	23/11/2016 (2 yr)
Kipp & Zonen	TIR CM6B	962301	(Starboard)	No	29/08/2017 (2 yr)
Kipp & Zonen	TIR CM6B	962276	(Port)	No	29/08/2017 (2 yr)
Gill	Windsonic Option 3	10280018	Starboard #250006705	No	N/A (tested 28/09/2015)
Vaisala	HMP155 Temp./Hum.	K0950056		No	09/03/2017
Vaisala	PTB210C Digital Barometer	N0930256		No	07/03/2017
Wet Labs	WS3S Fluorometer	WS3S-247 until 13:00 04/10/2017	WS3S-248 from 17:35 04/10/2017	No	11/04/2017
Wet Labs	CST Transmissometer	CST-1132PR		No	12/12/2016 (2 yr)
Sea-Bird	SBE38 Temperature	3854115-0490	-	No	07/07/2017
Sea-Bird	SBE45 TSG	4548881-0230	Installed and water-tested 23/09/2017	No	05/01/2017 (valid for 1 yr from 23/09/2017)

Table 2.10: Spare Sensors on-board, not fitted. Date as DD/MM/YYYY.

Manufacturer	Sensor	Serial No.	Comments	Calibrated?	Last calibration
Surface SV	AML Micro X-Series	11405/206138		Yes	18/08/2017
Skye	PAR	28561		No	08/08/2017
Skye	PAR	28562		No	23/11/2016
Kipp & Zonen	TIR	973134		No	14/03/2017
Gill	Windsonic Option 3	71123	#250004845	No	N/A (Tested 09/03/2015)
Vaisala	HMP155 Temp./Hum.	N1211119		No	23/03/2017
Vaisala	HMP155 Temp./Hum.	N1211120		No	23/03/2017
Wet Labs	WS3S Fluorometer	(WS3S-247)	(4-pin connector)	No	(14/04/2017)
Wetlabs	CST Transmissometer			No	(2 yr)
Sea-Bird	SBE38 Temperature	3854115-0491		No	02/08/2017
Sea-Bird	SBE45 TSG	4548881-0229		No	22/11/2016 (2 yr*)
Valeport	MIDAS SVP	41603		Yes	14/06/2017 (2 yr)
Vaisala	PTB110 Air Pres.	M1750058		No	29/04/2016
Vaisala	PTB210C Digital Barometer	N0930257	Unmodified cable	No	07/03/2017

2.8 Vessel-mounted acoustic doppler current profiler

Filipa Carvalho*
*(National Oceanography Centre)

2.8.1 Overview

Two Teledyne RDI vessel-mounted Acoustic Doppler Current Profilers (ADCPs) were operated
on RRS Discovery throughout the DY086 cruise to measure the horizontal velocity field. The two
instruments, a 75 kHz and a 150 kHz Ocean Surveyor VMADCP have different depth ranges and
resolutions. The 150 kHz provides good vertical resolution, but the signal is more rapidly attenuated
and it will only penetrate typically to depths up to 400 m. The 75 kHz instrument does not provide
as good vertical resolution, but it penetrates deeper in the water column, to depths around 800 m.

Transducers are fitted to the hull of the RRS Discovery at a depth of 6.6 m. Beam 3 (Y-axis)
is rotated -45 degrees (anticlockwise) relative to the ships central line, i.e. the mounting angle
of the transducers is -45 degrees. This needs to be taken into account during post-processing to
remove the ships velocity from the data. This is set in the command files run by VMDAS and the
opt_dy086.m cruise options script for post-processing.

2.8.2 VMADCP file types

Files produced have names of the form *OStt_DY086nnn_mmmmmm.ext*, where *tt* is either the 75
kHz instrument or the 150 kHz, *nnn* is the file sequence number, *mmmmmm* is the number of the
segment file within the sequence and ext is the extension. VMDAS automatically increments the
file segment number every time data collection was stopped and restarted.

List of files produced have the following extensions:

- *.ENR files: the binary raw data files (beam coordinates).
- *.ENS files: binary ADCP data after being screened for RSSI and correlation, with navigation
  data included.
- *.ENX files: ADCP single ping and navigation data after having been bin-mapped, trans-
  formed to Earth coordinates and screened for error velocity and false targets.
- *.STA files: binary files of short-term average ADCP data (120 sec, user-specified in VmDas).
- *.LTA files: binary files of long-term average ADCP data (600 sec, user-specified in VmDas).
- *.N1R files: ASCII text files of raw NMEA navigation data from the NMEA1 stream.
- *.NMS files: binary files of navigation data after screening.
- *.VMO files: ASCII text files specifying the option settings used for the data collection.
- *.LOG files: ASCII text files logging all output and error

Raw files were automatically synchronized to the discofs science network (*smb://discofs.discovery.local/DY086/Ship*
where *tt* is 75 or 150) and manually resynced to the vmadcp on Eriu (*/local/users/pstar/dy086/data/vmadcp/dy086_ostt*,
where *tt* is 75 or 150) using *vmadcp_linkscript* (on a terminal window). A rawdata### folder is
then created with all the raw files from each original VMADCP file.

2.8.3 Real-time data acquisition

Data was acquired from the instrument using the RDI VMDAS software, version 1.48, installed in
a computer in the computer room. Software carried out preliminary screening and transformation
of the data, from beam to earth coordinates. A default configuration file was set to facilitate
interchange depth ranges, bottom track to water track and whether the information was synced with
the other acoustic instruments (K-sync unit).

During the cruise, both instruments were managed using the K-sync unit. Data collection
was typically stopped and restarted to generate a new file segment number on a daily basis, thus
facilitating the incremental processing in both instruments.

At the beginning and end of the cruise, in shallow water (broadly <700 m, in and out of Stanley), the instrument was run in bottom track mode to obtain phase (angle) and amplitude calibrations. So the first and last file collected from each instrument are bottom track (file 001). An example of a bottom track file is *OS075_DY086_NB_BT_Sync_20171112T231252_001_000000.**, where *NB* is narrowband and BT is bottom track on. Due to a mix up, water-track files from instrument OS75 start at 026, while on OS150 there is a file 001 that is bottom track and a file 001 that is water track.

DY086 OS75 setup

All command files used with K-sync:
- DY086_OS75_NB_BT_with_sync_16m
  - Used to calibrate the instrument (misalignment angle calculation)
  - narrowband single-ping profile mode (NP), 100 (NN) 8 meter bins (NS), 8 meter blanking distance (NF)
- DY086_OS75_NB_NO_BT_with_sync_16m
  - narrowband single-ping profile mode (NP), 45 (NN) 8 meter bins (NS), 8 meter blanking distance (NF)

DY086 OS150 setup

All command files used with K-sync:
- DY086_OS150_NB_BT_with_sync_8m
  - Used to calibrate the instrument (misalignment angle calculation)
  - narrowband single-ping profile mode (NP), 96 (NN) 8 meter bins (NS), 4 meter blanking distance (NF)
- DY086_OS150_NB_NO_BT_with_sync_8m
  - narrowband single-ping profile mode (NP), 45 (NN) 8 meter bins (NS), 8 meter blanking distance (NF)

Common to all configuration files:
- 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

2.8.4 Data post-processing

Onboard post-processing was done using the old Matlab version of CODAS (Common Ocean Data Access System) suite of software provided by the University of Hawaii. The four main steps that characterizes the CODAS VMADCP processing:
1. Removal of the ship velocity;
2. Correction of the gyro heading with GPS-derived heading;
3. Estimate the heading misalignment from either bottom track (BT) or water-track (WT) data;
4. Manual inspection/editing of bad data.

The data can be loaded into daily and appended Mstar files using mcod_01.m, mcod_02.m and mcod_mapend.m. This data processing is simplified by wrapper script (vmadcp_proc.m and vmadcp.edit). In Matlab,
- run m_setup % to set up the environment for mexec processing
- doall=1;
- vmadcp_proc;

```
ADCP dy086001nbenx step size 1
    Time range 315.98 to 316.08
    Calculation done at 2017-11-25  23:40
     step: 1
     min_depth:  25   max_depth: 1500
     min_speed:  2.0 m/s   max_sig:  2.5 std devs
     max_gap:  0.10 minutes   tol_dt: 0.02 (fraction)
unedited: 30 points
edited:   29 points, 2.0 min speed, 2.5 max dev
               median      mean       std
amplitude    1.0053    1.0052    0.0046
phase        45.2936   45.2224   0.3838
```

Figure 2.16: Example of bottom-track cal file

This will prompt a set of choices (75 or 150 kHz), run quick_adcp.py (1) or apply angle/amplitude corrections (2). Then which dataset? As in the number following the rawdata### folder synced using *vmadcp_linkscript*. In the first run of *vmadcp_proc.m*. I always chose (1) for both datasets.

The calibration values are created in this round of processing. They are located at *dy086NNNnbenx/cal/watertrk/adcp* and *dy086NNNnbenx/cal/botmtrk/btcaluv.out*. An example of a bottom-track cal file is shown in Figure 2.16.

For the second stage of the processing we require calibration files collected during bottom-track mode. The script *opt_dy086.m* script was edited to include the calibration values (mean amplitude and mean phase) for step (2), amplitude/phase correction. Then in Matlab,
- doall=2
- vmadcp_proc

select (2) when prompt to run *quick_adcp.py* or apply corrections.

The third stage involves gautoedit (a GUI function that allows the user to manually review and flag data that are deemed to be bad). The flags are then passed into the next processing stage.

2.8.5 Output files

Once *vmadcp_proc.m* completes without errors, a folder named *dy086NNNnbenx* is created. Inside we can find the calibration files and two netcdf files. The first file is *os75_dy086NNNnnx.nc* that includes the following variables:
- time (in seconds since [2015 1 1 0 0 0])
- lon (0 to 360)
- lat (90 to 90)
- depth (of bin)
- uabs (absolute u velocity in cm/s)
- vabs (absolute v velocity in cm/s)
- uship (u velocity of ship over ground)
- vship (v velocity of ship over ground)
- decday (decimal day of year)

The second file is of the form *os75_ dy086NNNnnx _spd.nc* and includes, (in addition to the above variables):
- speed (scalar water speed, cm/s)
- shipspd (scalar ship speed over ground, m/s).

The individual *os75_ dy086NNNnnx _spd.nc* files are then appended into a single output file for the cruise using mcod_mapend (included in the *vmadcp_proc.m*). This command relies on an
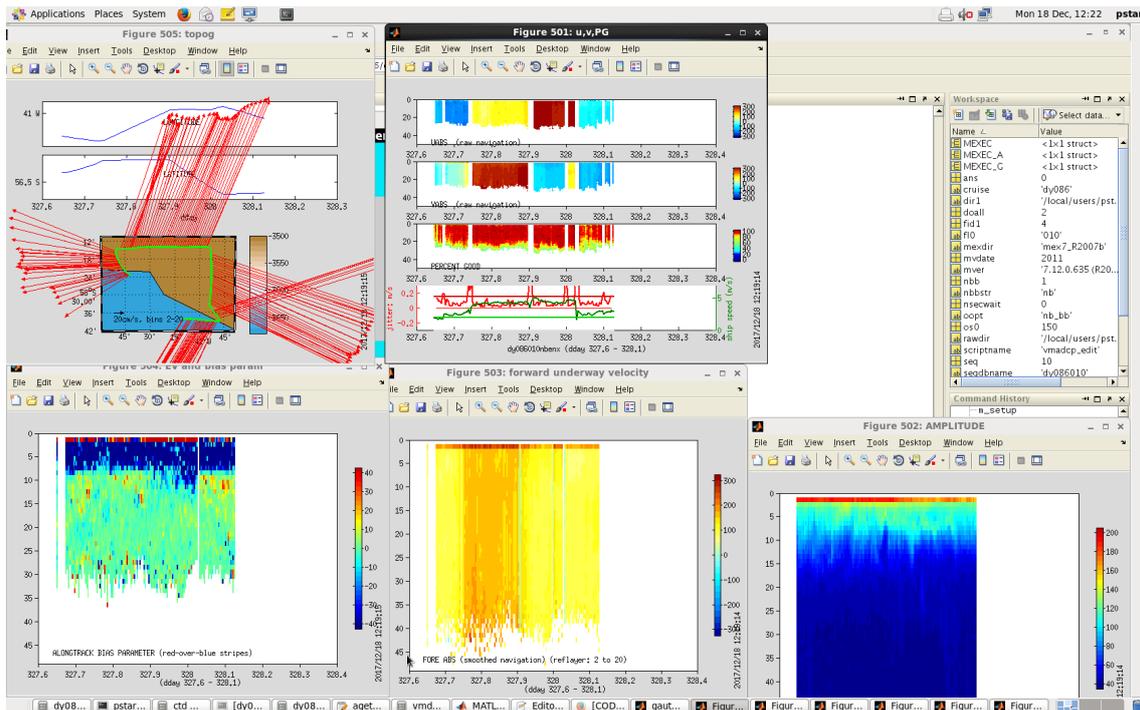
Figure 2.17: Problems when plotting current vectors

input file containing the paths of all the individual files to be merged. The final output file is *os75_dy086_01.nc*.

2.8.6 Problems encountered

I encountered issues when plotting the data created by the first and second run of *vmadcp_proc.m* (file generated is *os75_dy086NNNnnx.nc*) and when using gautoedit. As seen in Figure 2.17 (during an acoustic survey), the current vectors seem to be linked to the heading of the ship. Meaning there is a problem happening somewhere in the first/second run of *vmadcp_proc.m* when heading is taken into account to correct the data. I could not find out where the problem was, but I've gotten in touch with Yvonne Firing and this will be sorted out before the start of COMICS2 so this does not happen again.

Data was backed up and we should be able to reprocess the entire ADCP dataset back at NOC and eventually rerun the mcod_mapend.m to merge all the individual files and underway data into one individual file when we have Eriu back on RRS Discovery for COMICS2.

2.8.7 Acoustic Surveys

Several acoustic surveys (mostly attempts, aborted because of bad weather) integrating several acoustic instruments (see Section 2.9 for more details) were conducted throughout the cruise. Table 2.11 summarises these.

Table 2.11: Details of acoustic surveys

Survey name	Start date/time (GMT)	End date/time (GMT)	Comment
P3_A	19/11/2017 07:12	20/11/2017 02:43	Upwind direction. Survey scale 20nm
Eddy	24/11/2017 10:28	24/11/2017 17:40	Ship hove too – heading towards start of an acoustic survey
Eddy	24/11/2017 17:40	25/11/2017 06:45	Nominal survey of eddy whilst ship in bad weather
Eddy	25/11/2017 22:53	26/11/2017 10:00	Bad weather, survey didn't really start. Ship headed downwind, unable to turn
P3_B	03/12/2017 12:22	03/12/2017 20:12	Survey was 20 nm, cut early to do camera frame, and run at slow speed
P3_B	03/12/2017 22:30	04/12/2017 06:28	Night time survey, resized to 15 nm to allow for slower speed
P3_C	12/12/2017 06:57	12/12/2017 15:10	P3_C day time acoustic survey. Drop out in the upwind transect. Survey scale 15 nm
P3_C	12/12/2017 21:14	13/12/2017 03:00	First line completed, but ship unable to turn – survey abandoned
P3_C	14/12/2017 22:25	15/12/2017 06:20	Night-time attempt 2. Drop-keel up.

2.9 Acoustic measurements (EK60)

Sophie Fielding*
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2.9.1 Overview

The Simrad EK60 hull-mounted multifrequency echosounder was run throughout DY086 to collect information on the horizontal and vertical distribution of zooplankton and micronekton. A particular focus of DY086 is to parameterise diel vertical migration movement, and the mesoscale variability of organisms at the central carbon export stations.

2.9.2 System specification

The Simrad EK60 echosounder operating at 18, 38, 70, 120, 200 and 333 kHz was run using Simrad ER60 v2.4.3 software. The .raw data files were logged and backed up at regular intervals. Raw data were collected to 1500 m at all times, except the calibration. The echosounder operated using a 3 second ping rate (to allow data collection to 1500m) and was coordinated with the ADCP and EA640 system using a KSYNC synchronisation unit.

The EK60 settings were checked according to the manufacturers calibration certificates supplied by NMF, the environmental parameters were set to 2°C and 34.5 PSU, and power, pulse duration and depth settings were as in Table 2.12.

The EK60 was calibrated on 27/11/2017, after which the EK60 was run on updated parameters, as per Table 2.13.

During the station surveys the starboard drop keel was lowered for improved acoustic data collection (Figure 2.18). However, the ship preferred to run with the drop keel up, therefore there are also periods where the drop keel was retracted (Table 2.14).

Throughout the cruise the EK60 software crashed periodically (Table 2.15). There were no warnings, the system just shut down. On start up again, occasionally settings were lost, particularly the depth of the transducers. There are some files where the depth of the transducer is incorrect – this needs to be checked against the log of when the drop keel was up or down.

2.9.3 Mesoscale surveys

The EK60 was run continuously throughout the cruise on a 3 second ping rate with data collection to a depth of 1500 m. In order to parameterise mesoscale variability and the diurnal migration of organisms a dedicated survey was run at each of the three stations at P3, and an attempt to run a survey occurred at the abandoned eddy station (Table 2.16). The survey frequently occurred in poor weather, with the drop-keel deployed.

2.9.4 EK60 calibration

An acoustic calibration was carried out in Stromness Harbour, South Georgia on 27/11/2017. The ship utilised DP to maintain position and all over the side water deposits were stopped. All echosounders were stopped, and the EK60 was self-triggered at a rate of 1 ping per second. The ships own echosounder was not switched off. Each transducer was calibrated in turn, although all transducers were operating at the time. Standard ER60 calibration procedures were used where a relevant calibration sphere was moved through all quadrants of each transducer. In addition the sphere was held on-axis for extra periods of time to enable calibration variables to be determined in Echoview.

A CTD (Event 149) was undertaken on the morning of the calibration (Figure 2.19). Temperature and salinity were averaged from the 5 m to 55 m (depth of the calibration sphere) and were

1.3 °C and 33.8 PSU resulting in a speed of sound constant of 1457 m s^{-1} (Kongsberg software calculation).

This was the first time the RRS Discovery EK60 was calibrated. Andrew Moore (NOC-NMF) had provided calculated wire lengths and winch positions to undertake a three-point calibration of the EK60 transducers. RRS Discovery is 100 m long and 18 m wide, the EK60 transducers are located on the starboard drop-keel, and there are a number of protrusions projecting from the side of the ship. Therefore, line lengths and fishing rod lengths that keep the fishing line from rubbing the side of the ship were calculated – these were estimated to be 63.5 m and were measured and knotted prior to the ship departing Stanley. Winch locations on the port and starboard side are identified on Figure 2.20.

On arrival at Stromness two 30 m pieces of rope were tied to a large shackle and lowered over the bow to connect the port and starboard winch locations. An additional rope was laid between the two starboard winches, outboard of the lifeboat. The fishing line (using an additional shackle as a weight between the fishing line and rope) was transferred from the port side to starboard aft winch position. Likewise, the fishing line from starboard forward was pulled aft. At the aft position, the 38.1 mm tungsten carbide sphere was lowered first below a swivel. With all fishing lines paid out to the 63.5 m mark the sphere appeared in the aft quadrant of the edge of the 18 kHz transducer, suggesting the sphere was slightly behind the desired location. Minimal use of the winches put the sphere into the centre of the 38 kHz, the first transducer to be calibrated. Three quarters of the way through calibrating the first transducer it became apparent that the location of the winches and the depth of the sphere prevented the sphere from entering the port forward area of any of the transducers. We used a shackle (attached to a rope deployed from the deck above the port lifeboat) to move the port line forward in an attempt to view the sphere in the port forward quadrant of the 38 kHz. This worked – but at that point the wind significantly increased in strength (gusting 40 knots) and the ship swung about a lot. As a result, we lost sight of the sphere under the ship and were unable to locate it again. Noticing that the fishing line was angled aft (from the wind), we brought in the sphere (starboard aft side) where it became apparent that the fishing line on the port side was caught somewhere on the hull of the ship. We used a shackle on a rope dropped down the fishing line to free it partially. On retrieval of the sphere we added another weight below and redeployed. This cleared the line from where it was caught, as well as providing additional weight to keep the sphere under the ship in the higher winds. After calibration of the 38, 70, 120 and 200 kHz transducers using the 38.1 mm tungsten carbide sphere, the sphere and shackle were switch with the 22 mm tungsten carbide sphere and the 63mm copper sphere to calibrate the 333 kHz and 18 kHz respectively. In each case a shackle attached to a rope led from the port side was used to steer the sphere into the port forward quadrant. Looking at the winch locations, it is probable that the port side can't be moved, but the starboard winches could be placed further apart (both forward and aft) – although some more winch cable would be required for the starboard forward to reach the lab.

Once the spheres were correctly weighted, the calibration procedure went smoothly taking approximately 1 hour per frequency (calibration settings given in Table 2.17). The winch system of NMF working well, although the end hoop of all fishing rods failed. All calibrations were uploaded to the ER60 software, it is however noted that it is not clear that the 200 kHz transducer parameters has loaded correctly as they remain blank in the software, although they appear correctly in the .raw files. Recommendation from Simrad is to re-install the software, although at this point since the EK60 in general performs adequately this has not been undertaken.

2.9.5 Recommendations

1. The winches worked well, except the clutch/break kept slipping. The barrels of the winch drum have too much play and so the break can slip out. They need some mechanism to keep

them closer together.

2. The hoop on the end of each fishing pole has died (or fallen off). They can't take the weight. Ideally I would put a roller on the end part to run the wire over – this could be fitted into the pole. We need to do something for COMICS 2.

3. The winches are not quite in the right location. There is not quite enough play in the wire to allow the sphere to move round all quadrants. We had to keep moving the port one forward and aft to get in all quadrants. My suggestion would be to try keeping the port location where it is and changing the starboard ones to be further apart. But the maths needs examining.

4. Calibrating at 45 m depth of the sphere leaves too much play in the wire for doing it in any conditions less than a complete mill pond. I quite often cranked the sphere up to around 40 m (and I had an extra 6 m below the swivel – so I was forcing the sphere depth up significantly – by circa 10 m from the planned depth).

5. The EK60 periodically crashes. I have yet to find a reason for it. You are using the same software version as the JCR and that appears to be more steady, I have been in contact with Simrad for some suggestions.

6. You really really need hose reels for the cables. We have coiled as best we could but they are a little messy.

7. I have made a cradle for the RRS Discovery 38.1 mm tungsten carbide sphere. This one should be used in the future – so that you can monitor change. This is not in your calibration boxes, but is located with the copper spheres that came with the ship. You should not use the 38.1 mm tungsten carbide spheres that are pinned (i.e. not round!) they should be removed from the calibration boxes so no one uses them by mistake.

8. You should consider getting water proof connectors on the winches (or are they waterproof – didn't look it).

9. A little extendable pole with a hook on the end the distance of your fishing poles will help move the fishing line around at the end of the poles (we improvised with a broom taped to a boat hook).

Figure 2.18: Transducer layout on the starboard drop keel
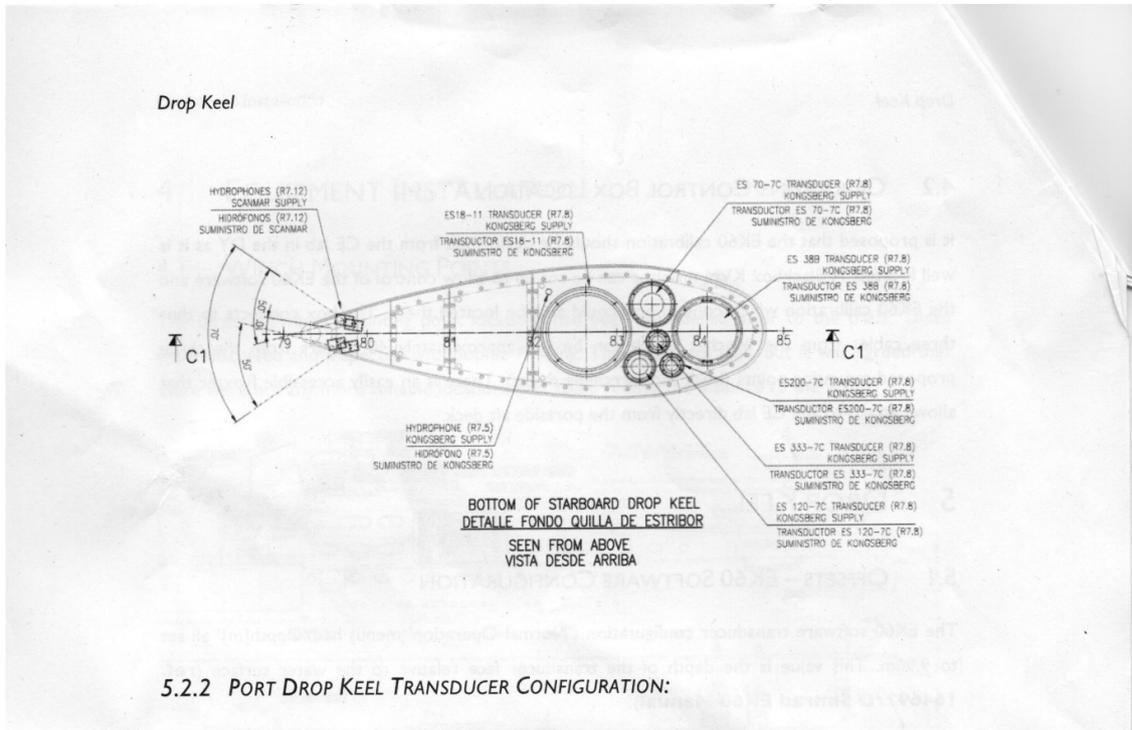
Figure 2.19: Temperature and salinity profiles from Event 149, calibration CTD in Stromness
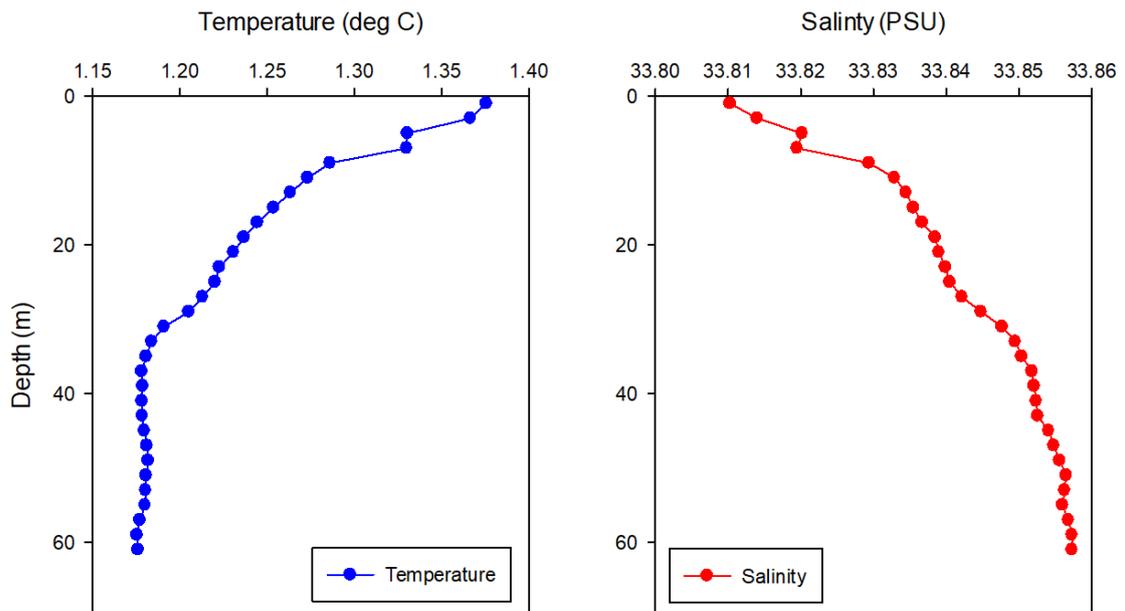
Figure 2.20: Port and starboard winch locations identified prior to calibration on DY086
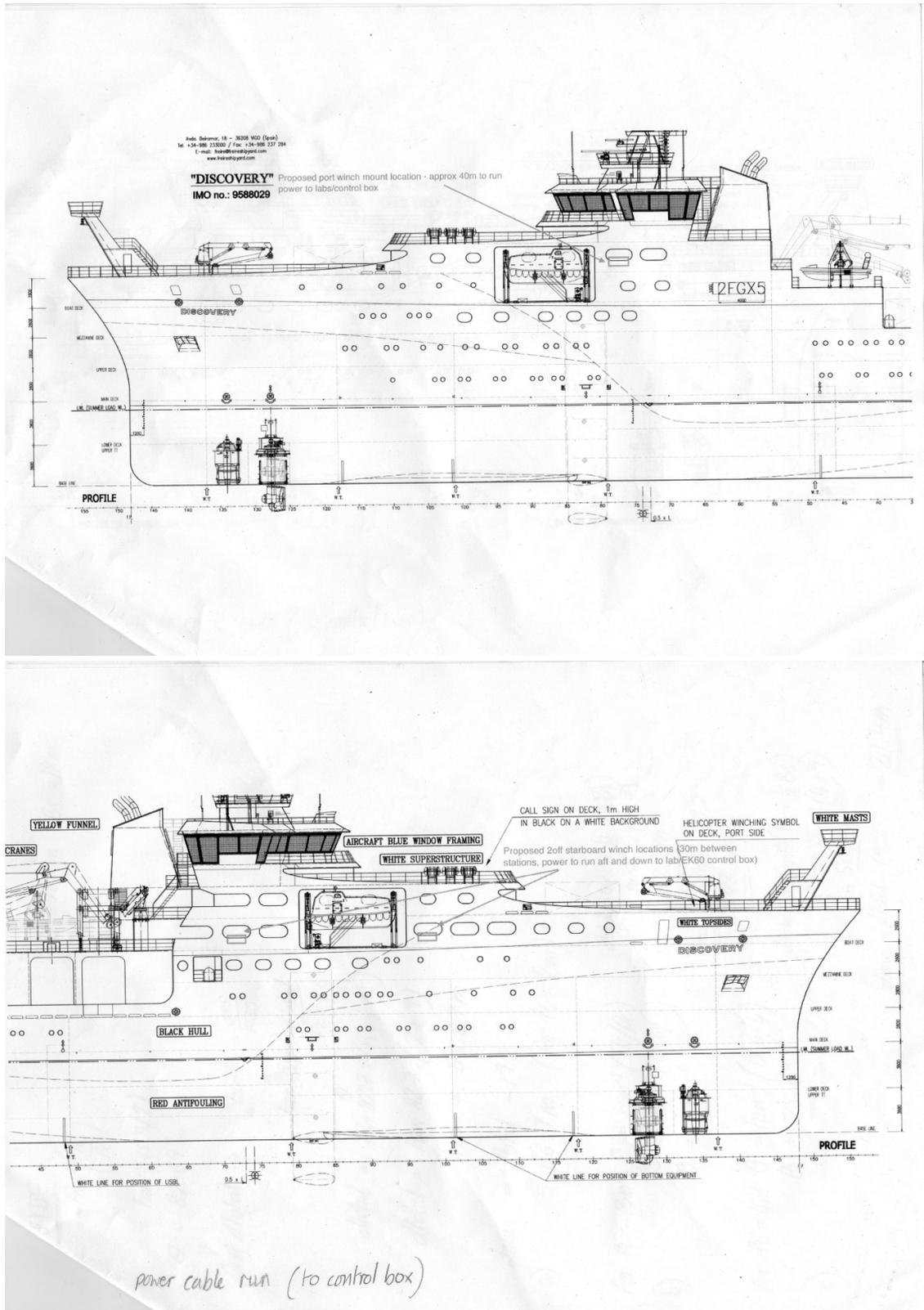
Table 2.12: EK60 initial settings. *Drop keel flush (6.6 m), drop keel lowered (9.9 m).

Variable	18 kHz	38 kHz	70 kHz	120 kHz	200 kHz	333 kHz
Transducer type	ES18-11	ES38B	ES70-7C	ES120-7C	ES200-7C	ES333-7C
Transducer Serial No.	2111	31185	258	890	533	125
Transducer depth (m)	6.6 (9.9)*	6.6 (9.9)*	6.6 (9.9)*	6.6 (9.9)*	6.6 (9.9)*	6.6 (9.9)*
Transceiver Serial No.	00907206dc83	00907206d08e	00907206b831	00907206ebdf	00907206b82f	00907206d0a4
Transducer power (W)	1400	1000	750	250	150	50
Pulse length (us)	1024	1024	1024	1024	1024	1024
Absorption coefficient (dB/km)	3.088	10.125	19.865	29.402	42.440	71.964
2-way beam angle (dB)	-17.1	-20.7	-20.5	-20.4	-20.3	-20.3
Transducer gain (dB)	22.4	26.5	27.0	27.0	27.0	27.0
Sa correction (dB)	0	0	0	0	0	0
3dB beam along (°)	10.8	7	7.2	7.3	7.3	7.3
3dB beam athwart (°)	10.4	7.1	7.2	7.3	7.4	7.3
Along offset (°)	0	0	0	0	0	0
Athwart offset (°)	0	0	0	0	0	0

Table 2.13: EK60 calibrated settings

Variable	18 kHz	38 kHz	70 kHz	120 kHz	200 kHz	333 kHz
Transducer type	ES18-11	ES38B	ES70-7C	ES120-7C	ES200-7C	ES333-7C
Transducer Serial No.	2111	31185	258	890	533	125
Transducer depth (m)	6.6 (9.9)*	6.6 (9.9)*	6.6 (9.9)*	6.6 (9.9)*	6.6 (9.9)*	6.6 (9.9)*
Transceiver Serial No.	00907206dc83	00907206d08e	00907206b831	00907206ebdf	00907206b82f	00907206d0a4
Transducer power (W)	1400	1000	750	250	150	50
Pulse length (us)	1024	1024	1024	1024	1024	1024
Absorption coefficient (dB/km)	3.288	10.014	18.164	26.361	39.808	72.988
2-way beam angle (dB)	-17.1	-20.7	-20.5	-20.4	-20.3	-20.3
Transducer gain (dB)	23.10	26.11	27.0	26.94	25.48	25.10
Sa correction (dB)	-0.67	-0.66	-0.32	-0.46	-0.27	-0.64
3dB beam along (°)	10.93	6.99	6.48	6.46	6.97	6.71
3dB beam athwart (°)	10.89	6.89	6.51	6.62	6.93	6.76
Along offset (°)	-0.09	-0.04	-0.02	0.02	-0.04	0.03
Athwart offset (°)	-0.17	-0.13	-0.09	-0.15	0.00	-0.11

Table 2.14: Drop-keel settings

Date/time (GMT)	Drop keel activity
12/11/2017 20:34	Drop keel up (transducer depth 6.6m)
19/11/2017 00:00	Drop keel lowered (transducer depth 9.9m)
26/11/2017 10:45	Drop keel raised (transducer depth 6.6m), note not corrected in .raw file
01/12/2017 20:27	Drop keel lowered (transducer depth 9.9m)
04/12/2017 11:30	Drop keel raised (transducer depth 6.6m)
11/12/2017 23:00	Drop keel lowered (transducer depth 9.9m)
13/12/2017 19:33	Drop keel raised (transducer depth (6.6m)

Table 2.15: EK60 crashes

Date/time (GMT)	Event
12/11/2017 20:34	EK60, ADCP, EA640 on. K-sync synchronised. ADCPs (150 and 75 kHz in bottom-tracking). Interference in both 120 and 70 kHz data. Environment settings 2°C and 34.5 PSU
13/11/2017 11:37	ADCPs changed to water tracking
22/11/2017 14:50	EK60 crashed – wasn't noticed until 20:00
27/11/2017 16:54	Environment settings changed to 1.25°C and 33.8 PSU
27/11/2017	EK60 calibration in Stromness. Calibration settings uploaded
27/11/2017	EK60 crashed during calibration
03/12/2017 11:57	EK60 crashed. Note transducer depth not changed for drop keel position after crash
13/12/2017 08:10	EK60 crashed, noticed at 14:50

Table 2.16: Mesoscale survey times. Times in GMT.

Survey name	Start date/time	End date/time	Comment
P3_A	19/11/2017 07:12	20/11/2017 02:43	Upwind direction suffers from attenuation and noise. Survey scale 20nm, no day/night version run
Eddy	24/11/2017 10:28	24/11/2017 17:40	Ship hove too – heading towards start of an acoustic survey
Eddy	24/11/2017 17:40	25/11/2017 06:45	Nominal survey of eddy whilst ship in bad weather
Eddy	25/11/2017 22:53	26/11/2017 10:00	Bad weather, survey didn't really start. Ship headed downwind, unable to turn
P3_B	03/12/2017 12:22	03/12/2017 20:12	Survey was 20 nmile, cut early to do camera frame, and run at slow speed
P3_B	03/12/2017 22:30	04/12/2017 06:28	Night time survey, resized to 15 nm to allow for slower speed
P3_C	12/12/2017 06:57	12/12/2017 15:10	P3_C day time acoustic survey. Noise and drop out in the upwind transect. Survey scale 15 nm
P3_C	12/12/2017 21:14	13/12/2017 03:00	First line completed, but ship unable to turn – survey abandoned
P3_C	14/12/2017 22:25	15/12/2017 06:20	Night-time attempt 2. Drop-keel up. Mid-line contains lots of noise

Table 2.17: Calibration parameters. TC: tungsten carbide.

Variable	18 kHz	38 kHz	70 kHz	120 kHz	200 kHz	333 kHz
Transducer type	ES18-11	ES38B	ES70-7C	ES120-7C	ES200-7C	ES333-7C
Transducer Serial No.	2111	31185	258	890	533	125
Transducer depth (m)	6.6	6.6	6.6	6.6	6.6	6.6
Transceiver Serial No.	00907206dc83	00907206d08e	00907206b831	00907206ebdf	00907206b82f	00907206d0a4
Transducer power (W)	1400	1000	750	250	150	50
Pulse length (us)	1024	1024	1024	1024	1024	1024
Absorption coefficient (dB/km)	3.288	10.014	18.164	26.361	39.808	72.988
Calibration sphere	63mm copper	38.1mm TC	38.1mm TC	38.1mm TC	38.1mm TC	22mm TC
Calculated TS (dB)	-34.39	-42.13	-40.63	-39.77	-39.49	-43.91
Sphere depth (m)	51	55	53	53	51	37
RMS beam model (dB)	0.11	0.14	0.22	0.30	0.37	0.73
RMS polynomial model (dB)	0.08	0.12	0.16	0.28	0.35	0.70

2.10 Underway data streams

Steph Henson*
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2.10.1 Ship's data streams

The SCS data streams (anemometer [met/surfmet], oceanlogger [ocl], gyro [nav/gyros, nav/gyropmv], seatext-gell [nav/seapos], position [nav/posmvpos, nav/posmvatt], em120 [em122]) were processed on eriu during the cruise. Most were processed in 24-hour segments, using m_daily_proc.m, with cleaning and appending as required.

Daily processing generates a best navigation file, *data/nav/posmvpos/bst_dy086_01.nc*. The final surface meteorological data file is *data/met/surfmet/surfmet_dy086_truav.nc*. Mmerge was used to merge the position data from *bst_dy086_01.nc* into the TSG and SBE files to create */data/ocl/tsg/met_dy086_merge.nc* and */data/ocl/tsg/sbe45_dy086_merge.nc* respectively.

2.10.2 Underway calibration samples

A total of 23 underway samples were analysed for oceanlogger salinity calibration. Samples were drawn from the underway supply in the Underway Lab nominally every 4 hours during passage between stations and during the acoustic surveys. Samples were analysed following the procedure described for CTD salinity samples. Underway salinity sample files are in *CTD/BOTTLE SAL/tsg_dy086_all.csv*.

Aside from reading in the data daily using *m_daily_proc* and merging with the navigation data, no further processing was done with the underway data streams. This means that the data are currently uncalibrated.

2.11 CTD operations (NMF)

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2.11.1 Overview

There were 33 CTD casts in total of which 25 were made with the stainless steel (S/S) system using the ships winches and the CTD2 wire. An insulation test gave a value of >999M ohms for CTD2 and a continuity test of 74 ohms. For the S/S system, the pressure sensor was located 16 cm below the bottom and approximately 71 cm below the centre of the 20-L water sampling bottles.

Due to restricted movement of the over-boarding sheave, it was decided to place strict operational limitations on the use of the Trace Metal Free (TMF) system. *This was decided as a result of an incident during cast 1 when the cable jumped off the sheave during the up-cast with 649m of cable out in marginal conditions.* Hence it was only deployed during daylight hours and if the sea state and ship manoeuvrability allowed. As a result only eight casts were made with the TMF frame using the Lebus contingency winch and Kevlar cable. Insulation tests gave approximately 20M ohms initially for the Kevlar cable but this subsequently changed to 0.18M ohms after re-termination before cast 19. For the TMF system, the pressure sensor was located 33cm below the bottom and approximately 72 cm below the centre of the 10-L water sampling bottles.

The configuration file, used is included in the appendix at the end of this report. This was *DY086_SS.xmlcon* for the S/S system and *DY086_TITA.xmlcon* for the TMF. The cast numbers of TMF deployments are: 1, 4, 7, 15, 19, 24, 26 and 29.

Sensor Failures

There were no sensor failures as such, but the rosette pylon had several extensions added to the latch release mechanism to reduce bottle closure failures.

LADCP Configuration

The TRDI WHM 300 kHz LADCP (s/n: 4275) was deployed in a downward-looking orientation on the S/S CTD frame. There was no LADCP on the TMF frame. Battery voltage could not be monitored as the cable was diode protected. The instrument was configured to ping as fast as possible, use 25 bins, a zero blanking distance and a depth cell size of 1 m thus yielding a range of approximately 25 m in ideal conditions. The ambiguity velocity was set to 250 cms^{-1} and ensemble time of 1.5 seconds.

Log files were recorded for each deployment and built-in pre-deployment test PC2 was run before each cast, and then the following command file sent (F2):

Master command file (DY086_Master.txt)

```
    WV250
    >WN25
    >WS1000
    >WF0
    >WB1
    >EZ0011101
    >EX00100
    >WP1
    >TP 00:00.00
    >TE 00:00:01.50
    >CF11101
```

```
>SM1
>SA011
>SW5500
>RNdy86_
>CK
[Parameters saved as USER defaults]
>CS
```

Data processing

Basic post-processing of the CTD cast data was done to guidelines established with BODC (ref. Moncoiffe 7th July 2010).

Salinity measurement

A Guildline Autosal 8400B salinometer, s/n: 71126, was used for salinity measurements. The salinometer was sited in the Salinometer room. The bath temperature was set at 21°C, the ambient temperature being approximately 20°C. A bespoke program written in Labview called "Autosal" was used as the data recording program for salinity values.

Salinity samples were taken and analysed from most casts, the results being tabulated in a spreadsheet SALFORM.xlsx.

2.11.2 Configuration file used for the stainless system

Instrument configuration file: *C:\Users\sandm\Documents\Cruises\DY086\CTD\Data\Seasave_ Setup_Files\DY086_SS.xmlcon*

Configuration report for SBE 911plus/917plus CTD

Frequency channels suppressed	:	0
Voltage words suppressed	:	0
Computer interface	:	RS-232C
Deck unit	:	None
Scans to average	:	1
NMEA position data added	:	No
NMEA depth data added	:	No
NMEA time added	:	No
Surface PAR voltage added	:	No
Scan time added	:	No

(1) Frequency 0, Temperature

Serial number	:	03P-4712
Calibrated on	:	30-Aug-2016
G	:	4.40407070e-003
H	:	6.33282349e-004
I	:	1.91122544e-005
J	:	1.15681240e-006
F0	:	1000.000
Slope	:	1.00000000
Offset	:	0.0000

(2) Frequency 1, Conductivity

Serial number : 04C-2858
Calibrated on   : 22-July-2016
G   : -1.02345351e+001
H   : 1.43851132e+000
I   : 5.69508998e-004
J   : 3.06309086e-005
CTcor   : 3.2500e-006
CPcor   : -9.57000000e-008
Slope   : 1.00000000
Offset   : 0.00000

(3) Frequency 2, Pressure, Digiquartz with TC

Serial number : 110557
Calibrated on   : 3-Nov-2016
C1   : -6.010548e+004
C2   : -1.565601e+000
C3   : 1.823090e-002
D1   : 2.668300e-002
D2   : 0.000000e+000
T1   : 3.020528e+001
T2   : -6.718318e-004
T3   : 4.457980e-006
T4   : 1.203850e-009
T5   : 0.000000e+000
Slope   : 1.00000000
Offset   : -0.09301
AD590M   : 1.280700e-002
AD590B   : -9.299640e+000

(4) Frequency 3, Temperature, 2

Serial number : 03P-4116
Calibrated on   : 22-July-2016
G   : 4.42601978e-003
H   : 6.84531920e-004
I   : 2.45408053e-005
J   : 2.03571998e-006
F0   : 1000.000
Slope   : 1.00000000
Offset   : 0.0000

(5) Frequency 4, Conductivity, 2

Serial number	:	04C-3768
Calibrated on	:	22-March-2016
G	:	-1.02297285e+001
H	:	1.49917603e+000
I	:	-1.55629820e-003
J	:	2.11343370e-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	:	43-1882
Calibrated on	:	28 Feb 2017
Equation	:	Sea-Bird
Soc	:	4.72300e-001
Offset	:	-5.06500e-001
A	:	-4.13880e-003
B	:	2.05530e-004
C	:	-2.78060e-006
E	:	3.60000e-002
Tau20	:	1.07000e+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, Altimeter

Serial number	:	59494
Calibrated on	:	
Scale factor	:	15.000
Offset	:	0.000

(9) A/D voltage 3, OBS, WET Labs, ECO-BB

Serial number	:	169
Calibrated on	:	09 August-2016
ScaleFactor	:	0.005228
Dark output	:	0.089000

(10) A/D voltage 4, PAR/Irradiance, Biospherical/Licor

Serial number	:	70520
Calibrated on	:	24-Jan-2017
M	:	1.00000000
B	:	0.00000000
Calibration constant	:	16835016800.00000000
Multiplier	:	1.00000000
Offset	:	-0.06092372

(11) A/D voltage 5, PAR/Irradiance, Biospherical/Licor, 2

Serial number	:	70510
Calibrated on	:	24-Jan-2017
M	:	1.00000000
B	:	0.00000000
Calibration constant	:	20449897800.00000000
Multiplier	:	1.00000000
Offset	:	-0.04979765

(12) A/D voltage 6, Transmissometer, WET Labs C-Star

Serial number	:	CST-1602DR
Calibrated on	:	24-May-2016
M	:	21.3038
B	:	-0.1065
Path length	:	0.250

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

Serial number	:	88-2615-126
Calibrated on	:	22-July-2016
VB	:	0.210900
V1	:	2.186200
Vacetone	:	0.303700
Scale factor	:	1.000000
Slope	:	1.000000
Offset	:	0.000000

Scan length   :   30

2.11.3   Configuration file used for the TMF system

Instrument configuration file: *C:\Users\sandm\Documents\Cruises\DY086\CTD\Data\Seasave_Setup_Files\DY086_TITA.xmlcon*

Configuration report for SBE 911plus/917plus CTD

Frequency channels suppressed	:	0
Voltage words suppressed	:	0
Computer interface	:	RS-232C
Deck unit	:	None
Scans to average	:	1
NMEA position data added	:	No
NMEA depth data added	:	No
NMEA time added	:	No
Surface PAR voltage added	:	No
Scan time added	:	Yes

(1) Frequency 0, Temperature
  Serial number   :   4593
  Calibrated on   :   01-June-16
  G   :   4.35402931e-003
  H   :   6.44517993e-004
  I   :   2.17307558e-005
  J   :   1.74609370e-006
  F0   :   1000.000
  Slope   :   1.00000000
  Offset   :   0.0000

(2) Frequency 1, Conductivity
  Serial number   :   2164
  Calibrated on   :   22-July-16
  G   :   -1.02211548e+001
  H   :   1.40891338e+000
  I   :   -2.45872860e-003
  J   :   2.39920831e-004
  CTcor   :   3.2500e-006
  CPcor   :   -9.57000000e-008
  Slope   :   1.00000000
  Offset   :   0.00000

(3) Frequency 2, Pressure, Digiquartz with TC
  Serial number   :   0758
  Calibrated on   :   26-May-15
  C1   :   -6.571123e+004
  C2   :   2.050504e-001
  C3   :   1.612220e-002
  D1   :   2.883800e-002
  D2   :   0.000000e+000
  T1   :   2.986693e+001
  T2   :   -2.678465e-004
  T3   :   3.986390e-006
  T4   :   7.472100e-010
  T5   :   0.000000e+000
  Slope   :   1.00000000
  Offset   :   -0.23180
  AD590M   :   1.250000e-002
  AD590B   :   -1.000000e+001

(4) Frequency 3, Temperature, 2
  Serial number   :   4381
  Calibrated on   :   30-Aug-16
  G   :   4.42362953e-003
  H   :   6.44986675e-004
  I   :   2.27008650e-005
  J   :   1.98024368e-006
  F0   :   1000.000
  Slope   :   1.00000000
  Offset   :   0.0000

(5) Frequency 4, Conductivity, 2

Serial number	:	2164
Calibrated on	:	01-June-16
G	:	-9.77671598e+000
H	:	1.27321341e+000
I	:	-1.45899853e-004
J	:	7.15112617e-005
CTcor	:	3.2500e-006
CPcor	:	-9.57000000e-008
Slope	:	1.00000000
Offset	:	0.00000

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

Serial number	:	1940
Calibrated on	:	14-Jun-16
Equation	:	Sea-Bird
Soc	:	5.35400e-001
Offset	:	-5.08700e-001
A	:	-4.04070e-003
B	:	1.86250e-004
C	:	-2.89540e-006
E	:	3.60000e-002
Tau20	:	1.14000e+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, Altimeter

Serial number	:	11255
Calibrated on	:	15 July 2013
Scale factor	:	15.000
Offset	:	0.000

(9) A/D voltage 3, OBS, WET Labs, ECO-BB

Serial number	:	BBRTD-758
Calibrated on	:	16 Aug 2016
ScaleFactor	:	0.004068
Dark output	:	0.051000

(10) A/D voltage 4, Free

(11) A/D voltage 5, Free

(12) A/D voltage 6, Fluorometer, Chelsea Aqua 3
Serial number   :   088163
Calibrated on   :   22 July 2016
VB   :   0.057900
V1   :   2.111100
Vacetone   :   0.240700
Scale factor   :   1.000000
Slope   :   1.000000
Offset   :   0.000000

(13) A/D voltage 7, Transmissometer, WET Labs C-Star
Serial number   :   1718
Calibrated on   :   15 April 2015
M   :   22.6643
B   :   -0.1654
Path length   :   0.250
    Scan length :   34

2.12   CTD data processing and calibration

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2.12.1   Data Processing

All data processing was performed on workstation Eriu supplied by MPOC using the mexec software suite. Multiple changes to the standard set of mexec scripts were required to process the ship's datastreams. All changes are commented with %DY086 in the relevant file. Some errors required help from Brian King and Yvonne Firing who were able to ssh into Eriu remotely. Fixes are documented in *\pstar\dy086\data\action_taken_at_noc_for_dy086.txt*.

The CTD data processing followed the methods used on previous MPOC cruises, using the mexec software suite. The initial SeaBird data conversion, align, and cell thermal mass corrections were performed using SBE Data Processing.

To match the file structure expected by mexec, the following was requested from the NMF techs running the CTD (Nick Rundle and John Wynar). To avoid annoying the techs by realising this was necessary after several CTD casts, I recommend passing this info on to them at the start of the cruise next time...

1. Data Conversion to convert the raw frequency and voltage data to engineering units as appropriate by applying the manufacturer's calibrations stored in the CON file and save both downcast and upcast to an ASCII format file, including hysteresis correction using SBE parameters.
   - Name the output files *ctd_dy086_nnn.cnv*, where nnn is CTD number, i.e. 001, 002, 003 etc. . . .
2. Align CTD to align the oxygen sensor in time relative to pressure.
   - Name the output files *ctd_dy086_nnn_align.cnv*.
3. Cell Thermal Mass to correct the pressure and conductivity.
   - Name the output files *ctd_dy086_nnn_align_ctm.cnv*.

These files can then be copied across into *discofs\Sensors_And_Moorings\CTD\Data\CTDProData*. The same naming convention should also be applied to the raw data files (.hdr, .hex etc.), which should be copied into *discofs\Sensors_And_Moorings\CTD\Data\CTDRawData*. *ctd_linkscript* was used to copy files from the NMF discofs mount to Eriu and set up additional symbolic links to filenames following mstar convention.

For each cast the following m-files were then run, using wrapper script *ctd_all_part1*: mctd_01, mctd_02a, mctd_02b, mctd_03, mdcs_01, mdcs_02. To get this wrapper running, I changed *minit.m* (which is called at the beginning of every mexec script) to account for the messy mix of capital and small letters for the cruise identifier (i.e. dy086 or DY086). The processes completed by wrapper *ctd_all_part1.m* include

- read ASCII cnv data from *ctd\ASCII_FILES\ctd_dy086_001_ctm.cnv*
- convert variable names from SBE names to mexec names using *data\templates\ctd_dy086_renamelist.csv* (**this file had to be adjusted to reflect the sensors mounted on the CTD frame – added 2 PAR sensors, only 1 oxygen sensor mounted. Normally 2 oxygen sensors are mounted, and this change caused much messiness in the scripts, which Brian was called in to fix. For DY090, this may need putting back if 2 oxygen sensors are in place).
- Copy raw file to 24hz file. Make oxygen hysteresis adjustment on 24hz file average to 1hz calculate derived variables psal, potemp. Extract information from bottom of cast identified by maximum pressure.

Subsequently *mdcs_03g* was run to inspect the profiles and hand-select cast start and end times. The way oxygen time lag is handled in the SBE align algorithm, and the weak dependence of

oxygen calculation on salinity, means that when air is ingested into the conductivity cell at the end of the cast, the oxygen becomes biased a few seconds earlier than the psal. Care should therefore be taken to select a cast end time for which all the important variables are free from bias.

The start, bottom and end data cycles are stored in files with names like *dcs_dy086_001.nc*. After selecting the limits for start and end, *ctd_all_part2* was then run, executing mctd_04, mfir_01, mfir_02, mwin_01, mwin_03, mwin_04. The processes completed by these scripts include

- Extract down and upcasts using scan numbers stored in *dcs_dy086_001*, and average into 2 dbar files (2db and 2up)
- Read the *data\ctd\ASCII_FILES\ctd_dy086_001.bl* file and extract scan numbers corresponding to bottle firing events.
- Add time from CTD file, merging on scan number
- Add CTD upcast data corresponding to bottle firing events
- Paste these data into the master sample file *data\ctd\sam_dy086_001.nc*
- Load winch telemetry data from winch SCS file
- Add winch wireout data to the *fir_dy086_001* file
- Paste winch wireout data into the master sample file

A change was made during DY086 to get *ctd_all_data_part2* working: cludge for the file directory structure in *mfir_01.m*.

The 24-Hz data were checked for spikes in either of the temperature, conductivity or oxygen sensors and, if necessary, edited using *mctd_rawedit*. (*mctd_checkplots* was also edited for DY086 to account for only one oxygen sensor). If spikes are removed, the derived files have to be regenerated using *smallscript_postedit.m*.

A variety of extra steps is available after other processing has been carried out; these steps can be run in any order. *Populate_station_depths.m* can be run to add station depths to CTD files. *Smallscript_botnav.m* adds the depth, navigation and bottle data. Only run this after the navigation data has been processed, as this will save you from having to re-run all the CTD processing when you realise it hasn't been ingesting lat\lon.

Smallscript_botnav.m runs the following scripts: Mbot_01, mbot_02, mdep_01,mdcs_04, mdcs_05 Mdcs_04 will generate files *dcs_dy086_001_pos.nc* which include position at start, bottom and end of profiles. *Mdcs_05* will then paste the position at the bottom of the cast into the header of all relevant files in *data\ctd*.

2.12.2 Merging bottle data with CTD data

Bottle sample data (conductivity and salinity) were provided by Nick Rundle and John Wynar from samples run on a Guildline Autosal. Files are saved as a comma-separated csv file, with the name *sal_dy086_nnn.csv*, which was then copied across to Eriu and saved in *CTD\BOTTLE_SAL*.

Oxygen, nutrient and chlorophyll samples collected from the CTD were also ingested into mexec routines by adapting *caldata_all_part1*. Note that this appends each new file, so if you revise a set of input data, the whole thing should be run from station 001 again. Getting the format of the csv files to read in is also critical. This involved quite a bit of cutting and pasting from the Excel files supplied by Mark Stinchcombe and Jo Ainsworth. In future, template files should be provided to the teams analysing bottle samples to complete which will make the process less painful.

msal_01, moxy_01, mnut_01 and (new script for DY086) mchl_01 read in the concatenated bottle samples and extract the sample data for each station based on the sample number. The scripts msal_02, moxy_02, mnut_02 and mchl_02 paste this information to *sam_dy086_nnn.nc*. The full bottle sample file for the cruise is *sam_dy086_all.nc*. (Note, in a change to the original mexec scripts, there is now no need to run *caldata_all_part2.m* if the adapted *caldata_all_part1.m* script is used).

2.12.3 CTD Conductivity, Oxygen and Fluorescence Calibration

ctd_evaluate_sensors.m was adapted to also examine the difference between bottle chlorophyll and CTD fluorescence sensors, in addition to salinity and oxygen. Plots are generated to reveal biases between sensors, and either pressure- or station-dependence of bottle minus sensor differences. The identified calibration for the oxygen sensor is:

$$oxy_{cal} = 20.08 - 0.00015press + 0.92658oxy_{ctd} + 0.005(statnum * oxy_{ctd}) \qquad (2.1)$$

Stations 3-6 had a totally different offset between the bottle oxygen and CTD optode. The issue was traced back to be with the CTD sensor and not the bottle data.
The identified calibration for the conductivity sensor (sensor 1) is:

$$cond_{cal} = 35e^3.(-28.269 - 0.0388statnum + 0.0001369press) \qquad (2.2)$$

The identified calibration for the conductivity sensor (sensor 2) is:

$$cond_{cal} = 35e^3.(-28.112 - 0.037436statnum + 0.0001423press) \qquad (2.3)$$

The identified calibration for the fluorescence sensor is:

$$chl_{cal} = 0.15477 + 1.5004fluorescence \qquad (2.4)$$

NOTE: The calibration equations identified above were not applied to the CTD data prior to disembarking. The corrections will need to be done back at NOC. The equations will need to be added to *opt_dy086.m*, and then the wrapper scripts *smallscript_tccal.m* (for conductivity) and *smallscript_ocal.m* (for oxygen) will need to be run to produce calibrated CTD profiles in all the derived files (i.e. 24hz, 1hz, psal, 2db, 2up). With the exception of the *ctd_dy086_nnn_raw.nc* files, which still contains raw data, calibrated data will then occur in all derived files.

2.13 Red Camera Frame

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2.13.1 Overview

The Red Camera Frame carries 4 optical sensors which measure the characteristics of the particle field in the epipelagic and upper mesopelagic zones: LISST HOLO, P-Cam, Eco Puck and RBR Concerto. Due to a 250 m depth limit on the LISST HOLO, two profiles were usually carried out at each opportunity, one to 250 m and another to 500 m. The descent speed was about 0.2 m s^{-1} and the ascent was either at 0.2 or 1.0 m s^{-1} depending on the available time.

Figure 2.21: The Red Camera Frame.

2.13.2 LISST-HOLO

Description

The LISST-HOLO is a submersible digital holographic camera. During the present cruise it was operated in a self-contained mode powered from an external battery pack. The instrument records in-line holographic images that are stored in internal flash memory or an 'external memory module' (EMM). These .PGM (portable grey map) images also code supporting data, date, time, temperature, depth, and instrument details in the file structure (see Sequoia manual section 12, p65 for details). This supporting data can be read in plain text at the end of the file using the 'HEXview' option in Irfanview (convenient software for opening and viewing the .PGM files). This is a useful feature where the file's original timestamp may have been lost on copying of file transfer.
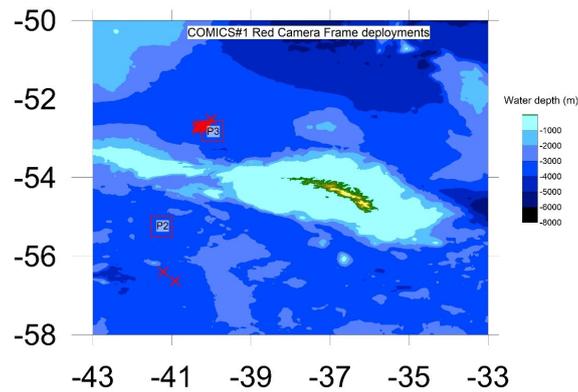
Figure 2.22: Deployment positions for the Red Camera Frame.
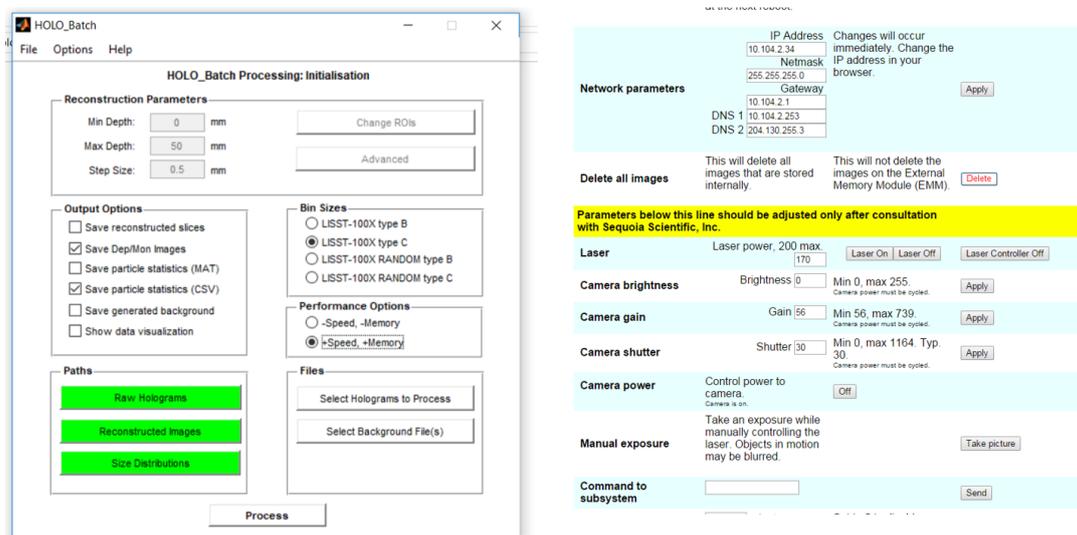
Figure 2.23: Screen-shots from the programming and processing of the LIST-HOLO images.

The notional capability of the instrument is the detection and volume measuring of particles in the size range 25-2500μm equivalent spherical diameter, through a path length of 50mm, having a sampled volume of 1.86 cm^3. Optical sections of the recorded image are reconstructed mathematically from the interference fringes produced by the interaction of particles with the laser illumination. Summary statistics are provided in terms of total particle volume concentration and volume concentration in size bins (note that four different bin size scales are offered – for processing on-board this cruise, the 'LISST-100X type C' was uniformly employed). Dep and Mon (Montage) images were saved but not the individual slices (100 per frame).

The Holographic system (LISST-HOLO) images 1.8 mL of water every 5 seconds providing an image approximately every metre.

LISST-HOLO Data processing

Image reconstruction and data generation requires use of Sequoia supplied software "*HOLO_Batch for batch processing and data generation*".
Other software is also required:
1. An image viewer that can read .PGM files, "Irfanview" was employed.

2. The External Memory Module (EMM) was used for all deployments, being easier to handle than the internal memory store. EMM can be treated as any normal memory stick to transfer data but taking extreme care every time only to remove it from the LISST-HOLO after it has entered "sleep mode" and to "eject the hardware" before removing it from the laptop connection. Failure to do this would have damaged the EMM.

Although the output from HOLO_Batch provides, as stated in the manual, data in 50 size bins logarithmically placed from 1.25-4923 µm, the effective resolution of the instrument is only about 25µm rendering the first 18 bins completely useless.

Data coverage

12 deployments of the LISST HOLO on the RCF were made during the cruise to 250 m depth with two deployments at the low productive southern superstation and 10 deployments at the more productive northern superstation, P3.

LISST-HOLO results

In contrast to previous cruises using the LISST-Holo where particle abundances were too low for reliable data acquisition, during this cruise, some high qualitative and quantitative data was obtained, the majority of which will need significant analysis in the future. The most prominent change during the occupations at Superstation P3 (Fe+) were from an environment with large numbers of diatom chains until 2nd December followed by a period during which particles with the appearance of zooplankton faecal pellets were abundant.

2.13.3 P-Cam
Description

The P-Cam consisted of a Canon EOS 6D digital SLR camera equipped with a 50 mm macro lens and a Canon Speedlite 600EX RT flash gun. The camera and the flash gun were places perpendicular to each other provide illumination from the right side of the captured images. We used a Hahnel Giga T Pro II remote timer to capture an image every five seconds. The camera was put in manual mode and the settings were adjusted to have an ISO of 2500, a shutter speed of 1/160 seconds, an aperture of f/32, and the lens focus was put to 1.5 feet. The flash was also in manual mode and put for straight flash direction and a flash output of 1/8.

We were able to capture individual particles through the water column in a water volume of 2.15 L for each captured image. The pixel size of the images changed depending on whether the particles were in the front or back of the field of depth. We determined a pixel size of 33 µm in the front of the depth of field (as seen from the camera) and a pixel size of 61 µm at the back of the depth of field. This suggested an average pixel size of 47 µm. The field of view for each image was 157 mm width, 101 mm height, and 135 mm depth. The width and height of the images were determined by the cropping of each image to compensate for uneven flash illumination and might change during final image processing.
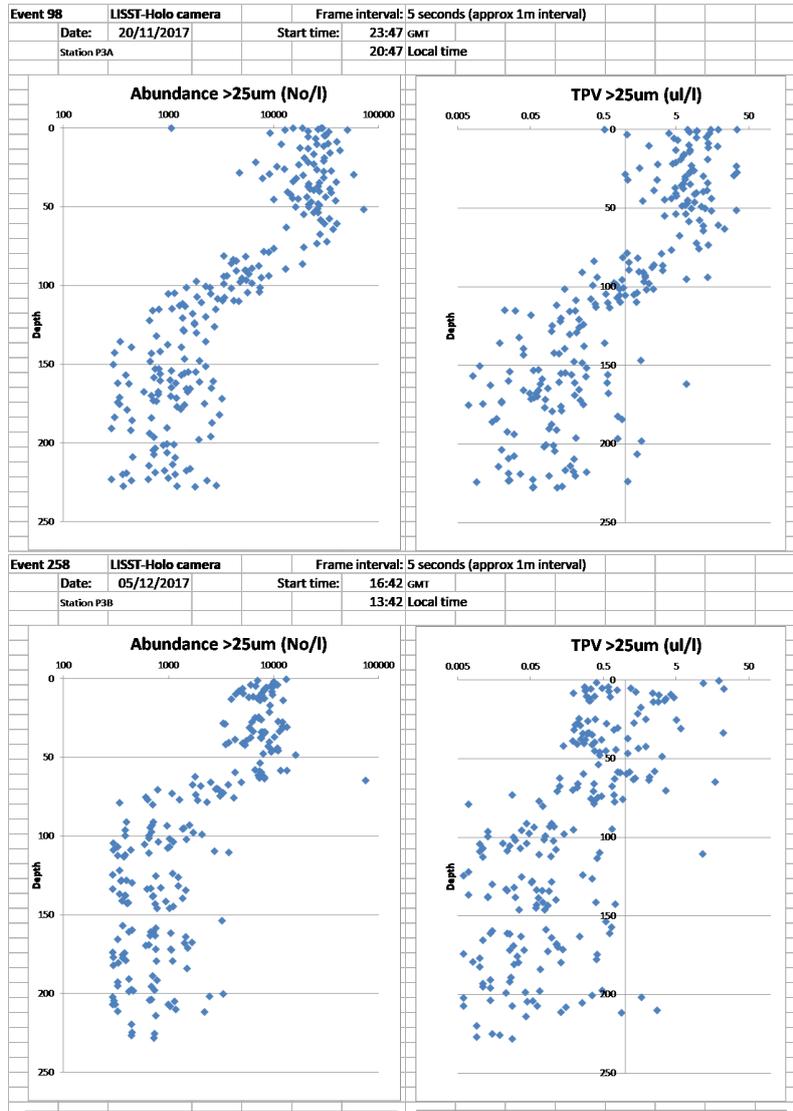
Figure 2.24: Examples of profiles of particles >25 μm in terms of abundance (left) and Total Particulate Volume (TPV) (Right). at Superstation P3 (Fe+) to show decline from late November (Top) (Event 98 on 20/11/2017) to early December (Bottom) (Event 258 on 5/12/2017.)
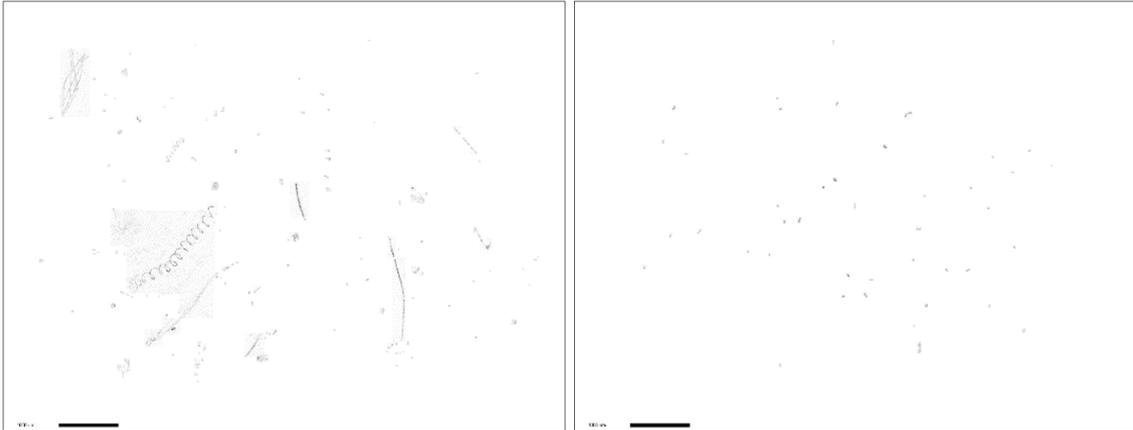
Figure 2.25: Montage of targets from LISST-HOLO frames at Superstation P3 (Fe+) to show prominence of diatom chains in late November (left) (Event 98 at 38 m depth on 20/11/2017, Frame 003-0922) and putative faecal material in early December (Right) (Event 258 at 40 m depth on 5/12/2017, Frame 003-4175).
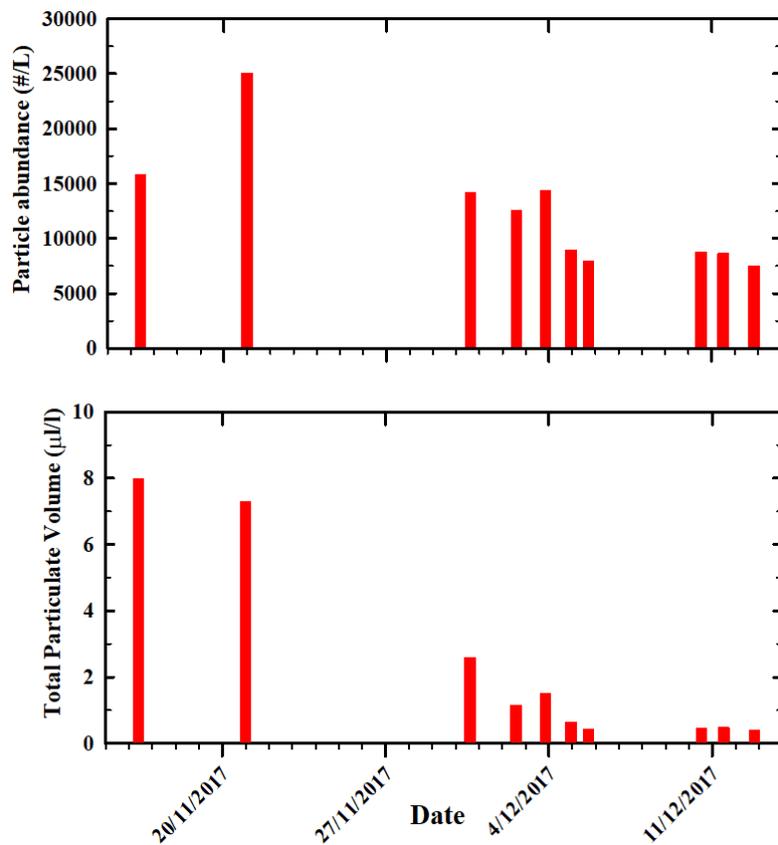
Figure 2.26: From LISST-HOLO, trend in mean abundance (top) and median volume concentration (bottom) of particles >25 μm at Superstation P3 (Fe+) over the upper 50m of the water column.

Specific settings for the Camera and Flash gun
Camera settings

Image quality:	jpeg highest quality, no raw
Beep:	Disable
Release shutter without card:	OFF
Image review:	OFF
Lens aberration correction:	Enable, Enable
External Speedlite control:	Enable, Evaluate, Auto
Mirror Lockup:	OFF
Expo. Comp./AEB:	0
ISO Speed settings:	blank
Auto lighting optimizer:	off
White balance:	Flash
Custom White Balance:	blank
WB Shift/Bkt.:	blank
Color space:	sRGB
Picture Style:	Auto
Long exp. Noise reduction:	OFF
High ISO speed NR:	middle
Highlight tone priority:	OFF
Dust Delete Data:	OFF
Multiple exposure:	Disable
HDR Mode:	Disable HDR
Live view shot:	Disable
AF Method:	FlexiZoneAF
Grid display:	OFF
Aspect Ratio:	3:2
Expo. Simulation:	Enable
Silent LV shoot:	Mode 1
Metering timer:	16 sec.
Auto Power Off:	1 min
LCD Brightness:	highest
LCD off/on btn:	Shutter btn.

Manual mode, set time and date to ships UTC time, ISO 2500, shutter 1/160, aperture to f/32, focus of the lens to 1.5 feet, set the lens to manual focus: MF.

Flash settings

Hold Zm/C.Fn botton to enter setup.

m/ft:	0: m
zZZ:	0:ON
Modelling:	0
Auto Cancel:	0
0:	0 → - → +
MODE:	0: ETTL-II/E-TTL
QUICK:	0:OFF
TEST:7 0:1/32	
AF:	0:ON
0:ON	
zZZ:	1:10min
zZZ:	0:8h
Remote:	0
Flash +/-:	0
Sound:	OFF
Direction: 1:	straight
Light:	1:OFF
Flash:	0

Manual mode, straight flash, flash output 1/8.

Timer settings

Scroll through to delay and set the delay between timing and first image, long can be left at 00 00' 00", INTVL1 is the time between each image within one cycle, N1 is the number of images taken at one cycle, INTVL2 is the time between each cycle , N2 is the number of cycles – put to "- -" and it is infinite.

Timer for PELAGRA:

Delay:	HH:MM:SS
Long:	00 00' 00"
INTVL1:	00 00' 02"
N1:	10
INTVL2:	00 59' 42"

Timer for Red Camera Frame:

Delay:	HH:MM:SS
Long:	00 00' 00"
INTVL1:	00 00' 00"
N1:	1
INTVL2:	00 00' 05"

2.13.4 ECO-Puck and RBR Concerto

Description

Each deployment of the Red Camera Frame was equipped with RBR Concerto CTD with Fluorescence and backscatter sensors and an ECO-Puck that measured backscatter at three wave-lengths (532, 695, and 700). Both the ECO-Puck and the RBR Concerto was timed according to the ship's GMT time and we used the time-stamp of each image to determine the depth where it was captured from the RBR Concerto.
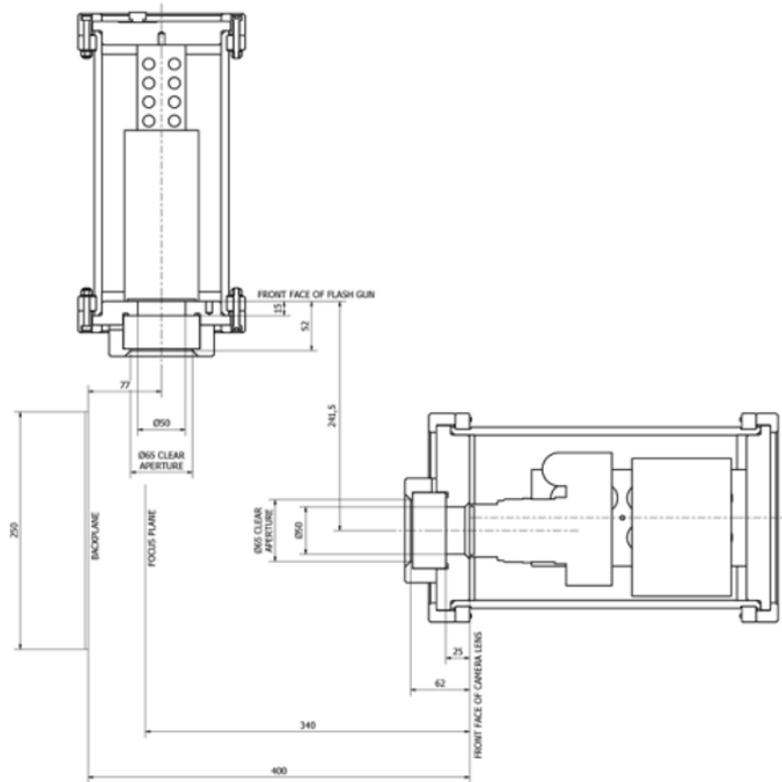
Figure 2.27: Overview figure of the P-Cam configuration. The pressure housing in the lower right part of the image contained the camera and the upper left pressure housing contained the flash gun.

2.13.5   Preliminary results

26 Red Camera Frame profiles were made during the cruise. Generally the P-Cam detected most of the particulate material in the upper 50m of the water column. This was in good agreement with both the fluorescence signal and the turbidity signal from the RBR Concerto. However, the fluorescence signal in the figure below is not calibrated. The particles at depths below 50m were smaller and less abundant. As the cruise progressed, we observed an increasing abundance of faecal pellets at depths below 50 m.
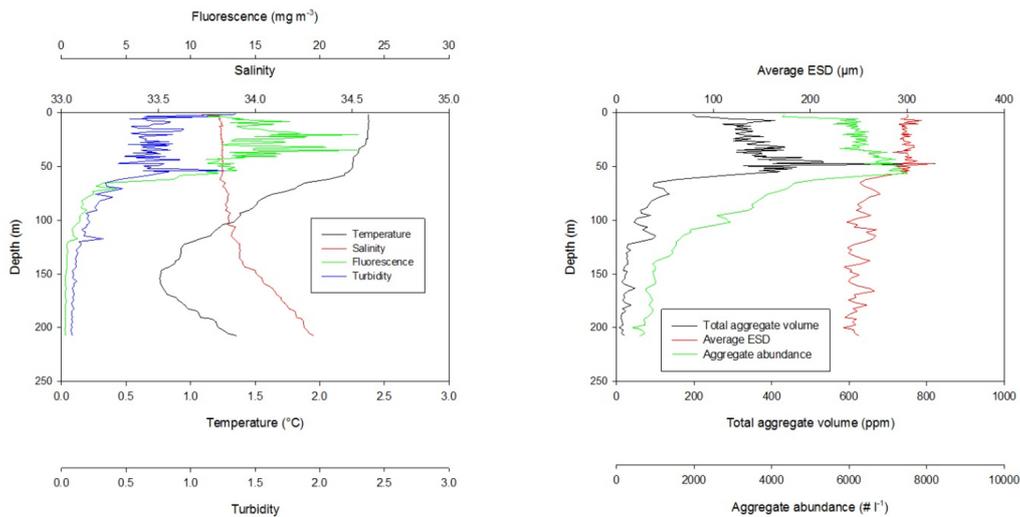
Figure 2.28: Example of a profile with the Red Camera Frame for the RBR Concerto and the P-Cam. RCF003 Event 43.

Table 2.18: Deployment events of the Red Camera Frame. The LIST-HOLO was only on the Red Camera Frame during deployments to 250 m (see Notes in the table). All other deployments (except Event 43) were done to 500 m with the P-Cam, ECO-Puck, and RBR Concerto.

Event	Station	Deployment	Date	Time	Lat (S)	Lon (W)	Notes
34	P3A	RCF001	16-Nov	10:09	52 41.40	40 07.50	250m
36	P3A	RCF002	16-Nov	14:00	52 41.40	40 07.50	500m
43	P3A	RCF003	17-Nov	09:30	52 41.4	40 07.6	
55	P3A	RCF004	17-Nov	15:36	52 41.5	40 08.0	
98	P3A	RCF005	20-Nov	23:50	52 46.52	40 20.96	
99	P3A	RCF006	21-Nov	00:44	52 46.52	40 20.96	
120	P2A	RCF007	24-Nov	01:35	56 24.0	41 13.0	
121	P2A	RCF008	24-Nov	02:19	56 24.0	41 13.0	
145	P2A	RCF009	25-Nov	16:15	56 38.0	40 55.0	
146	P2A	RCF010	25-Nov	17:16	56 38.0	40 55.0	
172	P3B	RCF011	30-Nov	15:09	52 42.27	40 06.14	
173	P3B	RCF012	30-Nov	16:16	52 42.27	40 06.14	
205	P3B	RCF013	02-Dec	14:27	52 41.74	40 15.17	
227	P3B	RCF014	03-Dec	20:25	52 31.0	40 0.21	
228	P3B	RCF015	03-Dec	21:22	52 31.0	40 0.21	
241	P3B	RCF016	04-Dec	18:28	52 41.3	40 20.7	500 m
247	P3B	RCF017	04-Dec	22:32	52 43.24	40 19.57	
258	P3B	RCF018	05-Dec	16:56	52 43.3	40 19.6	
259	P3B	RCF019	05-Dec	17:38	52 43.3	40 19.6	
274	P3C	RCF020	09-Dec	14:25	52 43.2	40 19.7	
293	P3C	RCF021	10-Dec	13:14	52 41.7	40 19.4	
294	P3C	RCF022	10-Dec	13:54	52 41.7	40 19.0	
313	P3C	RCF023	11-Dec	13:30	52 43.0	40 14.3	
314	P3C	RCF024	11-Dec	15:20	52 42.99	40 14.32	
330	P3C	RCF025	12-Dec	19:48	52 38.8	40 12.6	
331	P3C	RCF026	12-Dec	20:20	52 38.8	40 12.6	

2.14　ECO Triplet fluorometer and backscattering sensor

Filipa Carvalho* & Stephanie Henson*
*(National Oceanography Centre)

2.14.1　Overview

A 1000-m rated standalone Wetlabs Environmental Characterization Optics (ECO) Triplet Fluorometer and Backscattering Sensor, measuring backscatter at 2 wavelengths (532nm and 700 nm) and chlorophyll fluorescence was used during DY086. This sensor is the same one found on both Slocum gliders deployed during the cruise as part of the GOCART project and it will be used to improve calibrations between optical backscatter and chlorophyll fluorescence with in situ POC and chlorophyll concentrations data, respectively.

This ECO puck was deployed on the Red Camera Frame (RCF) as well as on the CTD rosette on profiles to a maximum of 1000 m. This sensor does not have a pressure sensor, so it relies heavily on the time variable that is then matched to the RBR (on the red camera frame) and the Seabird CTD (on the rosette). On both deployments, the sensor was horizontal, facing the outside. Two brackets were used to secure the instrument to the RCF. These brackets were also used to secure the instrument to the vane on the CTD rosette frame. Bolts size 17mm were used to secure the brackets onto the frames.

2.14.2　Calibrations

S/N: BB2FLWB-1633

Date: 9/15/2017

CHL (μg L^{-1})= Scale Factor x (Output-Dark counts)

$\beta(\theta_c)$ m^{-1}sr^{-1} = Scale Factor x (Output-Dark counts)

Table 2.19: Factory supplied Parameters used to convert raw data into chlorophyll fluorescence and backscatter concentrations

	ECO Chlorophyll Fluorometer	Scattering meter at 700 nm	Scattering meter at 532 nm
Scale Factor (SF)	0.0305 μg/l/count	3.004E-06 (m^{-1}sr^{-1})/counts	6.974E-06 (m^{-1}sr^{-1})/counts
Maximum output	4130	N/A	N/A
Dark Counts	53 counts	52 counts	53 counts
Resolution	1.2 counts	1.3 counts 3.94E-06 (m^{-1}sr^{-1})	1.3 counts 8.77E-06 (m^{-1}sr^{-1})
Ambient temperature during characterization	21.5 ∘C	N/A	N/A

2.14.3　Standard operating procedures

Prior to the deployment of the RCF and the CTD rosette, the sensor needs to be turned on. A computer with EcoView123 software is required as well as a USB to serial cable (and Windows drivers!) For COMICS 2 we need to acquire one of these so we don't have to rely on the BAS one as well as a field computer running windows!

Before deployment

Bring PC, comms cable and blue power plug

1. Launch EcoView123 software
2. Compare PC clock with ship's clock – VERY IMPORTANT step as this sensor requires accurate time to get pressure from other sensors. If necessary, adjust PC clock (see section 'Adjust Time' below)
3. Remove dummy plugs from sensor
4. Attach blue power plug and comms cable
5. Attach comms cable to PC using USB to serial connector
6. Select COM port (yellow buttons top right) – COM Port 3 on RICS laptop. If different computer, check 'Device Manager'
7. Select Device File (BB2FLWB-1633.dev) from the ECO puck folder
8. Press Stop Data in EcoView123
9. Click Set Date, Set Time and/or Get Date/Time/Setup until correct time appears in top left of window
10. On Meter Setup tab, change settings to:
    (a) Avg/Data Rate 18
    (b) Number of Samples 0
    (c) Number of Cycles N/A
    (d) Cycle Interval N/A
    (e) After each change click the relevant button 'Set …..' to update settings. These settings will run the sensor continuously at 1 Hz frequency until switched off again.
11. Press Turn Logging On
12. Press Store To Flash (yellow Setup not stored message in top right should disappear)
13. When ready to deploy, press Start Data
14. Disconnect comms cable and attach dummy plug
15. Take sensor cap off

Items 11 and 12 are sometimes interchangeable. If the order below doesn't work, try step 12 before step 11.

After deployment

Bring PC, comms cable, dummy plug, bottle of water to rinse instrument and sensor cap.

1. Connect comms cable to PC
2. Select COM port and device file, if necessary
3. Press Stop Data
4. Click Turn Logging Off
5. On Transfer Data tab, click Receive Data and save file
6. Open transferred file with text editor to verify data transfer
7. Press Erase Memory
8. Disconnect comms cable. Disconnect blue power plug.
9. Replace dummy plugs, rinse the instrument and place sensor cap.

Adjust time

To adjust the time to the ship's time server:

1. Right click on the time on the left right corner of the Windows screen
2. Scroll down to 'Additional date, time and regional settings'
3. In the 'Date and Time' menu, select 'Set the time and date'
4. On the 'Internet Time' tab, select 'Change settings'
5. Click 'Synchronize with an 'internet time server'
6. For DY086, the ship's server was 192.168.63.222

2.14.4   Data and operations during DY086

CTD frame

The ECO puck was on the CTD profiles listed in Table 2.20.

Table 2.20: CTD profiles with ECO Puck

Event	Station	Deployment	Date	Time (GMT)	Lat (S)	Lon (W)
101	P3A	CTD009	21-Nov	05:20	52 43.9	40 13.1
108	P3A	CTD010	21-Nov	14:00	52 42.09	40 08.39
118	Argo	CTD011	23-Nov	04:55	53 58.1	41 2.2
122	P2A	CTD012	24-Nov	04:00	56 24.0	41 13.0
144	P2A	CTD013	25-Nov	13:49	56 38.0	40 55.0
166	P3B	CTD017	30-Nov	10:14	52 42.53	40 04.6
252	P3B	CTD023	05-Dec	05:04	52 43.3	40 19.6
287	P3C	CTD027	10-Dec	05:10	52 41.7	40 19.4
319	P3C	CTD031	12-Dec	04:07	52 42.1	40 15.3

Red Camera Frame

The Red Camera Frame deployments with ECO puck are listed in Table 2.21.

2.14.5   Data analysis

Example is shown for a red camera frame profile (Figure 1). Three variables measured by the ECO puck (chlorophyll fluorescence and backscatter at 532nm and 700nm) show reasonable numbers. Differences between upcast and downcast show slight offset due to improper time setup before deployment. A 22 second offset (ECO puck measuring at GMT+22sec) needs to be added to the time to depth conversion.

At 50m, difference is due to rapid ascent (and consequent lower resolution as the instrument is measuring at 1Hz).

For the Red Camera Frame deployments, Morten Iverson assigned depths to the dataset by matching timestamps on the ECO puck and the RBR concerto. The same process needs to be repeated for the CTD DEPLOYMENTS.

The excel files (named EcoPuck_RCF###_Event##_DownCast_COMICS_DY086.xlsx) were then imported to Matlab using *import_ecopuck_xlsx.m*. Data plotting was done using *COMICS_plot_ecopuck.m*.

Table 2.21: Red Camera Frame deployments with ECO puck

Event	Station	Deployment	Date	Time (GMT)	Lat (S)	Lon (W)
34	P3A	RCF001	16-Nov	10:09	52 41.40	40 07.50
36	P3A	RCF002	16-Nov	14:00	52 41.40	40 07.50
43	P3A	RCF003	17-Nov	09:30	52 41.4	40 07.6
55	P3A	RCF004	17-Nov	15:36	52 41.5	40 08.0
98	P3A	RCF005	20-Nov	23:50	52 46.52	40 20.96
145	P2A	RCF009	25-Nov	16:15	56 38.0	40 55.0
146	P2A	RCF010	25-Nov	17:16	56 38.0	40 55.0
172	P3B	RCF011	30-Nov	15:09	52 42.27	40 06.14
173	P3B	RCF012	30-Nov	16:16	52 42.27	40 06.14
205	P3B	RCF013	02-Dec	14:27	52 41.74	40 15.17
227	P3B	RCF014	03-Dec	20:25	52 31.0	40 0.21
241	P3B	RCF016	04-Dec	18:28	52 41.3	40 20.7
247	P3B	RCF017	04-Dec	22:32	52 43.24	40 19.57
258	P3B	RCF018	05-Dec	16:56	52 43.3	40 19.6
259	P3B	RCF019	05-Dec	17:38	52 43.3	40 19.6
274	P3C	RCF020	09-Dec	14:25	52 43.2	40 19.7
293	P3C	RCF021	10-Dec	13:14	52 41.7	40 19.4
294	P3C	RCF022	10-Dec	13:54	52 41.7	40 19.0
313	P3C	RCF023	11-Dec	13:30	52 43.0	40 14.3
314	P3C	RCF024	11-Dec	15:20	52 42.99	40 14.32
330	P3C	RCF025	12-Dec	19:48	52 38.8	40 12.6
331	P3C	RCF026	12-Dec	20:20	52 38.8	40 12.6

Figure 2.29: Depth profiles of data collected using the ECO puck on the Red Camera Frame. Upcast (light colours) and downcast (dark colours) raw data are shown in dots and 20-point moving average in solid line.

## 2.15	Dissolved oxygen

Mark Stinchcombe*
*(National Oceanography Centre)

### 2.15.1	Methods and equipment

Dissolved oxygen was measured on the majority of stainless steel CTD casts during DY086 to calibrate the dissolved oxygen sensor on the CTD. A full list of casts and the number of samples and duplicates can be found in Table 2.22. Samples for dissolved oxygen were taken first from each cast, the deepest Niskin being sampled first. A piece of silicaon tubing, approximately 20 cm long and kept in a bucket of water between casts, was attached to the spigot of the Niskin bottle. Water was collected into wide neck borosilicate glass bottles, the tube being put to the bottom of the bottle and being allowed to overflow, using the tube to wash down the insides of the bottles. Once washed the tube was kept stationary at the bottom of the tube and the bottle was allowed to overflow for approximately three times as long as it takes to fill up, i.e. being flushed by at least three times its volume, before the tube was pinched to stop the flow of water and carefully removed from the sample bottle.

Once filled, the temperature of the sample is measured using a Checktemp Electronic Thermometer by Hanna Instruments (Code: HI98509) and recorded onto a logsheet. The sample was then fixed by adding 1ml of a manganese (II) chloride solution (600 g L^{-1}) using an automatic dispenser, followed by 1ml of an alkaline iodide solution (320 g L^{-1} sodium hydroxide and 600 g L^{-1} sodium iodide) also via an automatic dispenser. The nozzles of the dispensers were placed gently below the surface of the sample to prevent bubbles being drawn into the sample.

The lids of the bottles were gently inserted into the bottle at a slight angle, again to prevent bubbles being trapped in the bottle with the sample. The now filled sample bottles were shaken vigorously for approximately 30 seconds to allow the reagents to mix and form the precipitate before being placed back in the crate. The sample bottles were allowed to sit for approximately an hour to let the precipitate settle before being shaken again for approximately 30 seconds and allowed to settle for a second time. Once settled, again approximately 1 hour, the samples were ready for analysis.

The analysis was done using a Metrohm 716 DMS Titrino. 1 mL of 280 mL L^{-1} sulphuric acid was added to the sample, as well as a stirring bar, and put on a magnetic stirrer. It was then titrated with 50 g L^{-1} sodium thiosulphate solution using an electrode with amperometic end-point detection. The resultant volume of titrant was converted to a dissolved oxygen concentration. Five times during DY086 a blank check of the reagents and a standardisation of the sodium thiosulphate was completed using potassium iodate standard from OSIL. These results can be seen in Tables 2.23 and 2.24.

Full calibration of the dissolved oxygen sensor on the CTD will take place back at the NOC, however some preliminary comparisons were performed between the sensor data and the discrete sample data. These can be seen in Figures 2.30 and 2.31. Figure 2.30 shows comparisons between the reiduals and station number and depth (a and c) and CTD oxygen against discrete oxygen. The residual value is just the difference between the sensor and the discrete samples and it should be noted that these are prior to calibration. There was a difference in residual value for stations three, five and six compared to the rest of the stations (Figure 2.30a). This difference was also apparent when comparing the CTD sensor data to the discrete sample data (Figure 2.30b). There was also a difference in residual values with depth (Figure 2.30c). To check whether this was the sensor or the discrete samples we plotted both against depth (Figure 2.31). This showed that the shift was in the CTD sensor data and not the discrete sampling, and so would be corrected for once the full calibration was completed.

Table 2.22: The number of depths sampled for dissolved oxygen for each CTD cast and the number of duplicates also sampled.

CTD	Depths Sampled	Number of Duplicates
2	16	4
3	12	3
5	15	6
6	12	6
9	12	5
10	7	7
11	12	4
12	12	4
16	11	4
20	13	0
21	12	3
22	15	0
23	12	3
27	12	5
28	11	3
31	12	5
33	12	4

Table 2.23: The volume sodium thiosulphate required to titrate 5 mL of the potassium iodate standard for the standardisation procedure. The figures marked with an * are not used in the final calculation.

Date	Volume of Sodium Thiosulphate								Average	Std Dev
15.11.2017	0.485	0.482	0.4805	0.481	0.4845				0.4826	0.002
18.11.2017	0.4875*	0.4795	0.4805	0.479	0.48	0.482	0.48	0.48	0.4801	0.0009
22.11.2017	0.5885*	0.477	0.4775	0.477	0.4775	0.477			0.4772	0.0003
30.11.2017	0.4815	0.4815	0.481	0.4805	0.4815				0.4812	0.0004
09.11.2017	0.4795	0.478	0.478	0.478	0.479	0.4765	0.4775		0.4781	0.001

Table 2.24: The volume of sodium thiosulphate required to titrate 1 mL of potassium iodate standard for the reagent blanks.

Date	Volume of Sodium Thiosulphate			1st – Avg(2nd&3rd)	Average	Std Dev
	1st	2nd	3rd			
15.11.2017	0.0995	0.0985	0.0975	0.0015	0.0007	0.0007
15.11.2017	0.0985	0.0985	0.098	0.0003		
15.11.2017	0.0985	0.0975	0.099	0.0003		
18.11.2017	0.099	0.0975	0.0985	0.001	0.0009	0.0003
18.11.2017	0.099	0.098	0.0985	0.0008		
18.11.2017	0.0995	0.0985	0.098	0.0013		
18.11.2017	0.0985	0.098	0.098	0.0005		
18.11.2017	0.0975	0.0975	0.0985	-0.0005		
22.11.2017	0.098	0.0975	0.0965	0.001	0.0005	0.0005
22.11.2017	0.0975	0.097	0.097	0.0005		
22.11.2017	0.097	0.097	0.097	0		
30.11.2017	0.0975	0.0985	0.097	-0.0003	0.0016	0.0017
30.11.2017	0.097	0.0985	0.098	-0.0013		
30.11.2017	0.098	0.099	0.0975	-0.0003		
30.11.2017	0.1	0.098	0.0985	0.0018		
30.11.2017	0.098	0.0995	0.0975	-0.0005		
30.11.2017	0.101	0.099	0.098	0.0025		
30.11.2017	0.1015	0.1	0.0975	0.0028		
30.11.2017	0.098	0.0985	0.098	-0.0003		
09.12.2017	0.1	0.0965	0.097	0.0033	0.003	0.0006
09.12.2017	0.1	0.096	0.0965	0.0038		
09.12.2017	0.0995	0.096	0.0975	0.0028		
09.12.2017	0.099	0.097	0.0965	0.0023		
09.12.2017	0.0995	0.097	0.096	0.003		
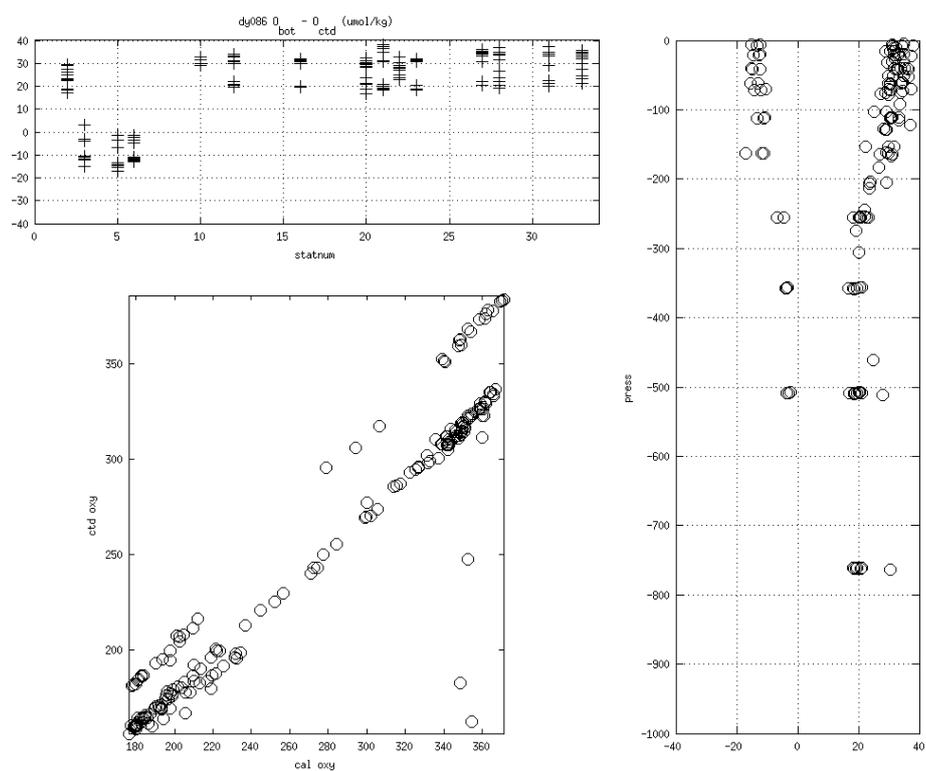
Figure 2.30: Plots of (a) residual value against station number, (b) CTD value against discrete sample value, and (c) residual values against depth.
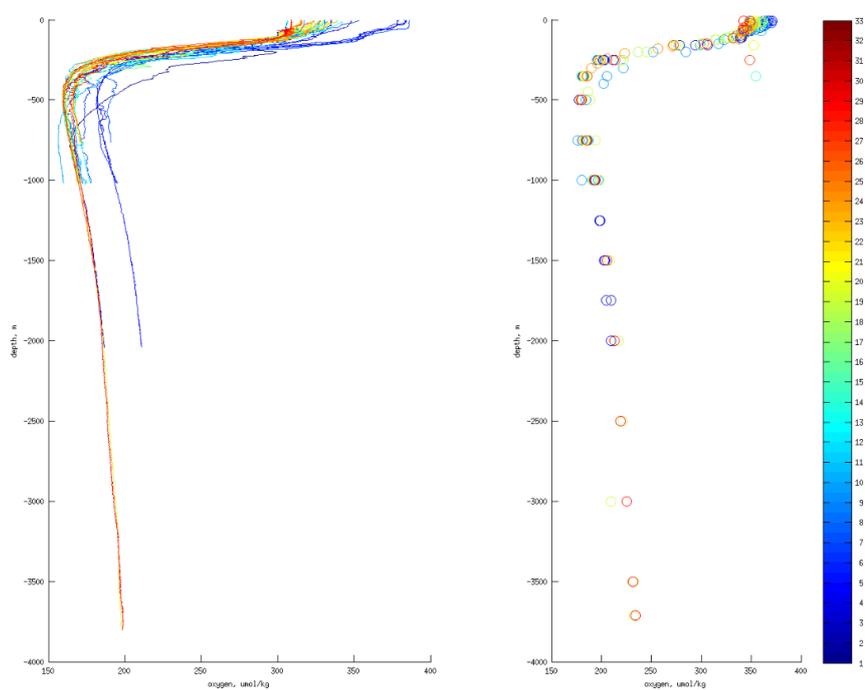
Figure 2.31: Plots of (a) CTD dissolved oxygen against depth, and (b) discrete dissolved oxygen against depth.

2.16 Inorganic nutrients

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2.16.1 Methods and equipment

During DY086 water samples were analysed for the determination of inorganic nutrient concentrations. The analyses were for nitrate and nitrite (NO_3+NO_2), silicate (SiO_2), nitrite (NO_2) and phosphate (PO_4). The water samples were drawn from Niskin bottles from the majority of the stainless steel CTD's and a few of the titanium CTDs, underway samples drawn from the ships non-toxic water supply in the Clean Seawater Laboratory, experimental water samples from other scientific personnel as well as a few other samples here and there when requested.

Sampling protocols used were similar regardless of where the samples was drawn from. From the Niskin bottles for example, pre-labelled 15 mL centrifuge tubes were rinsed three times with water from the same Niskin that was being sampled, before being filled to between the 10-15 mL level. Where possible all samples were stored in pre-labelled centrifuge tubes that had been rinsed 3 times with the same water as the sample was taken from. Only if sample volume was restricted, for example some of the experimental water samples, was rinsing reduced.

Analysis was within 24 hours of the samples being taken, although on a few occasions it was after 36 hours. Analysis was on a QuAAtro 39 segmented flow autoanalyser linked to a XY-2 Sampler, both by SEAL Analytical UK Ltd, and controlled via a DELL Latitude laptop using the appropriate software package supplied by SEAL, called AACE 7.09. The chemistry methods used were also supplied by SEAL and can be seen in Table 2.25.

During runs, an artificial seawater (ASW) solution was used as a wash, to provide the baseline and was also the matrix that the mixed calibrants were made up in. It was a 40 g L^{-1} sodium chloride solution using analytical grade sodium chloride from Fisher Scientific (S/3160/68, lot number 1557449). The background nutrient concentration of the ASW was determined by comparing the change in the baseline between ultra-pure water (MQ) and ASW. A low-level standard was used to gauge the concentration of the change. The background concentrations can be found in Table 2.26 and these concentrations were used in the calibration as an extremely low standard and were taken into account for the correlation coefficient calculation (see below).

2.16.2 Analyser performance

During DY086 NN analytical runs were completed. Certain parameters were noted for every run to determine how well the system was behaving. Here are the parameters recorded and a brief description of their meaning and how they are calculated:

1. **Baseline/Offset** – sets the baseline to 5% of the chart window. During a run, the AACE software shows data as a percentage of the chart window so that the Y-axis is always 0-100%.

Table 2.25: Inorganic nutrient method documents used during DY086 for QuAAtro applications as supplied by SEAL Analytical UK Ltd.

Channel Number	Method Name	Method Number	Low Range (μmol L^{-1})	High Range (μmol L^{-1})
1	Nitrate and nitrite in water and seawater (with Cd coil)	Q-068-05 Rev. 11	$0-5$	$0-250$
2	Silicate in water and seawater	Q-066-05 Rev. 5	$0-5$	$0-165$
3	Nitrite in water and seawater	Q-070-05 Rev. 6	$0-1$	$0-45$
4	Phosphate in water and seawater	Q-064-05 Rev. 8	$0-1.3$	$0-6$

Table 2.26: Background concentration for the ASW wash.

Channel Number	Chemistry	ASW concentration (μmol L^{-1})
1	NO_3+NO_2	0.08
2	SiO_2	0.37
3	NO_2	0.06
4	PO_4	0.00

2. **Gain** – sets the top standard to 90% of the chart window. The higher the standard the smaller the gain as less change is required to set the chart window.

3. **Correlation Coefficient** – a measurement of the accuracy with which the calibration standards fit the linear calibration used during DY086. A correlation coefficient of >0.999 is required for high accuracy.

4. **Sensitivity** – calculated for the primer on each run using the following formula, where AD is absorbance:

$$E_{primer} = \frac{(AD_{primer} - AD_{Base}) \cdot 10}{MaxAD \cdot Gain}$$ (2.5)

5. **Coefficient of Variation** – in each run, twenty replicates of the top standard were analysed to calculate this as a percentage.

6. **Detection Limit** – AACE uses the procedure described in US EPA document Pt. 136 App B. for 'Method Detection Limit', which is defined as the standard deviation of multiple measurements of a near-zero sample multiplied by a factor between 2.3 and 3.1 depending on the number of measurements. Twenty replicates of the lowest standard were used.

7. **Cadmium Coil Efficiency** – for NO_3+NO_2 analysis, NO_3 is reduced to NO_2 using cadmium in a coil. The efficiency of this reduction is calculated by comparing a NO_2 sample of known concentration to an identical concentration NO_3 sample. Efficiency should be above 90%.

The following sections show plots of each of the above parameters with a description of any important features or changes seen over the course of DY086. Please note that although during DY086 NN analytical runs were completed, not all of these were for just inorganic nutrients. Some of the runs also included biogenic silica samples, and some runs were for biogenic silica samples only. Please see section 2.17 for biogenic silica methods and during these runs only channel 2 (SiO_2) was used. This explains the apparent gaps in recorded parameters for NO_3+NO_2, NO_2 and PO_4.

Baseline/offset

The baseline (or offset) of the wash solution is always set at 5% of the chart window. However, recording the actual absorbance values for the baseline can give an indication of stability of the wash solution as the values may change if a higher or lower wash is used. It may also change if there are changes in the reagents, although some variation is to be expected. Figure 2.32 show the baseline values for all four nutrient chemistries. The baseline for SiO_2, NO_2 and PO_4 remained stable throughout DY086 with only minor variation. Only the baseline for NO_3+NO_2 showed any great change between the 23rd and 25th of November. This coincided with a change in the artificial seawater and a reactivation of the cadmium coil. Either of these could have caused the baseline to change. Having checked the sensitivity and gain, which would also have changed at this point if there was a contamination or reagent absorbance issue, there was no corresponding shift and so the system seems to have remained stable (see following section for cadmium coil efficiency, gain and sensitivity values)
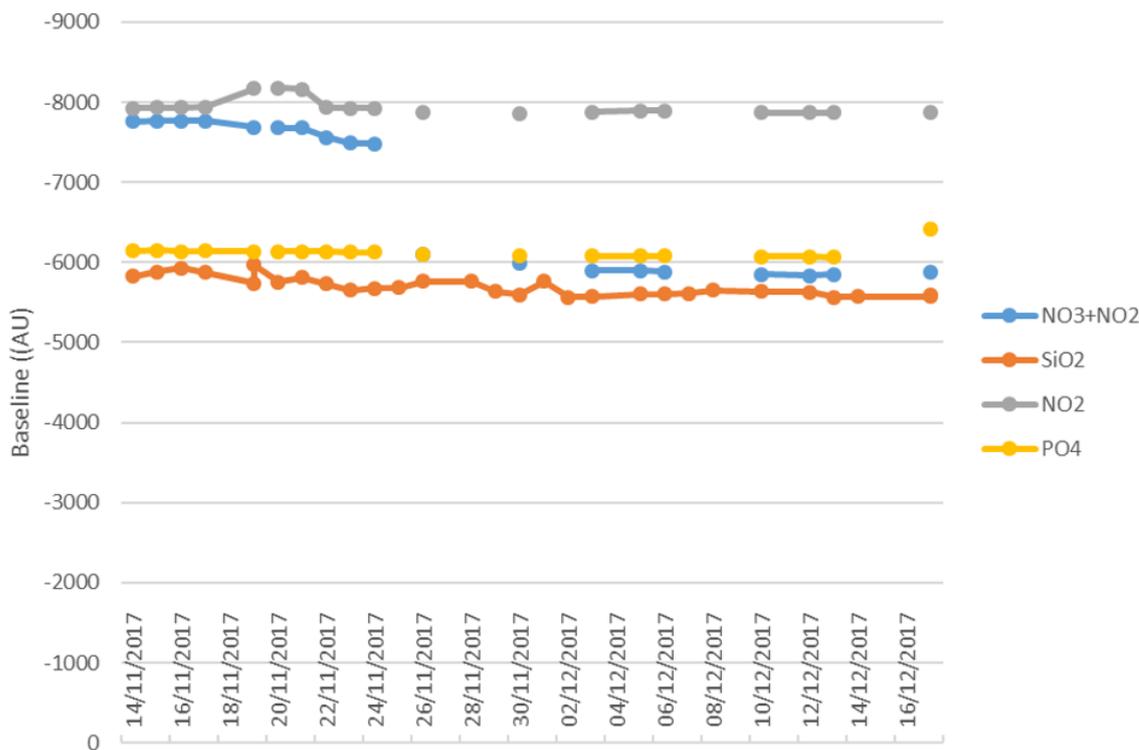
Figure 2.32: Baseline values for all chemistries during DY086.

Gain

The gain is set by running the highest sample through the system and selecting 'set gain' in the software. The chart window is then automatically adjusted so that the top standard peak sits at the 90% point. If there were problems with the standards, reagents or cadmium coil efficiency for the NO_3+NO_2 then the gain would start varying. Figure 2.33 shows the gain values for each chemistry throughout DY086. The gain for NO_3+NO_2, SiO_2 and NO_2 was extremely stable. The slight changes that can be seen in the first three data points coincide with where the top standards were being adjusted to best fit the sample range. After the third run the top standards were set for the rest of DY086. The gain for PO_4 did vary at times. These variances were due to the reagents going off and so the peaks of the top standard were reducing causing an increase in the gain. This increase can be seen between 14th and 16th November and 22nd and 26th November. The reagents were then changed, causing the gain to drop again.

Correlation coefficient

The correlation coefficient shows how close the standards are to a true linear calibration. The standard concentrations used during DY086 can be seen in Table 2.27. The concentrations were amended after the first runs to best cover the sample range. These early standard concentrations are not shown here as these runs were either standard test runs or the samples were rerun with the new standards. The stated correlation coefficient value for high accuracy is greater than 0.9990, the highest possible value is 1. As can be seen in Figure 2.34 the correlation coefficient for all chemistries during all runs was higher than 0.9990. In fact, the lowest value seen throughout DY086 was 0.9996 and this low value only occurred once.

Sensitivity

The sensitivity is a ratio of the absorbance units for the primer peak against the total absorbance units possible and is calculated using the equation at the start of this section. The methods have a
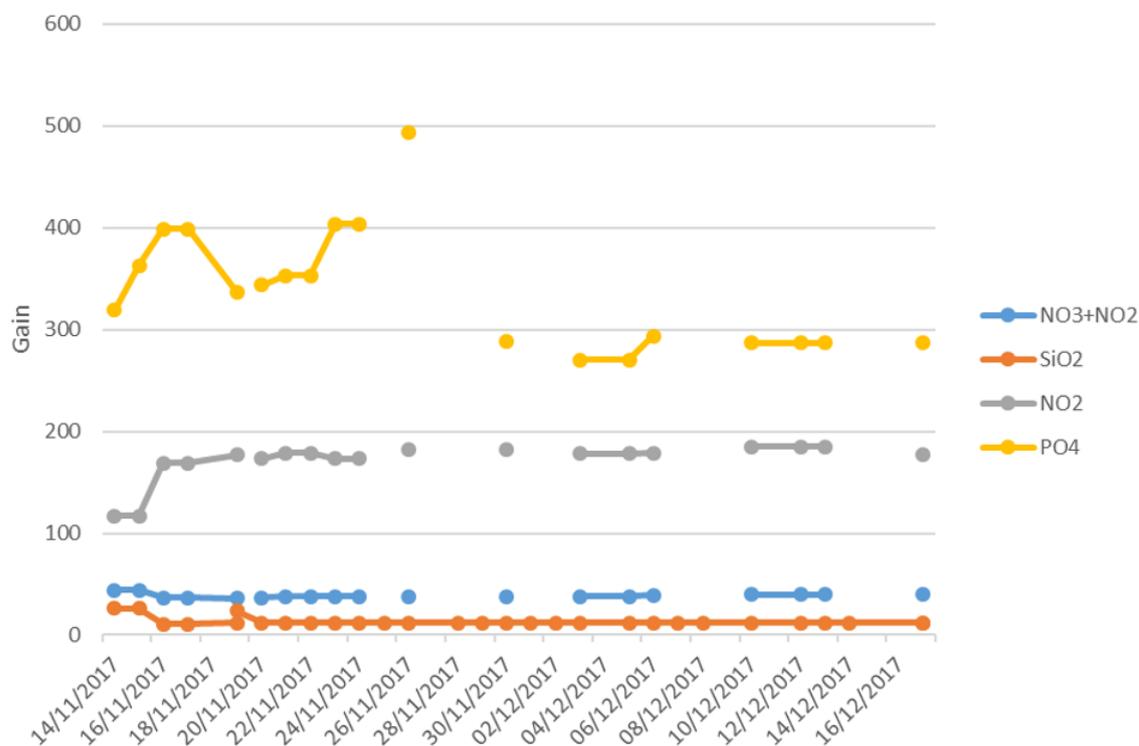
Figure 2.33: The gain values for all the chemistries throughout DY086.

Table 2.27: The standard concentrations used for each chemistry during DY086.

Chemistry	Baseline	Standard 1 (μmol L^{-1})	Standard 2 (μmol L^{-1})	Standard 3 (μmol L^{-1})	Standard 4 (μmol L^{-1})	Standard 5 (μmol L^{-1})
NO_3+NO_2	0.08	7.30	14.83	22.46	30.09	37.71
SiO_2	0.37	5.39 (to 8.12.17) 2.38 (from 10.12.17)	30.49	55.59	80.69	110.81
NO_2	0.06	0.16	0.56	1.07	1.57	2.08
PO_4	0.00	0.51	1.01	1.52	2.02	2.53
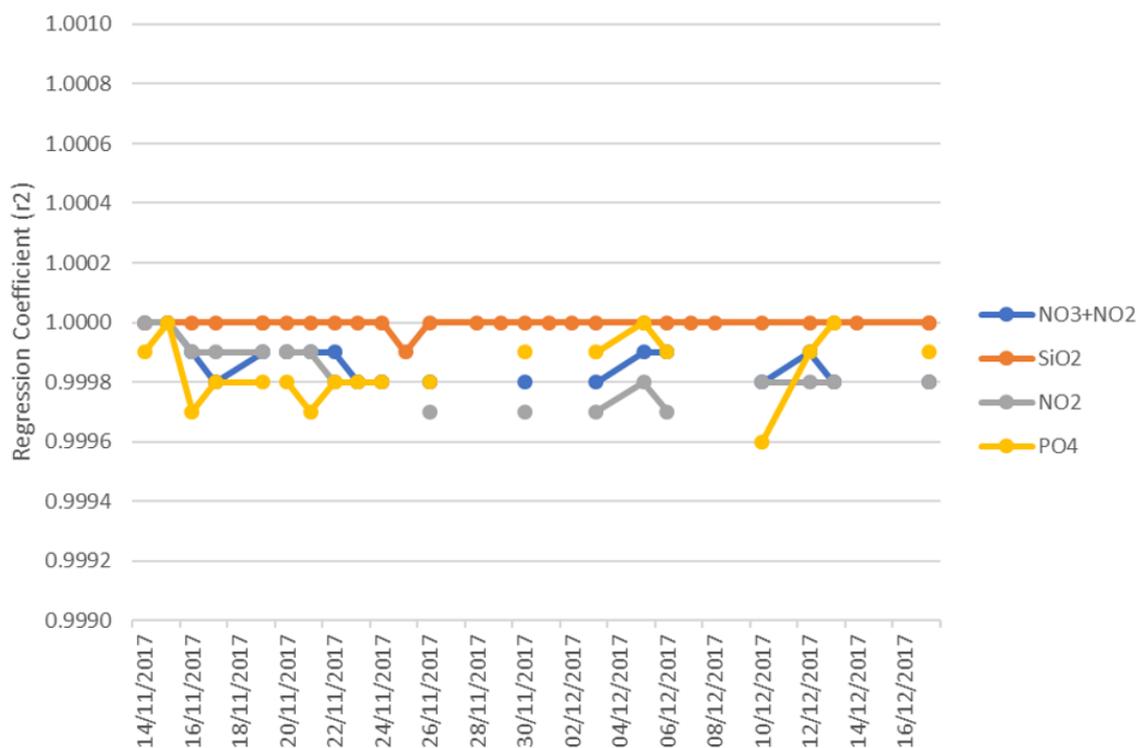
Figure 2.34: Correlation coefficients for all the chemistries during DY086.

Table 2.28: Method Sensitivity Range (at top standard concentration)

Chemistry	Sensitivity Range	$\pm 15\%$ acceptance limit
NO_3+NO_2	0.124 - 0.143	0.093 - 0.164
SiO_2	0.554 - 0.665	0.415 - 0.765
NO_2	0.042 - 0.050	0.032 - 0.058
PO_4	0.032 - 0.044	0.024 - 0.051

target sensitivity range and the sensitivity of the runs should be within $\pm 15\%$ of this range. The target range, and the $\pm 15\%$ acceptance limits, can be seen in Table 2.28. The sensitivity values fo each chemistry across the whole of DY086 can be seen in Figure 2.35. This shows that the sensitivity for SiO_2, NO_2 and PO_4 in each run is within the acceptable bounds of the methods. The changes in sensitivity in SiO_2 can be attributed to the fact that for the runs with the lower values, a lower top standard was used. It was roughly half the value of the normal top standard and the sensitivity is also roughly half the value so it can be concluded that it is ok for these runs too. There was a slight change in NO_2 and PO_4 top standard concentrations too after the first couple of runs and these can also be seen. The sensitivity for NO_3+NO_2 is a little high, averaging at just over 0.20 when it should be no higher than 0.16. This is most likely due to the reagents, possibly a higher than normal contaminant in one of them. All reagents were analytical grade and newly opened on DY086. As there was no way to change the reagents, and due to the fact that all the NO3+NO2 samples were high (15 μmol L^{-1} or above in most cases), the higher sensitivity value was not thought to be an issue.

Coefficient of variation

The coefficient of variation was determined at the high standard concentration during every run by analysing 20 replicates of the high standard. This would allow the reproducibility at the high end of
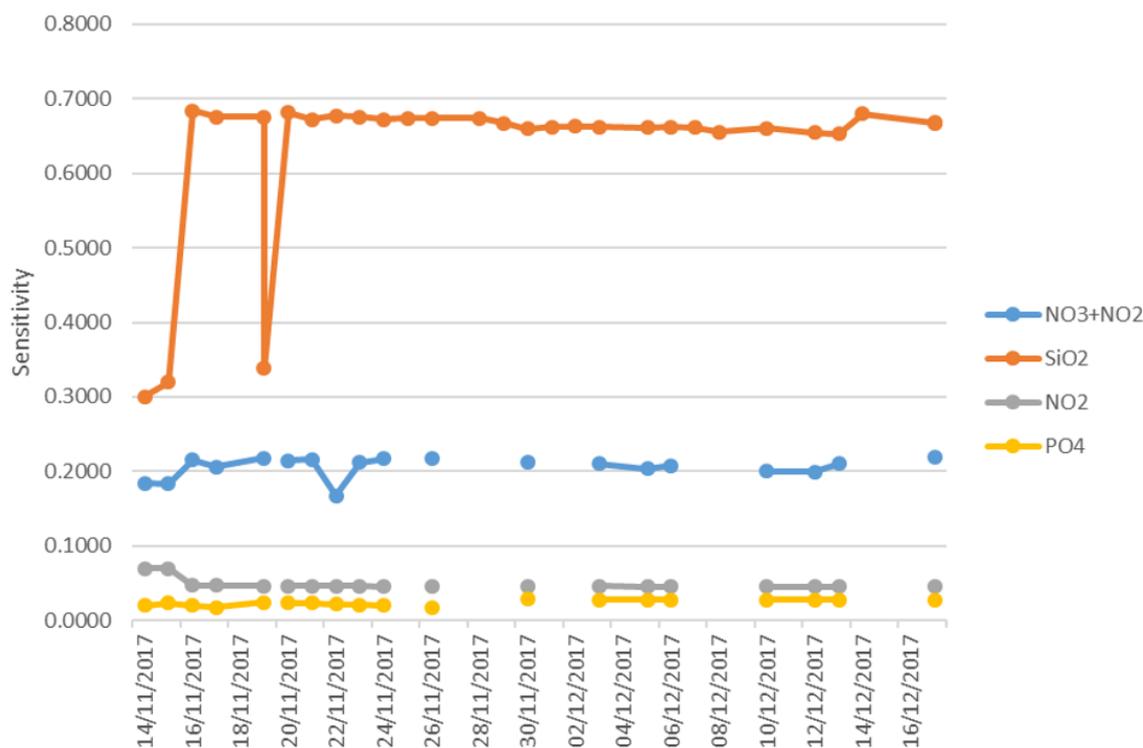
Figure 2.35: Method sensitivities for each chemistry during DY086.

the concentration range to be calculated. The coefficient of variation values for each chemistry can be seen in Figure 2.36. For all chemistries, the coefficient of variation was below 0.5% for almost all runs and there was only one point where it was above 0.6%. This higher value (0.85%) was for the NO_3+NO_2 chemistry and coincided with a sudden large drop in the cadmium coil efficiency (see section on cadmium coil efficiency). Once this was correct the coefficient of variation dropped again to below 0.5%.

Detection limit

The detection limit was calculated from 20 replicates of the lowest concentration standard for each run. The detection limit for each chemistry during DY086 can be see in Figure 2.37. For NO_2 and PO_4 he detection limit stayed stable throughout DY086 at approximately 0.00 µmol L^{-1} and 0.01 µmol L^{-1} respectively. The detection limit for NO_3+NO_2 and SiO_2 varied a bit more at the start of DY086 but became stable from the 23rd November onwards. Even with the variation of 0.02 – 0.16 µmol L^{-1} for NO_3+NO_2 and 0.02 – 0.11 µmol L^{-1} for SiO_2, the samples analysed were never below detection. The large spike in the NO_3+NO_2 coincides with the drop in cadmium coil efficiency.

Cadmium coil reduction efficiency

Throughout DY086 the efficiency of the reduction from NO_3 to NO_2 by the cadmium coil was calculated by comparing a single NO_2 standard against a single NO_3 standard (Figure 2.38). If the efficiency started reducing then the NO_2 standard would start increasing in size compared to the NO_3 standard. The efficient should be kept as close to 100% as possible and certainly above 90%. A couple of times during DY086 the efficiency started to decrease but each time it was brought back to 100% once reactivated with dilute hydrochloric acid and copper (II) sulphate. Only once did it drop dramatically to below 90%.
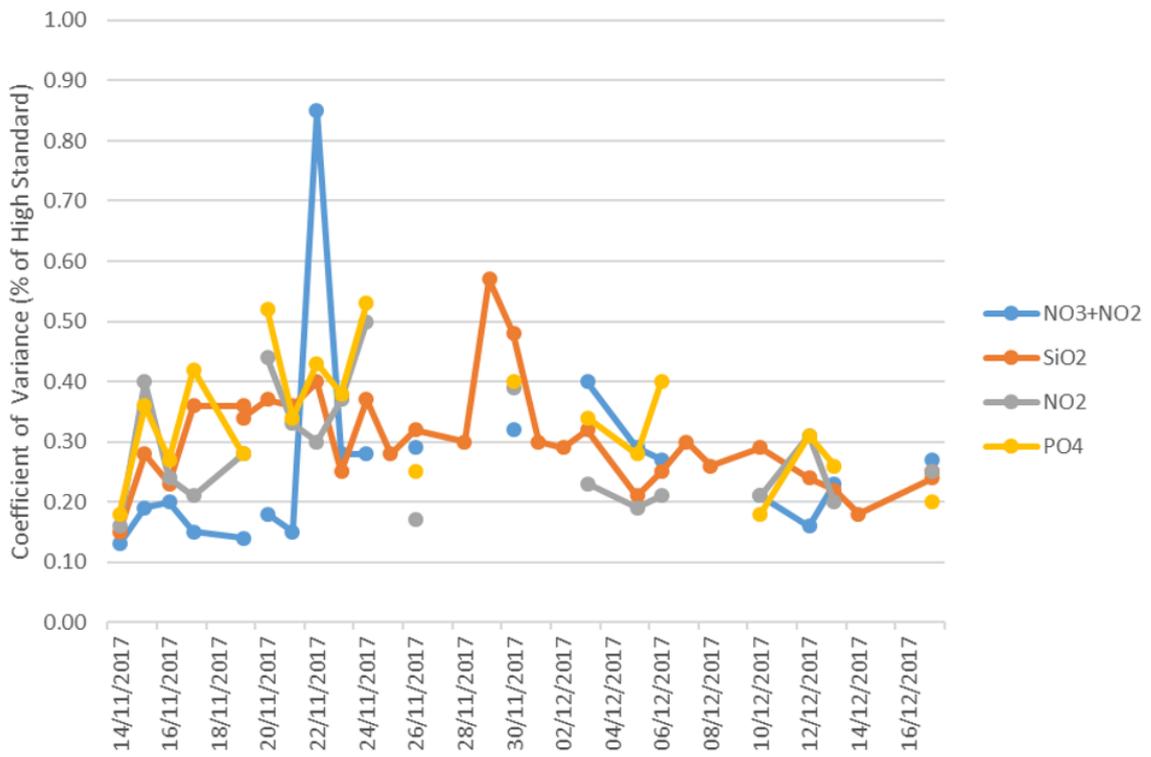
Figure 2.36: Coefficient of variation values for all the chemistries during DY086.
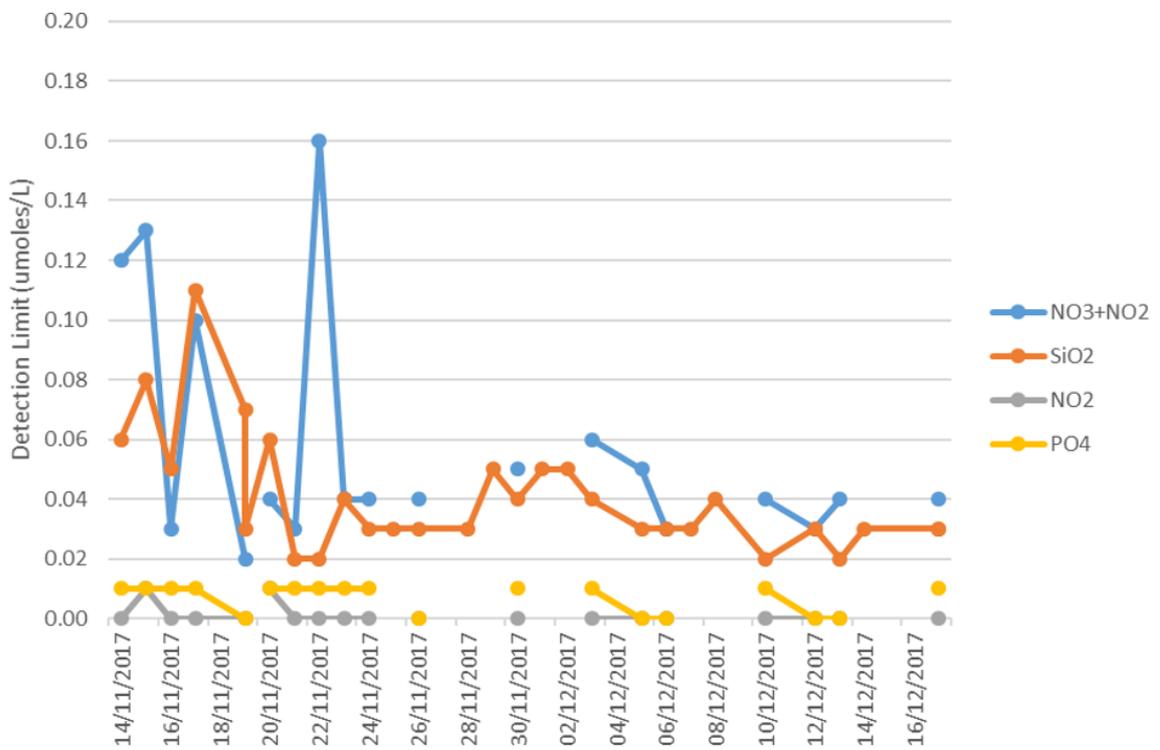
Figure 2.37: Detection limits for each chemistry thoughout DY086.
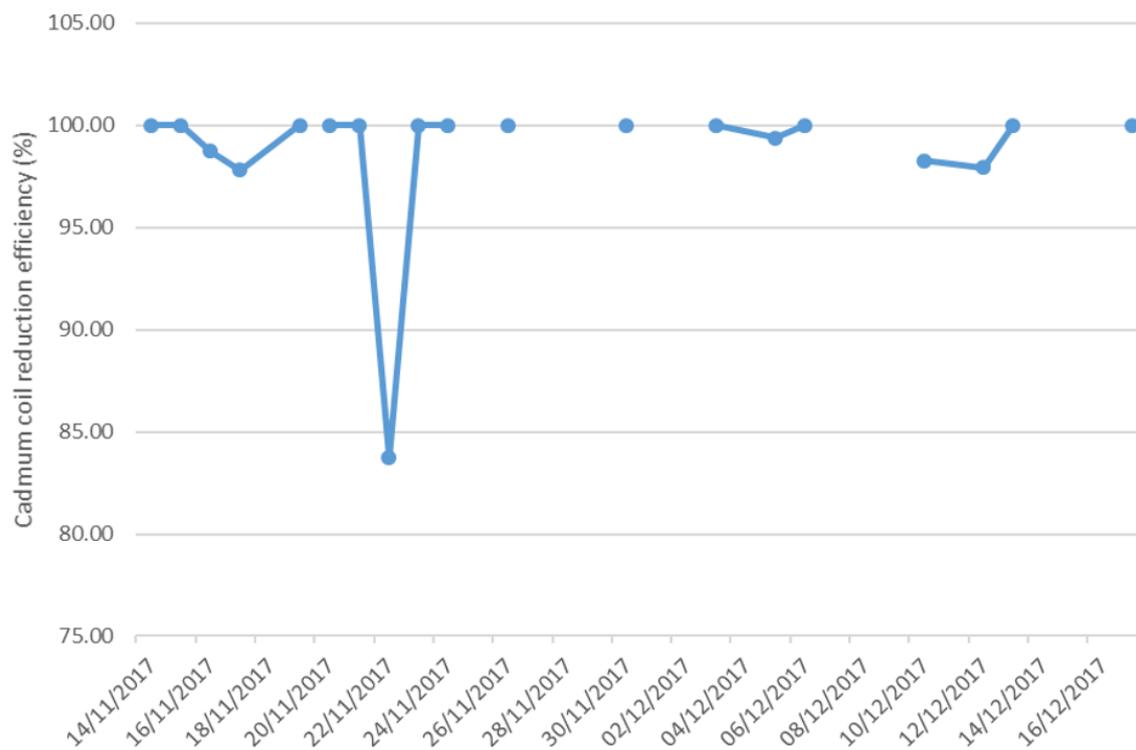
Figure 2.38: The cadmium coil reduction efficiency during DY086.

Table 2.29: DY086 CTD Niskin bottle misfires.

CTD	Niskin misfired	Target depth	Approximate depth
CTD009	5	350 m	
CTD012	13	70 m	
CTD016	5	350 m	
CTD021	11	110 m	40-50 m
CTD022	11	450 m	3500-bottom
CTD023	8	160 m	25-50 m
CTD031	6	250 m	40-50 m

CTD niskin misfires

The nutrient profile can be used to check whether the CTD Niskin bottles fired at the correct depth. If there was a misfire there would be a high concentration where a low cocnetration would be expected, or vice versa. All the misfired Niskins can be seen in Table 2.29.

2.17 Biogenic silica

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2.17.1 Method

Filters for the determination of biogenic silica were placed in a 15 mL centrifuge tube. The tubes were put in an oven set at 50°C for at least twelve hours to dry completely. The tubes were then sealed and the sample was stable at room temperature until they could be analysed. To be analysed the biogenic silica first needed to be digested and in solution. They were digested by adding 5 mL of a 0.2 M sodium hydroxide solution to the 15 mL tube and then incubated in an oven at 85°C for two hours. Once removed they were allowed to cool to room temperature before being neutralised by adding 0.2 M hydrochloric acid solution. This solution then was analysed using normal colourimetric techniques for silicate analysis. See Brown et al (2003) for a full description of the biogenic silica method and section 2.16 on the analytical methods used for silicate analysis during DY086.

2.18   Organic biogeochemistry

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2.18.1   Objectives

Organic biogeochemical analyses have been used to understand pelagic foodwebs for many years, although such observations focussing on the biological pump in the mesopelagic are few (Wolff et al., 2011; Salter et al., 2012). There is considerable variability in the composition, and hence fate, of exporting organic particles, potentially affecting the efficiency of the biological pump. This is driven partly by the nature of the surface primary production, but also by the function of mesopelagic ecosystems that rely upon it.

Certain organic chemicals such as fatty acids, sterols, pigments, or amino acids encountered in these particles can retain information on their biological origin (often termed biomarkers). Changes in the distributions of biomarkers and their isotopic composition can shed light on the transformations of the organic material as it sinks through the water column. In addition, biomarkers and their stable isotopic composition are often used to trace the trophic relationships of many marine communities. This may help to determine the trophic transfer efficiency (i.e. the energy transfer) of the mesopelagic ecosystems of the twilight zone, a key component in understanding loss of bioavailable carbon from the system.

Collecting particles from the water can be carried out in a variety of ways. Large volume in situ filtration systems (SAPS) and sediment traps (fixed or free drifting) have been used routinely for this purpose, recently some workers have been using marine now catchers (e.g. Cavan et al. in prep). SAPS can pump several hundred L of water through a filter in a short period of time (usually 1-2 hours), thus providing a large and presumably representative sample. The particles that are collected by SAPS can be heterogeneous with unknown but probably variable sinking speeds, whereas sediment traps are thought to better capture the vertically sinking particles. Marine now catchers (MSCs) have the potential to sample the full spectrum of particles (i.e. total, suspended, slow sinking and fast sinking) by fractionated sampling although the technique is at an early stage (see Cavan et al., in prep). Filter screens (mesh filters of a certain pore size) have occasionally been used to fractionate the particles collected by SAPS into 'large' and 'small' pools however little is known about the relationship between the SAPS and MSC fractionations. The exchange mechanisms between these different "pools" of particles are virtually unknown but can potentially affect the export of organic matter at depth. Comparison of the chemical composition between the different pools of particles sampled concurrently and at similar water depths may provide a new insight in these processes.

2.18.2   Particle sampling with Stand Alone Pumping Systems (SAPS)

Particulate material from a range of water depths was collected using standalone pumping systems (SAPS; Challenger Oceanic; Table 2.30). Two size fractions were recovered (see Table 2.30). The small particle fraction (>53 μm) was collected on large (293 mm diameter) precombusted (400°C; 4 h) GF/F filters (nominal pore size 0.7 μm). Each SAPS carried two stacked GF/F filters.

Large particles were collected on acid (10% HCl) cleaned Nylon mesh screens (Nitex; pore size 1 μm) that were placed on top of the GF/F filters. Upon recovery the Nitex screens were carefully placed on the side of a suitably large funnel and rinsed with Thorium-free seawater into 1 L acid (10% HCl) clean glass bottles. Thorium-free seawater was obtained by filtration through ashed GFF filters. The volumes of filtering ranged between 0.6 – 1 L; see Table 2.30). The filters were rinsed with MilliQ ph 8 adjusted water. The water was then split as follows:

- 1/2 for organic biogeochemical work (i.e. POC, PIC, PN, lipids, amino acids, stable isotopes) to be carried out in ULIV/LJMU
- 1/4 for Thorium analyses (see Section 2.30)
- 1/4 for Polonium analyses

The Polonium splits were stored in clean plastic bottles for further processing (see methods in Section 2.31). The portion for organic biogeochemical analyses was then filtered using a glass rig through precombusted (400°C; 4 h) 47 mm GF/F filters; these were then temporarily frozen at -80°C and subsequently freeze-dried for easier transport to the UK.

Five SAPS units were used on the same deployment (depth profile deployments) and the pumps were operated for 1 or 1.5 hours (see Table 2.30). There was at least one pump in the mixed layer (ML), one at or close to the bottom of the ML, one at 150-170 m (i.e. ca. ML + 100 m), one at 250-260 m (ca. ML + 200 m) and one are 440-460 m. Operating issues relating to wire length from the winch used prevented deeper deployment (i.e. closer to 500 m). There were two depth profile deployments in P3A and P3B and one in P3C. Flat batteries were the reason that one of the pumps (belonging to ULIV/LJMU) did not operate at the shallowest depth (30 m) in the last profile deployment at P3C (see Table 2.30). For exact dates, depths, coordinates and volumes pumped see Table 2.30.

2.18.3   Particle sampling with Marine Snow Catchers (MSC)

Particulate material from a range of water depths (depth profile) was also collected using four Marine Snow Catchers (MSCs; for full operating details see Section 2.29). The depths were ca. 30 – 50 m for obtaining material in th ML, then ca. 75 -100 m, 150 – 165 m, and 500 m. For full details see Table 2.31. From each MSC samples were collected as follows:

- Immediately upon recovery; these presumably represent non- fractionated (i.e. all) particles, similarly to samples from CTD bottles (labelled tzero in Table 2.31).
- After ca. 2 h from the top chamber of the MSC; these presumably represent suspended particles (labelled 'top' in Table 2.31)
- After ca. 2 h from the bottom chamber of the MSC, presumably representing slow-sinking particles (labelled 'bottom' in Table 2.31)
- After ca. 2 h from the tray installed at the centre of the bottom chamber of the MSC, presumably representing fast-sinking particles (labelled 'tray' in Table 2.31)

Once water was sampled in clean plastic carboys the particles were collected by filtration, using a glass rig, through precombusted (400°C; 4 h) 47 mm GF/F filters. These were then temporarily frozen at -80°C and subsequently freeze-dried for easier transport to the UK. No sample was obtained from the shallow MSC (50 m) during deployment at P3B (EV196) due to a heavy leak of the instrument. Samples from one MSC at 500 m depth were also obtained in P3C, however the separation between slow/fast sinking particles was not carried as the tray was not installed during that deployment.

2.18.4   Particle sampling with PELAGRA traps

Splits from formalin-preserved and processed PELAGRA samples from all deployments and depths are anticipated from Richard Lampitt. However since the samples will remain in formalin and will not be available for several months (due to logistical reasons) the usefulness of these samples for organic biogeochemical analyses is questionable. A better approach needs to be agreed for future cruises. A small number of unprocessed ('live') samples were obtained (see Table 2.32). Particles were obtained by filtration as described above and eventually also freeze-dried (see above).

Table 2.30: SAPS sampling information. Delay refers to pumping delay to allow positioning of the pump to the required depth. Pump refers to pumping time. Volume pumped refers to water volume pumped. The volumes in the last four columns refer to the rinsing volumes (with Thorium-free seawater) of the Nitex screens for the collections of large particles and the subsequent volume splits for organic biogeochemical, [234]Th and [210]Po analyses respectively.

Date	Station	Event	Lat (N)	Long (E)	Depth (m)	Delay (min)	Pump (min)	V pumped (L)	Start time pumping*	End time pumping*	Nitex rinse (L)	Lipids split (mL)	[234]Th split (mL)	[210]Po split (mL)
17/11/2017	P3A	58	52 42.0	40 06.4	5	90	90	408	20.30	22.00	0.8	400	200	200
17/11/2017	P3A	58	52 42.0	40 06.4	32	90	90	433	20.30	22.00	0.6	300	150	150
17/11/2017	P3A	58	52 42.0	40 06.4	85	90	90	529	20.30	22.00	0.8	400	200	200
17/11/2017	P3A	58	52 42.0	40 06.4	185	90	90	738	20.30	22.00	0.6	300	150	150
17/11/2017	P3A	58	52 42.0	40 06.4	435	90	90	379	20.30	22.00	0.6	300	150	150
20/11/2017	P3A	94	52 44.9	40 11.9	25	90	60	191	14.35	15.35	1	500	250	250
20/11/2017	P3A	94	52 44.9	40 11.9	49	90	60	349	14.35	15.35	1	500	250	250
20/11/2017	P3A	94	52 44.9	40 11.9	153	90	60	679	14.35	15.35	1	500	250	250
20/11/2017	P3A	94	52 44.9	40 11.9	255	90	60	550	14.35	15.35	1	500	250	250
20/11/2017	P3A	94	52 44.9	40 11.9	448	90	60	588	14.35	15.35	1	400	200	200
01/12/2017	P3B	183	52 42.3	40 06.2	25	90	60	66	03.37	04.37	0.6	300	150	150
01/12/2017	P3B	183	52 42.3	40 06.2	51	90	60	268	03.37	04.37	0.8	400	200	200
01/12/2017	P3B	183	52 42.3	40 06.2	155	90	60	269	03.37	04.37	0.8	400	200	200
01/12/2017	P3B	183	52 42.3	40 06.2	258	90	60	448	03.37	04.37	0.8	400	200	200
01/12/2017	P3B	183	52 42.3	40 06.2	460	90	60	608	03.37	04.37	0.8	400	200	200
05/12/2017	P3B	253	52 43.3	40 19.6	30	90	60	139	06.00	07.00	0.8	400	200	200
05/12/2017	P3B	253	52 43.3	40 19.6	53	90	60	317	06.00	07.00	0.8	400	200	200
05/12/2017	P3B	253	52 43.3	40 19.6	158	90	60	477	06.00	07.00	0.8	400	200	200
05/12/2017	P3B	253	52 43.3	40 19.6	259	90	60	460	06.00	07.00	0.8	400	200	200
05/12/2017	P3B	253	52 43.3	40 19.6	462	90	60	527	06.00	07.00	0.8	400	200	200
10/12/2017	P3C	288	52 41.7	40 19.4	30	90	60	0	05.30	06.30	+	+	+	+
10/12/2017	P3C	288	52 41.7	40 19.4	66	90	60	311	05.30	06.30	0.8	400	200	200
10/12/2017	P3C	288	52 41.7	40 19.4	170	90	60	435	05.30	06.30	0.8	400	200	200
10/12/2017	P3C	288	52 41.7	40 19.4	268	90	60	142	05.30	06.30	0.8	400	200	200
10/12/2017	P3C	288	52 41.7	40 19.4	460	90	60	577	05.30	06.30	0.8	400	200	200

* Ship time: GMT-3 (hh.mm); + Pump malfunction - kept GF/F for DOM blank

Table 2.31: Marine Snow Catcher Sampling information for organic biogeochemical analyses. t_0 = sample non-fractionated particles soon after recovery; top = sample from the top chamber after 2 h (suspended particles); bottom = sample from bottom chamber after 2 h (slow-sinking particles); tray = sample from tray below bottom chamber after 2 h (fast-sinking particles). For Event 292 the tray was not put in pace, therefore there is no separation between slow and fast sinking particles. $^{+}$ leaked; no sample

Date	Station	Event	Lat (S)	Lon (E)	MSC	Depth (m)	V filtered (L)			
							t_0	top	bottom	tray
22/11/2017	P3A	103	52 45.09	40 12.25	36	150	2	8.7	1.8	0.75
22/11/2017	P3A	104	52 45.09	40 12.25	37	500	3.5	9.2	2.5	0.75
22/11/2017	P3A	105	52 45.09	40 12.25	38	50	3	8	2.5	0.75
22/11/2017	P3A	106	52 45.08	40 12.25	39	100	3	9.5	2.1	0.75
01/12/2017	P3B	193	52 42.33	40 06.08	77	500	3.2	3.2	2.65	0.75
01/12/2017	P3B	194	52 42.33	40 06.08	78	150	3.2	3.65	2.7	0.75
01/12/2017	P3B	195	52 42.33	40 06.08	79	100	3.3	3.25	2.55	0.8
01/12/2017	P3B	196	52 42.33	40 06.08	80	50	$+$	$+$	$+$	$+$
10/12/2017	P3C	292	52 41.7	40 19.4	110	500	5.2	5.2	4.9	
15/12/2017	P3C	342	52 42.1	39 57.0	125	500	3.35	3.45	3.85	0.73
15/12/2017	P3C	343	52 42.09	39 56.99	126	165	3.55	3.5	3.3	0.75
15/12/2017	P3C	344	52 42.09	39 56.99	127	75	3.3	3.1	1.85	0.7
15/12/2017	P3C	345	52 42.09	39 56.99	128	30	3.6	3.45	2	0.72

$^{+}$ leaked; no sample

Table 2.32: Details of PELAGRA sampling for organic biogeochemical analyses. These samples are only 'live' unpreserved samples from short deployments.

Date	Station	Event	PELAGRA trap	Lat (N)	Lon (E)	Depth (m)	Cup
15/11/2017	P3A	3	9	52 42.0	40 06.4	260	2
04/12/2017	P3B	213	9	52 41.7	40 15.08	250	
04/12/2017	P3B	214	7	52 41.7	40 15.08	150	
04/12/2017	P3B	216	2	52 41.7	40 15.08	85	

2.19 Upper ocean pelagic sampling for chlorophyll, POC/N, PIC, BSi, HPLC, Lugols, SEM and CN filters

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2.19.1 Introduction

The composition, size-structure and activity of upper ocean plankton communities has a strong influence on the magnitude and nature of sinking organic and inorganic material. As part of the COMICS project, work package 2 (Pelagic Biogeochemistry) is addressing the linkages between surface plankton communities and the export of material out of the upper ocean (considered the euphotic zone) and through the upper mesopelagic (<1 km). One of the key COMICS hypotheses relates plankton community composition to the efficiency with which organic carbon penetrates into the ocean interior, with phytoplankton blooms exporting labile material that is remineralised shallow in the water column and non-bloom communities exporting more refractory material that reaches deeper depths.

To examine relationships between surface plankton and deep-sea fluxes, a series of measurements were collected on DY086 to assess: levels of phytoplankton biomass (chlorophyll-a, carbon), community composition (preserved and filtered water samples for microscopy, size-fractionated chlorophyll-a, flow cytometry (see C Evans section), diagnostic pigments (via High-Performance-Liquid-Chromatography), primary and biomineral (calcite, opal) production (see A Poulton section), biomineral standing stocks, nitrate uptake, and total particulate organic carbon and nitrogen concentrations. As well as measurements in the upper euphotic zone, profiles of all of these parameters were collected throughout the upper 1000 m to examine deep-sea trends between sampling stations and time-points. Furthermore, large-volume (500 mL) acidic Lugol's samples were collected from the deep-sea to examine microzooplankton biomass and potential contribution to respiration and remineralisation profiles.

2.19.2 CTD Sampling

For each stainless steel CTD cast (CTDs), seawater was typically collected from 12 depths from the near surface down to appr. 1000 m to incubate for rate measurements (see section by Poulton) or to filter for pigments (chlorophyll-a via fluorometric analysis, carotenoids via High-Performance-Liquid-Chromatography), particulate organic and inorganic carbon (POC, PIC), particulate organic nitrogen (PON) and biogenic silica ($bSiO_2$). Additionally, seawater was collected and processed for evaluation of phytoplankton community structure determined by microscopy from preserved (acidic Lugol's solution) and filtered (Scanning Electron Microscopy, light microscopy) samples. Water samples were also sequentially filtered to determine chlorophyll-a concentrations in different size-fractions (0.2-2 μm, 2-10 μm, >10 μm). Samples for the isotopic signature of dissolved Si was also collected for a subset of stations via collaboration with Dr Kate Hendry (University of Bristol). Sampling and protocols typically followed those employed previously and described in detail elsewhere (see e.g. Moore et al. 2007a&b; Poulton et al. 2006, 2013). An overall list of samples collected is provided in Table 2.33.

Particulate Organic Carbon and Nitrogen (POC/N)

POC/N samples were collected from both the CTD and underway non-toxic supply. For POC/N, 1000 mL of seawater was filtered onto pre-ashed (400°C, 12 h) Whatman GF/F filters. These were then placed in clean Eppendorf tubes, and dried overnight (50°C) for storage prior to analyses back at NOC.

Table 2.33: Collected samples

Date	Site	Event	CTD	Niskin Bottle	Depth (m)	Filtered for
15/11/2017	P3A	14	2	6, 8, 9, 11, 12, 14, 16, 17, 18, 20, 22, 24	1000, 750, 500, 350, 250, 150, 100, 75, 50, 30, 10, 5	Chl-a, POC/N, HPLC
16/11/2017	P3A	26	3	1, 2, 3, 5, 6, 8, 11, 13, 16, 19, 21, 23	1000, 750, 500, 350, 250, 160, 110, 70, 60, 40, 20, 6	Chl-a, SF Chl-a, POC/N, BSi, PIC, HPLC
17/11/2017	P3A	42	5	7, 11, 12, 14, 15, 17, 19, 20, 22, 23, 24	1000, 500, 350, 250, 160, 110, 70, 60, 40, 20, 6	Chl-a, POC/N, HPLC
18/11/2017	P3A	63	6	1, 2, 3, 5, 7, 8, 11, 14, 16, 19, 21, 23	1000 750, 500, 350, 250, 160, 110, 70, 60, 40, 20, 6	Chl-a, SF Chl-a, POC/N, BSi, PIC, HPLC
21/11/2017	P3A	101	9	1, 2, 3, 5, 6, 8, 11, 13, 16, 19, 21, 23	1000, 750, 500, 350, 250, 170, 120, 80, 70, 45, 20, 6	Chl-a, SF Chl-a, POC/N, BSi, PIC, HPLC
21/11/2017	P3A	108	10	2, 4, 6, 8, 10, 11, 12, 14, 16, 18, 20, 23	500, 350, 250, 200, 150, 125, 100, 75, 50, 30, 20, 10	Chl-a, POC/N
23/11/2017	P3A	118	11	1, 3, 5, 8, 9, 11, 14, 15, 17, 19, 21, 23	1000, 750, 500, 400, 300, 200, 150, 100, 75, 50, 20, 10	Chl-a, POC/N
24/11/2017	P2	122	12	1, 2, 3, 5, 6, 8, 11, 13, 16, 19, 21, 23	1000, 750, 500, 350, 250, 160, 110, 70, 60, 40, 20, 6	Chl-a, SF Chl-a, POC/N, BSi, PIC, HPLC
30/11/2017	P3B	164	16	1, 2, 3, 5, 6, 10, 11, 13, 16, 19, 21, 23	1000, 750, 500, 350, 250, 160, 110, 70, 60, 40, 20, 6	Chl-a, SF Chl-s, POC/N, BSi, PIC, HPLC
03/12/2017	P3B	218	21	1, 2, 3, 5, 6, 8, 11, 13, 16, 19, 21, 23	1000, 750, 500, 350, 250, 160, 110, 70, 50, 40, 20, 6	Chl-a, SF Chl-a, POC/N, BSi, PIC, HPLC
05/12/2017	P3B	252	23	1, 2, 3, 5, 6, 8, 11, 13, 16, 19, 21, 23	1000, 750, 500, 350, 250, 160, 110, 70, 50, 25, 15, 6	Chl-a, SF Chl-a, POC/N, BSi, PIC, HPLC
10/12/2017	P3C	287	27	1, 2, 3, 5, 6, 10, 11, 13, 16, 19, 21, 24	1000, 750, 500, 350, 250, 165, 115, 75, 60, 40, 20, 6	Chl-a, SF Chl-a, POC/N, BSi, PIC, HPLC
12/12/2017	P3C	319	31	1, 2, 3, 5, 6, 9, 12, 13, 16, 19, 21, 23	1000, 750, 500, 350, 250, 160, 110, 70, 60, 40, 20, 6	Chl-a, SF Chl-a, POC/N, BSi, PIC, HPLC

Particulate Silica (bSiO$_2$)

Particulate silica (bSiO$_2$) water samples were collected from both the CTD and underway non-toxic supply. For bSiO$_2$, 500 mL of seawater was filtered onto Whatman 0.8 μm polycarbonate filters. After filtration, the filters were placed into plastic 15 mL centrifuge tubes, dried overnight in an oven prior to digestion and analysis (see Section 2.17).

Particulate Inorganic Carbon (PIC)

PIC samples were collected from both the CTD and underway non-toxic supply. For PIC, 500 mL of seawater was filtered onto Whatman 0.8 μm polycarbonate filters that were then rinsed with pH-adjusted MilliQ (pH appr. 8.5-9) to remove saltwater residue. The filters were placed in 50 mL centrifuge tubes and oven dried (50°C, overnight) prior to later digestion and analyses at NOC via ICP-OES.

High Performance Liquid Chromatography (HPLC)

For phytoplankton pigment analysis (chlorophylls, carotenoids), 1000 mL of seawater was filtered onto Whatman GF/F filters for later extraction and analysis of pigments by HPLC. After filtration, HPLC filters were placed into nuncTM CryoTubeTM vials or similar and stored at -80°C prior to later analyses back at Plymouth Marine Laboratory.

Scanning Electron Microscopy (SEM)

For SEM samples, 500 mL was filtered onto Whatman 0.8 μm polycarbonate filters. These were rinsed with pH-adjusted MilliQ to remove saltwater and prevent salt crystal growth. The filters were placed in Millipore Petri slides and dried overnight at 50°C before being stored at room temperature for later analysis at Heriot Watt.

Polarising Light Microscopy

For polarising light microscopy, 500 mL samples were filtered onto Whatman 0.8 μm cellulose nitrate filters. The filters were placed in Millipore Petri slides, dried (50°C, overnight), stored at room temperature for later preparation as permanent slides with Norland Optical Adhesive and coccolithophore enumeration.

Isotopic compositon of silicic acid (dSi)

At a subset of stations, 250 mL water samples were collected in HDPE bottles, filtered under gentle pressure through 1 mm polycarbonate filters and stored at room temperature later analysis at the University of Bristol.

Preserved phytoplankton (acidic Lugol's solution)

Water samples of between 100 and 5000 mL were preserved in acidic Lugol's solution (0.5-1% final solution) for later enumeration and identification of phytoplankton species by inverted light microscopy. Samples were stored in brown 250-500 mL medicine bottles containing acidic Lugol's solution.

Chlorophyll analysis

See next section.

2.19.3 Chlorophyll analysis

In order to provide an index of overall phytoplankton biomass, water samples for the determination of chlorophyll-a concentrations were collected from:

1. CTD deployments
2. Underway sampling
3. Marine Snow Catchers (see Section 2.29)

4. Experiments on surface iron limitation experiments (see Section 2.20)
5. Experiments on zooplankton grazing experiments (see Section 2.32.8)

Further details specific to different sampling types can be found in the corresponding sections of the cruise report, but briefly:

1. CTD samples: The stainless steel CTD was used to collect samples from 1000 m to the surface, typically at 12 different depths (See Table 2.34). Between 100 mL and 250 mL of sea-water were filtered onto Whatman glass fibre GF/F filters for total chlorophyll concentration and sequentially through polycarbonate 0.2 μm, 2 μm and 10 μm filters for size-fractionated chlorophyll-a.
2. For the Underway samples, water was collected off the ships underway system at a nominal depth of 5 m and a volume of 200 mL filtered onto GF/F filters.
3. For the MSC samples were filtered from the various fractions collected (see Section 2.29)
4. For the surface limitation experiments, 50 mL was filtered (see Section 2.20)
5. For the zooplankton grazing experiments, 50 mL was filtered (see Section 2.32.8)

The underway and CTD samples are listed in Table 2.34. Specific cruise report sections should be consulted for the other sample sources.

In all cases, chlorophyll-a was extracted in 6 mL of 90 % acetone over >24 hours at 4°C in a fridge in the dark. Measurements of chlorophyll-a were subsequently made on board using a Turner Designs Trilogy fluorometer set up with a non-acidification kit (after Welschmeyer, 1994). The fluorometer was calibration against a pure chlorophyll-a extract in 2015. A Turner solid standard (Part No. 8000-952) was used at the start and end of each set of readings as well as an acetone blank sample to monitor for instrument drift. Both of these readings are subsequently used in the calculations to determine chlorophyll-a concentrations (see Equation 2.6). Chlorophyll-a concentrations in mg m-3 were calculated as:

$$Chla = Dilution * R_{adj} * (F - blank) * (v/V) \qquad (2.6)$$

where *Dilution* = 1 (unless required for an over-range sample), R_{adj} = response factor adjusted for the shift in the solid standard, F = sample fluorescence, *blank* = acetone blank reading, v = acetone extracted volume (6 mL), and V = filtered sample volume in mL.

Table 2.34: Underway and CTD chlorophyll samples

Date	Site	Gear Code	Cast	Event	Niskin	Depth (m)
13/11/2017	UW-1	UW				
13/11/2017	UW-2	UW		1		
13/11/2017	UW-3	UW		2		
13/11/2017	UW-4	UW		3		
14/11/2017	UW-5	UW		4		
14/11/2017	UW-6	UW		5		
14/11/2017	UW-7	UW		6		
15/11/2017	UW-8	UW		7		
15/11/2017	P3A	CTD	2	14	6, 8, 9, 11, 12, 14, 16, 17, 18, 20, 22, 24	1000, 750, 500, 350, 250, 150, 100, 75, 50, 30, 15, 5

Table 2.34: continued

Date	Site	Gear Code	Cast	Event	Niskin	Depth (m)
16/11/2017	P3A	CTD	3	26	1, 2, 3, 5, 6, 8, 11, 13, 16, 19, 21, 23	1000, 750, 500, 350, 250, 160, 110, 70, 60, 40, 20, 6
17/11/2017	P3A	CTD	5	42	7, 11, 12, 14, 15, 17, 19, 20, 22, 23, 24	1000, 500, 350, 250, 160, 110, 70, 60, 40, 20, 6
18/11/2017	P3A	CTD	6	63	1, 2, 3, 5, 7, 8, 11, 14, 16, 19, 21, 23	1000, 750, 500, 350, 250, 160, 110, 70, 60, 40, 20, 6
19/11/2017	P3A	UW		9		
19/11/2017	P3A	UW		10		
19/11/2017	P3A	UW		11		
19/11/2017	P3A	UW		12		
19/11/2017	P3A	UW		13		
19/11/2017	P3A	UW		14		
19/11/2017	P3A	UW		15		
20/11/2017	P3A	UW		16		
20/11/2017	P3A	UW		17		
21/11/2017	P3A	CTD	9	101	1, 2, 3, 5, 6, 8, 11, 13, 16, 19, 21, 23	1000, 750, 500, 350, 250, 170, 120, 80, 70, 45, 20, 6
21/11/2017	P3A	CTD	10	108	2, 4, 6, 8, 10, 11, 12, 14, 16, 18, 20, 23	500, 350, 250, 200, 150, 125, 100, 75, 50, 30, 20, 10
23/11/2017	P3A	CTD	11	118	1, 3, 5, 8, 9, 11, 14, 15, 17, 19, 21, 23	1000, 750, 500, 400, 300, 200, 150, 100, 75, 50, 20, 10
24/11/2017	P2	CTD	12	122	1, 2, 3, 5, 6, 8, 11, 13, 16, 19, 21, 23	1000, 750, 500, 350, 250, 160, 110, 70, 60, 40, 20, 6
24/11/2017	P2	UW		18		
24/11/2017	P2	UW		19		
24/11/2017	P2	UW		20		
24/11/2017	P2	UW		21		
24/11/2017	P2	UW		22		
25/11/2017	P2	UW		23		
30/11/2017	P3B	CTD	16	164	1, 2, 3, 5, 6, 10, 11, 13, 16, 19, 21, 23	1000, 750, 500, 350, 250, 160, 110, 70, 60, 40, 20, 6

Table 2.34: continued

Date	Site	Gear Code	Cast	Event	Niskin	Depth (m)
03/12/2017	P3B	CTD	21	218	1, 2, 3, 5, 6, 8, 11, 13, 16, 19, 21, 23	1000, 750, 500, 350, 250, 160, 110, 70, 50, 40, 20, 6
05/12/2017	P3B	CTD	23	252	1, 2, 3, 5, 6, 8, 11, 13, 16, 19, 21, 23	1000, 750, 500, 350, 250, 160, 110, 70, 50, 25, 15, 6
10/12/2017	P3C	CTD	27	287	1, 2, 3, 5, 6, 10, 11, 13, 16, 19, 21, 24	1000, 750, 500, 350, 250, 165, 115, 75, 60, 40, 20, 6
12/12/2017	P3C	CTD	31	319	1, 2, 3, 5, 6, 9, 12, 13, 16, 19, 21, 23	1000, 750, 500, 350, 250, 160, 110, 70, 60, 40, 20, 6

## 2.20	Titanium CTD rosette ('Trace Metal, TM') sampling operations

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### 2.20.1	Introduction

In common with other sub-Antarctic Island systems of Crozet and Kerguelen (Blain et al. 2007; Pollard et al. 2009), the bloom 'downstream' of South Georgia is understood to be a result of natural iron fertilisation from the land-mass and shallow sediments of the islands and associated shelf (Nielsdottir et al. 2012). In order to both provide context for the overall work performed within COMICS and investigate the potential interactions between the carbon and major nutrient cycles and trace-metals within the mesopelagic, a series of trace-metal sampling and experimental work was implemented during DY086.

### 2.20.2	Trace metal CTD operations

A Titanium framed CTD rosette and associated clean bottles was used for trace metal clean sampling for state variables and experiments. The Titanium CTD was fitted with 24 x 10 L OTE bottles that have been modified for trace metal work by use of epoxy coated external springs, coating of stainless ferrules and fitting of PTFE taps. Trace metal clean protocols were employed in the deployment and sampling of the TM CTD. Briefly, bottles were clean from the prior cruise and were hence just given a soak cast (water collected from depth and left in bottles for 4 h before being drained). Bottles were subsequently then only opened within dedicated class-100 air-filtered clean lab (for sampling) or on deck immediately prior to the CTD being deployed over the side. Handling of the TM CTD bottles was only performed with clean gloves, all sampling hoses and attachments were acid washed prior to use and subsequent sampling/experimental bottles were also acid washed and were double plastic bagged if/when moved outside of a filtered air environment. Clear iron-limitation responses within surface experiments (Figure 2.39) confirmed the cleanliness of the trace-metal clean protocols. Table 2.35 provides a listing of samples collected and experiments commenced from the TM CTD listed by the event ID, CTD number, OTE bottle and nominal depth of firing.

### 2.20.3	Surface ocean Fe Limitation experiments

In order to determine whether the surface phytoplankton communities were iron limited during the sampled stages of the bloom, while simultaneously confirming that the trace metal clean sampling/handling processes were effective, a series of 4 surface community iron limitation experiments were performed using protocols similar to those employed previously (Moore et al. 2007a&b, Nielsdottir et al. 2012). Briefly, for each experiment 6 sub-samples were collected from OTE bottles fired in the surface mixed layer (20-30 m nominal depth; Table 2.36) into acid-washed 250 mL polycarbonate bottles. Of these, 3 bottles were left as un-amended controls and 3 were amended with iron additions (50 µl of 10 µM $FeCl_3$ in 10% HCL) to a final concentration of 2 nM. The samples were incubated in the light with 100 mL subsamples for active chlorophyll fluorescence measurements and chlorophyll (50 mL) taken at 2 days and 4-5 days (Table 2.36).

### 2.20.4	Sub-surface Fe limitation of bacterial production

In order to investigate the potential for iron limitation of sub-surface bacterial production, a parallel series of experiments were performed using similar protocols to above with samples collected from the upper meso-pelagic. Within each experiment 6 samples (125 mL) were taken from nominal
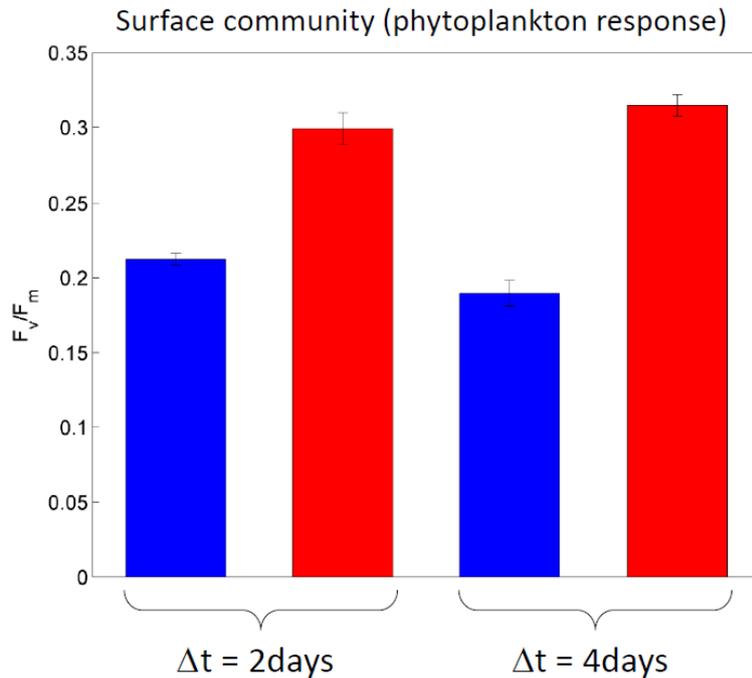
Figure 2.39: Example response of Fv/Fm (apparent photochemical quantum efficiency) to incubation with (red bars) and without (blue bars) iron. Experiment S1. Clear statistically significant response to iron amendment is observed indicating iron stress within extant surface phytoplankton community and adequacy of trace metal clean sampling and incubation protocols.

Table 2.35: State variable sampling from TM CTD

Date	Site	Event	CTD	OTE Bottle	Depth (m)	Variable
16/11/2017	P3A	39	4	2, 4, 6, 8, 12, 14, 16, 18, 22	500, 350, 250, 160, 110, 70, 60, 40, 30	dFe, TFe, Sterivex
18/11/2017	P3A	72	7	2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24	1000, 750, 500, 250, 160, 110, 70, 60, 40, 30	dFe, TFe, pFe, Sterivex
29/11/2017	P3B	151	15	1, 2, 3, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24	1000, 750, 500, 250, 160, 110, 100, 70, 70, 60, 40, 30, 30, 30	dFe, TFe, nutrients, Sterivex
02/12/2017	P3B	204	19	2, 4, 6, 8, 10, 12, 18, 20, 22, 24	500, 350, 250, 160, 110, 110, 70, 60, 40, 30	dFe, TFe, Sterivex
05/12/2017	P3B	254	24	2, 4, 6, 8, 10, 12, 14, 18, 20, 22	750, 500, 250, 160, 110, 90, 70, 50, 40, 20	dFe, TFe, nutrients
09/12/2017	P3C	275	26	2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22	750, 500, 350, 250, 160, 110, 90, 70, 50, 40, 18	dFe, TFe, nutrients
11/12/2017	P3C	312	29	1, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22	750, 500, 350, 250, 160, 110, 110, 90, 70, 50, 40, 20	dFe, TFe, pFe, nutrients, Sterivex

Table 2.36: Surface iron limitation experiments

Water collection date	Site	Event	CTD	OTE bottle	Depth (m)	Surface experiment identifier	Time step dates	Additional samples
16/11/2017	P3A	39	4	22	30	S1	T1 – 19/11 T2 – 21/11	
29/11/2017	P3B	151	15	20	30	S2	T1 – 01/12 T2 – 04/12	POC/N, Lugol's
05/12/2017	P3B	254	24	22	20	S3	T1 – 07/12 T2 – 09/12	Lugol's
11/12/2017	P3C	312	29	22	20	S4	T1 – 13/12 T2 – 15/12	POC/N, Lugol's

depths of between 70 m and 110 m, with 3 controls and 3 iron amended (25 μL of 10 μM $FeCl_3$ in 10% HCL, 2 nM final concentration) bottles subsequently incubated in the dark for 4-5 days. Sub-samples were collected into 30 mL bottles at T_0, +2 days and +4 days and at each of these time steps 1.8 mL were placed in 3 vials for each subsample, with 16 μL of a 3.85 kBq μL^{-1} ^{3}H-Leucine stock added.

2.20.5 Relative remineralisation/partitioning rates of carbon, silicate and iron

In order to investigate the remineralisation potential of fresh surface organic material, a series of experiments were performed to follow the partitioning between dissolved and (size fractionated) particulate phases, adapting the protocols of Azam and Biddle (1999) and Boyd et al. (2010). Within phase 1 of this experiment the uptake rates of iron, carbon and silicon within the surface phytoplankton/microbial community were measured through radio-labelling and subsequent incubation. The larger size fraction (>5 μm) of this isotopically labelled community was then harvested to determine the subsequent remineralisation potential of this material at depth by the meso-pelagic microbial community, through determining the fractional (re-)distribution of each radio- isotope/element within the various dissolved and particulate phases measured.

Protocol
Phase 1
Near surface samples (20-30 m; Table 2.38) were collected into triplicate acid-washed 125 mL Nalgene polycarbonate bottles for each isotope (^{14}C, ^{32}Si and ^{55}Fe). In order to promote the active uptake of isotopes through the generation of fresh organic material, all samples were also amended with 2 nM Fe (added as 25 μl of 10 μM $FeCl_3$ in 10% HCl). Samples were then spiked with the radio-isotopes (^{55}Fe – 2 kBq: ^{14}C – 74 kBq: ^{32}Si – 3 kBq) and placed in an incubator at in situ temperatures and in the light, 16:8 Light:Dark cycle for 48-56 h (Table 2.38) before evaluating the overall uptake of each isotope. Sub-samples were then harvested through filtration onto 0.2 μm and 5 μm polycarbonate filters, in order to measure both total community and >5um community uptake. Additional samples were also collected for overall activities for all 3 isotopes. To differentiate between uptake into cells relative to apparent uptake due to adsorption of ^{55}Fe onto external cell surfaces, subsets of filters and cells were rinsed at the end of the sample filtration with a buffered Ti-EDTA-citrate solution which scavenges adhered 55Fe (Hudson and Morel 1989). Filter samples were then placed in 6 ml Ultima Gold scintillation cocktail before being counted on a liquid scintillation counter (Perkin Elmer TriCarb 3180 TR/SL) on board ship.

Table 2.37: Bacterial iron limitation experiments

Date	Site	Event	CTD	OTE bottle	Depth (m)	Bacterial production experiment identified	Time step dates
16/11/2017	P3A	39	4	12	110	BP (D1)	T1 – 19/11 T2 – 21/11
29/11/2017	P3B	151	15	8	110	BP (D2)	T0 – 29/11 T1 – 01/11 T2 – 04/11
				12	70	BP (D3)	T0 – 29/11 T1 – 01/11 T2 – 04/11
05/12/2017	P3B	254	24	14	70	BP (D4)	T0 – 05/12 T1 – 07/12 T2 – 09/12
11/12/2017	P3C	312	29	12	110	BP (D5)	T0 - 11/12 T1 – 13/12 T2 – 15/12

Phase 2

at the termination of stage 1, the remainder of the samples not used for measuring total uptake (see above) were harvested by gravity filtration through a 47 mm, 5 μm polycarbonate filter. Particulate material was then rinsed twice with clean filtered (0.2 μm) meso-pelagic water (see Table 2.38) before being resuspended in mesopelagic water to create triplicate samples for 3 subsequent harvesting time steps for each isotope. Within the standard experimental treatments, resuspension was performed with whole (i.e. unfiltered / amended) mesopelagic water. However, within a subset of the experiments (see Table 2.38), resuspension with 0.2 μm filtered (i.e. mesopelagic bacteria removed) or whole community incubations with the addition of picked zooplankton (*Calanoides acutus*) were performed to investigate differential partitioning and the uptake of isotopes/elements from the produced organic matter by these separate community components. All phase 2 samples were incubated in the dark at in situ temperatures within a refrigerated container and processed at 3 time steps to determine the resultant activity in each phase of remineralisation using methods similar to the end-point measurements at the termination of experimental phase 1 (see Table 2.38).

Table 2.38: Experimental remineralisation potential

Date	Site	Event	CTD	OTE bottle	Depth (m)	Variables	Time step dates
16/11/2017	P3A	39	4	22	30	Remin R1 (Phase 1)	T0 – 18/11
18/11/2017	P3A	72	7	12	110	Remin R1 (Phase 2)	T1 – 20/11
							T2 – 22/11
							T3 – 24/11
29/11/2017	P3B	151	15	20	30	Remin R2 (Phase 1)	T0 – 02/12
02/12/2017	P3B	204	19	10	110	Remin R2 (Phase 2)	T1 – 03/12
							T2 – 06/12
				12	110		T3 – 10/12
09/12/2017	P3C	275	26	22	18	Remin R3 (Phase 1) POC	T0 – 11/12
11/12/2017	P3C	312	29	10	110	Remin R3 (Phase 2)	T1 – 12/12
							T2 – 14/12
							T3 – 16/12

2.21 Nitrate uptake rates estimated using ^{15}NO$_3$

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2.21.1 Overview

Daily nitrate uptake rates were estimated for the 'pre-dawn' stainless steel CTD casts through collecting samples to measure the incorporation of 15N labelled nitrate. Briefly, 500 mL samples were collected in triplicate from the upper 4 sampled depths on the 'pre-dawn CTD' (see section by Poulton) and spiked with 200 μL of a 3.902 nm μL^{-1} ^{15}NO$_3$ stock, hence to a final ^{15}NO$_3$ concentration of 1.56 μM, corresponding to around a 9% enrichment of the ambient pool (appr. 18 μM). Samples were then placed within the refrigerated container at irradiances approximating the in situ daily light does (see Section 2.23) and incubated for appr. 24 hrs (Table 2.39) before being terminated by filtration onto pre-ashed Whatman GF/F filters. These were then placed in Eppendorf tubes and dried overnight in an oven at 50°C for storage prior to analyses back at NOC.

Table 2.39: Incubations for ^{15}NO$_3$ uptake. Times in GMT.

CTD	Depths (m)	Start date	Start time	End date	End time
3	60, 40, 20, 6	16/11/2017	08:30	17/11/2017	08:30
7	60, 40, 20, 6	18/11/2017	08:30	19/11/2017	08:00
9	70, 45, 20, 6	21/11/2017	08:15	22/11/2017	08:25
12	60, 40, 20, 6	23/11/2017	06:55	24/11/2017	08:20
16	60, 40, 20, 6	30/11/2017	09:48	01/12/2017	09:40
21	50, 40, 20, 6	03/12/2017	08:25	04/12/2017	09:05
23	50, 25, 15, 6	05/12/2017	07:42	06/12/2017	08:35
27	60, 40, 20, 6	10/12/2017	08:10	11/12/2017	08:50
31	60, 40, 20, 6	12/12/2017	07:05	13/12/2017	08:08

2.22   Active chlorophyll fluorescence measurements

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2.22.1   Objectives

Chlorophyll fluorescence, using techniques such as Fast Repetition Rate fluorometry (FRRf), can provide a useful non-destructive and rapid index of the physiological status of phytoplankton (e.g. Moore et al. 2007). Instruments such as FRR fluorometers are capable of measuring a suite of parameters pertaining to the photosynthetic physiology of the entire phytoplankton community, most commonly including the photosynthetic energy transfer efficiency (Fv/Fm) which can provide a proxy of the overall photosynthetic 'health' of the community and in particular an indication of nutrient and specifically iron limitation (Figure 2.39). The FRRf technique measures in real time, in situ and at high sensitivity.

A variety of active chlorophyll fluorometers were employed during DY086, in both underway sampling mode of the ship's non-toxic supply and in discrete sampling mode for samples drawn from experiments (see Section 2.20) and Marine Snow Catcher samples (see Section 2.29).

2.22.2   Underway sampling

Three separate active chlorophyll fluorometers were employed in underway sampling. Chelsea Technologies Group (CTG) FASTtrackerTM and FastOceanTM fluorometers (Kolber et al. 1998) were connected in parallel to the ships non-toxic supply within main lab in order to assess and monitor the physiological state of Photosystem II (PSII) within the surface phytoplankton population of the study area. Additionally, a developmental 'Single turnover active fluorescence (STAF)' system based on a CTG 'FastBallast' fluorometer was connected into the underway system within the general purpose laboratory. The FASTtracker FRRf had the following settings:

  6. Acq = 0
  7. Flash seq/Acq = 16
  8. Sat flash/seq = 100
  9. Sat flash duration = 4
  A. Sat interflash delay = 0
  B. Relax flash – Enabled
  C. Relax flash/seq = 20
  D. Relax flash/seq = 4
  E. Relax flash int. = 61
  F. Sleeptime – 30000
  G. Gain – autoranging – 1
  H. Analyse out – disabled
  I. Verbose – enabled

The data were stored internally on the instrument and were downloaded every 1-4 days throughout the cruise. The Instrument optics were cleaned whilst the download operation was being carried out and before the protocol was set to run again, blank measurements were performed to calibrate the results. Data will then be analysed using custom software in a MatlabTM environment, however significant problems with the flashcard memory on this old instrument were encountered during the cruise and considerable post processing will be required before it is clear how much usable information will be recoverable from this data stream.

The FastOcean instrument was set up with the following settings:

Gain = auto-ranging

Saturation phase = 100 flashlets

Relaxation phase = 40 flashlets

Acquisition pitch = 30s

Sequence repetition = 64

Sequence interval = 100 ms

Three different LED combinations were also used in series:

1. 450nm = 0.92 x 1022 photons m^{-2} s^{-1}, 530nm = 0, 624nm = 0;
2. 450nm = 0.92 x 1022 photons m^{-2} s^{-1}, 530nm = 0.5 x 1022 photons m^{-2} s^{-1}, 624nm = 0;
3. 450nm = 0.92 x 1022 photons m^{-2} s^{-1}, 530nm = 0, 624nm = 0.8 x 1022 photons m^{-2} s^{-1};

The gain was set using the instruments auto-ranging mode. Data were stored internally on the instrument and were downloaded every 1-4 days throughout the cruise. The Instrument optics were cleaned whilst the download operation was being carried out. Data will be analysed using the instrument manufacturers software post – cruise, then files will be combined for archiving.

The developmental 'STAF' system typically employed the following settings:

Saturation pulse (SP) duration = 120 μs

Relaxation pulse (RP) duration = 120 μs

Shortest gap (between SP and RP) = 80 μs

Longest gap (between SP and RP) = 2000 μs

Sequence interval = 100 ms

Sequences per acquisition = 20

Acquisitions per super-acquisition = 4

The following LED combinations were used:

455 nm = 420 mA

470 nm = 420 mA

The gain was set using the instruments auto-ranging mode. Data from this instrument when used underway was automatically archived onto a laptop and intermittently backed up. Data quality will be assessed in detail following the cruise. Additionally a series of test files, including blanks and 'instrument response functions' were collected in order to fully characterise this new instrument.

Much of the underway signal was dominated by marked diel variability in the parameters that can be measured by active chlorophyll fluorometers deployed in this mode (Fv'/Fm' and σPSII') while some differences were apparent between regions.

2.22.3 Discrete sampling

The STAF system was also employed in measurements of sub-samples from both the surface iron enrichment experiments (Figure 2.39) and in measurements of samples drawn from both the Marine Snow Catchers and PELAGRA traps. An example plot of the preliminary data from the PELAGRA traps is displayed in Figure 2.40.
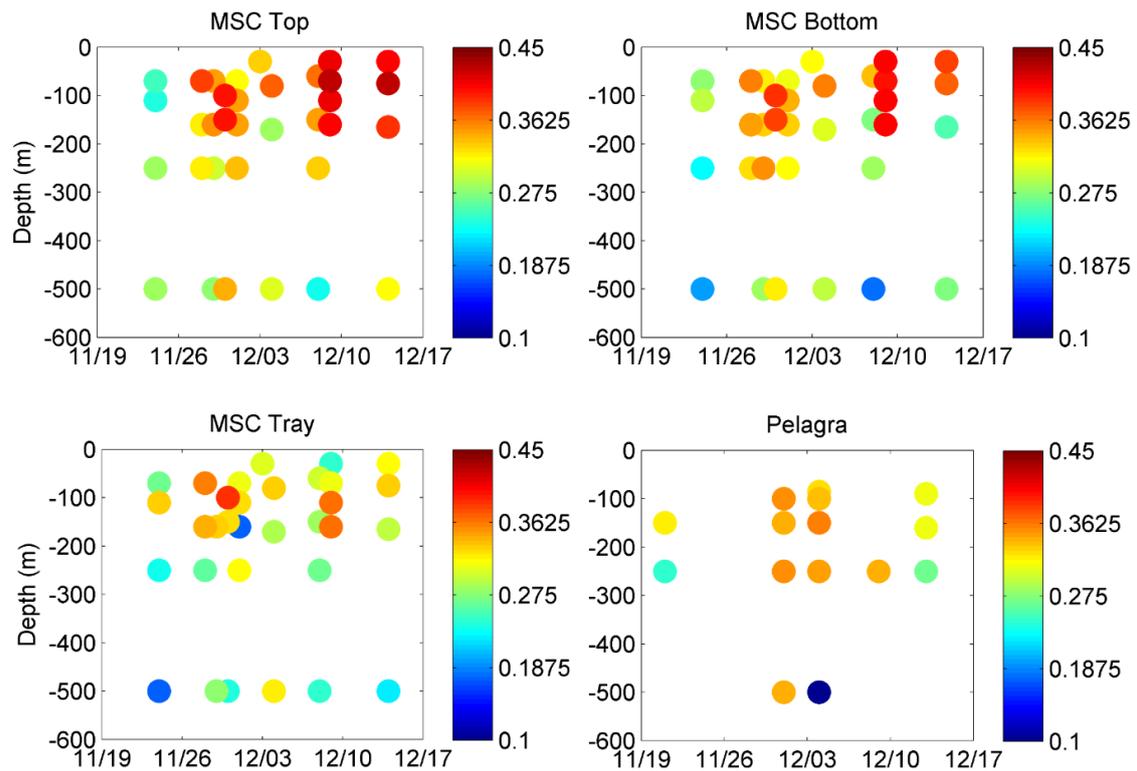
Figure 2.40: Example response of Fv/Fm (apparent photochemical quantum efficiency) to incubation with (red bars) and without (blue bars) iron. Experiment S1. Clear statistically significant response to iron amendment is observed indicating iron stress within extant surface phytoplankton community and adequacy of trace metal clean sampling and incubation protocols.

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2.22.4 References

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2.23 Primary, calcite & particulate silica production

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2.23.1 Overview

Upper ocean rates of primary production (PP), calcite production (CP) and particulate silica production (ρP) were measured from pre-dawn (0200-0400 local time) CTD casts at nine stations (Table 2.40). Water samples (1.5 L) from four light levels (60, 25, 5 and 1% of surface irradiance) in the upper mixed layer were collected. Uptake of ^{14}C into particulates measured primary production and calcite production, while the isotope ^{32}Si was used to measure ρP.

Rates of PP were measured over both short-term (5-8 h; 'Gross primary production', GPP) and long-term (24 h; 'Net primary production', NPP) incubations in a temperature controlled (2 ± 1^oC) reefer container with light supplied by LED daylight panels after Poulton et al. (2017). Each incubation depth was supplied with a daily (16 h; 0430-2030) light dose equivalent to the average light dose for November and December at that light depth determined from MODIS satellite PAR data. Light doses were 21.2 mol quanta m^{-2} d^{-1} (60% surface irradiance), 9 mol quanta m^{-2} d^{-1} (25%), 2.9 mol quanta m^{-2} d^{-1} (5%) and 0.3 mol quanta m^{-2} d^{-1} (1%).

Rates were determined following Poulton et al. (2006) for size-fractionated (SF) NPP (0.2-2, 2-10 and >10 μm), Poulton et al. (2014) for CP (and also NPP) and Krause et al. (2010) for ρP. Short-term GPP incubations were coupled by measurements of DOC production following a modified method from Lopez-Sandoval et al. (2011).

Triplicate cold (no isotope) water samples (0.5 L) for each light depth were incubated in parallel and in combination with time zero measurements of particulate silicate (bSiO$_2$) are to be used to estimate net bSiO$_2$ production and rates of bSiO$_2$ dissolution (after Krause et al. 2010).

Table 2.40: Sampling stations and measurements

Sampling details					Measurements				
Date	Event	CTD	Sampled bottles	Site	SF-NPP	CP/NPP	GPP	DOC	ρP
16-Nov	026	003	23, 21, 19, 16	P3A	X	X	X	X	X
18-Nov	063	006	24, 22, 20, 17	P3A	X	X	nd	nd	X
21-Nov	101	009	24, 22, 20, 17	P3A	X	X	X	X	X
24-Nov	122	012	24, 22, 20, 17	P2	X	X	X	nd	X
30-Nov	164	016	24, 22, 20, 17	P3B	X	X	X	X	X
03-Dec	218	021	24, 22, 20, 17	P3B	X	X	nd	nd	X
05-Dec	252	023	24, 22, 20, 17	P3B	X	X	X	X	X
10-Dec	287	027	24, 22, 20, 17	P3C	X	X	X	X	X
12-Dec	319	031	24, 22, 20, 17	P3C	X	X	X	X	X

(nd indicates not determined)

2.23.2 References

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2.24 Bacterial growth efficiency & dissolved organic matter functionality

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2.24.1 Background

Bacterial production is typically estimated from substrate uptake rates of a radiolabelled tracer, most frequently leucine at saturating concentrations (10 to 50 nM), in accordance with the method of Simon and Azam (1989). However, enrichment with saturating concentrations of leucine artificially elevates rates of both production and respiration in marine bacterial communities (Hill et al. 2013), thus invalidating the estimates of bacterial growth efficiency calculated from them. The accuracy of in situ bacterial production estimates is improved by examining uptake of leucine at concentrations akin to those in situ using isotopic dilution time series bioassays (Hill et al. 2013). Respiration rates specific to bacteria can also be estimated by radiotracer-based assay to quantify the conversion of ^{14}C labelled leucine into carbon dioxide. To our knowledge, these methods have only ever been applied to bacterial communities within the mixed layer at the uppermost part of ocean. Furthermore, no conversion factors exist to translate the rates these methods yield into carbon either assimilated or respired by bacteria.

Oceanic bacteria utilise dissolved organic matter (DOM) as a substrate and it is still unknown as to how the DOM pool is able to accumulate given bacteria's abundance in seawater. Despite its importance as one of the largest exchangeable carbon pools on the planet with major significance to carbon cycling and climate, DOM is poorly molecularly characterised. This is because it represents a complex pool of widely ranging size and chemical characteristics and current harvesting and analysis methods capture only a fraction of the DOM pool complexity. Furthermore, what influences the suitability of various components of the DOM pool as bacterial substrates, which thereby in part determines its residence time in the oceans, isn't well understood.

2.24.2 Objectives

We aimed to examine bacterial growth efficiency in the mesopelagic and the surface ocean, and to determine the composition and functionality of marine dissolved organic matter (DOM) by the following objectives:

- To assess bacterial production over a depth profile from the surface waters to mid- mesopelagic via isotopic dilution time series bioassays at in situ leucine concentrations
- To assess bacterial respiration over a depth profile from the surface waters to mid- mesopelagic via conversion of ^{14}C labelled leucine into $^{14}C02$
- To generate appropriate conversion factors to determine carbon assimilated and respired from the microbially-mediated rates generated and thus accurately determine BGE for the mesopelagic
- To collect DOM samples throughout the water column to serve as a resource for later characterisation in the laboratory
- To trial two new organic matter extraction protocols and compare these to the current protocol with the aim of improving marine DOM harvests
- To determine whether different source of marine DOM have variable functionality as indicated by their effect on bacterial growth efficiency

2.24.3 Materials and methods

For all parameters other than DOM and associated measurements, we employed a 6 depth sampling strategy encompassing surface, DCM, mixed layer +10 m, mixed layer +100 m, 250 m and

500 m (Table 2.41). In addition to free living bacteria an attempt was made to measure leucine incorporation and respiration from particle associated bacteria collected from the Marine Snow Catcher. Preliminary results indicated that bacterial leucine uptake was inhibited from the fast and slow sinking fractions, most likely due to enriched background DOM concentrations.

Bacterial and heterotrophic nanoflagellate abundance

Samples for bacterial abundance were fixed with (1% final concentrations) paraformaldehyde for 30 minutes at room temperature, before flash freezing in liquid nitrogen and storage at minus 80°C. Samples will be analysed by flow cytometry at the NOC. Samples for heterotrophic nanoflagellate abundance were stained with Lysotracker (final concentration 50 nM) at room temperature for 3 minutes before snap freezing and storage at minus 80°C.

Molecular ecology

Samples for later molecular analysis of free-living key microbial groups (1.6 mL) were collected by flash freezing fixed (1% final concentrations) or unfixed seawater. Additional samples samples of 50 ml volume, both fixed and unfixed, were concentrated over a 0.2 μm polycarbonate filter which was then collected and placed in a cyrovial and snap frozen. These samples will be analysed at NOC by flow cytometric sorting prior to CARD-FISH analysis.

Bacterial production (^{3}H-Leucine uptake rates)

For the isotopic dilution time series bioassay L-[$^{4,5-^3}$H]-leucine (specific activity 101 Ci mmol^{-1}) was preloaded into 2 mL polypropylene crystal clear microcentrifuge tubes (Starlab, Milton Keynes) to make a final concentration series ranging from 0.2 to 1 nM when combined with the 1.6 mL seawater samples. Immediately after collection, seawater was combined with the labelled substrate (marking the start of the experiment) and a sample from each concentration was fixed at 10, 20, 30 and 40 min by addition of 1% final concentration paraformaldehyde. Particulate matter in the samples was harvested by filtration onto 0.2 μm pore-size polycarbonate filters, which were then washed twice with 3 mL of deionised water. To determine the radioactivity of the retained particulate matter the filters were analysed by liquid scintillation counting (Tri-Carb, 3100TR, Perkin-Elmer, Beaconsfield, UK). Leucine uptake rate was calculated as previously described by Zubkov and colleagues (2007). Owing to slower metabolic rates and lower leucine concentrations below the mixed layer the assay was adapted for those samples collected at depths below 75 m. Specifically lower leucine concentrations were used 0.005, 0.01, 0.025, 0.04 and 0.05 nM in combination with longer incubation periods of time (30, 60, 90 and 120 min) and larger volumes of 30 ml. The incubations were stopped by pouring the sample into 50 mL centrifuge tubes preloaded with PFA to make a final concentration of 1% and filtered as above.

In order to derive a carbon conversion factor a regrowth experiment was conducted whereby 0.6 μm filtered seawater was combined with particle free water at a ratio of 1 in 10. Bacterial numbers were followed in line with leucine incorporation rates.

Bacterial respiration (^{14}C-Leucine respired

The rate of ^{14}C-Leu respiration was determined from 70 mL samples incubated in 125 mL crimp sealed glass bottles. The acid cleaned bottles were rinsed three times with seawater sample and ^{14}C-Leu added at 0.4 nM. Respiration samples were terminated by the addition of 1 mL of 10% HCl through the lid using a hypodermic needle and syringe, which also acidified the samples to <pH2, thereby driving any ^{14}CO$_2$ out of solution. Respiration bottles were bubbled for 2 h with CO$_2$-free air and evolved CO$_2$ trapped by Carbo-sorb bubblers. Radioactivity of samples was measured as disintegrations per minute (DPM) by liquid scintillation counting.

Respiration was also measured by determining changes in oxygen concentrations over time in mL Chromacol vials equipped with sensor spots and an Optode (Presense) for the purposes of intercalibration. vials were incubated in the dark at in situ temperature and all sample handling was

Table 2.41: Metadata and parameters collected by the Microbial Biogeochemistry team during DY086.

Date	Event	CTD	Depths (m)	Niskin Bottles	Samples and Measurements
16/11/2017	26	3	6, 60, 70, 160, 250, 500	23, 16 & 17, 13, 8, 6, 3	Bacterial cell counts, molecular identification, bacterial production and respiration
18/11/2017	63	6	6, 60, 70, 110, 160, 250, 500	24, 17, 15, 12, 9, 7, 4	Bacterial cell counts, molecular identification,
21/11/2017	101	9	6, 70, 80, 170, 250, 500	24, 17, 14, 9, 7, 4	Bacterial cell counts, molecular identification, bacterial production and respiration
24/11/2017	122	12	6, 60, 70, 160, 250, 500	6, 5, 4, 3, 2, 1	Bacterial cell counts, molecular identification, bacterial production and respiration
30/11/2017	164	16	6, 60, 110, 160, 250, 500	24, 17, 12, 10, 7, 4	Bacterial cell counts, molecular identification, bacterial production and respiration
03/12/2017	218	21	6, 40, 110, 160, 250, 500	24, 20, 12, 9, 7, 4	Bacterial cell counts, molecular identification
04/12/2017	230	22	6, 25, 63 & 65, 83, 113, 127, 163, 200, 250, 450, 500, 750, 1000, 1500, 2000, 2500, 3000, 3500, 4000	23 & 24, 22, 20 & 21, 19, 17 & 18, 16, 15, 14, 12 & 13, 11, 9 & 10, 8, 7, 6, 5, 4, 3, 2, 1	Bacterial cell counts, molecular identification, bacterial production and respiration, DOM, Lyso Tracker
10/12/2017	287	27	6, 60, 75, 165, 250, 500	24, 17, 14, 9, 7, 4	Bacterial cell counts, molecular identification, bacterial production and respiration, Lyso Tracker
12/12/2017	319	31	6, 60, 70, 160, 250, 500	24, 17, 14, 10, 7, 4	Bacterial cell counts, molecular identification, bacterial production and respiration, Lyso Tracker
15/12/2017	349	33	8, 51, 152, 253, 503, 1003, 1508, 2008, 2514, 3016, 3519, 3733	23, 21, 19, 17, 15, 13, 11, 9, 8, 6, 4, 2	DOM

done under red light. Measurements were performed with the Unisense sensor by placing it into the chamber and allowing 10 minutes for the signal to stabilize. For the Presense system the optode was held against the sensor spot and a measurement was taken after the signal had stabilized.

Dissolved organic matter harvesting

Samples for marine DOM were collected over full profiles of the water column at a depth resolution of 1000 m and also at around 500, 50 (DCM) and 5 m. After collection the seawater samples were filtered through 47-mm GF/F (Whatman precombusted at 450°C) and acidified to pH 2 using HCL. Samples were then extracted using either the established protocol of 1 g PPL sorbent (Agilent Bond Elut PPL), or by 1 g Oasis HLB (Waters Corporation) or by a combination of 500 mg Oasis MAX (Anion exchange) in sequence with 500 mg Oasis MCX (Cation exchange: both Waters Corporation). In the case of the former after extraction samples were washed with acidified HCl and blown to dryness using N_2 gas before elution with 4 mL methanol and storage at -20°C in precombusted glass vials. Oasis HLB cartridges were washed with 5% methanol in Milli-Q and eluted with methanol. MCX cartridges were washed with 5% formic acid in Milli-Q and eluted with 5% ammonium hydroxide in methanol. MAX cartridges were washed with 5% ammonium hydroxide in Milli-Q and eluted with methanol and 5% formic acid in methanol.

For each extraction a DOC sample was taken and also a particulate sample collected and stored frozen for potential later analysis. Extraction efficiencies will be calculated using DOC concentrations in the extracts and chemical characterisation will be via a variety of targeted and untargeted mass spectrometry platforms.

Dissolved organic matter functionality

DOM for functionality characterisation was generated in laboratory cultures from phytoplankton and cyanobacteria via either zooplankton grazing, light starvation, viral lysis or exudation. Matter was extracted (using PPL), blown to dryness using N2 gas and stored frozen. DOM samples were reconstituted using 0.2 μm filtered seawater at an appropriate volume to generate the desired final concentration according to experimental requirements when combined with whole seawater. Rates of bacterial production and respiration (as detailed above) were then derived to establish the influence of DOM on BGE.

We conducted experiments to determine the effective DOM concentration required to produce a measurable change in leucine uptake and respiration rates using the concentrations of 25, 50 and 100 μM in water collected from the mixed layer. While this initial experiment worked further attempts to determine the influence of DOM on BGE failed despite testing seawater from different depths, ageing seawater to promote ambient DOM consumption, increasing the spike of leucine added, altering the concentrations of DOM used, altering the types of DOM used.

2.24.4 Results

Preliminary analysis indicated a large range in leucine incorporation rates according to depth, with those in the surface waters being three orders of magnitude higher compared with those in the mesopelagic (Figure 2.41). Rates of leucine respiration were also successfully measured throughout the water column. Less variability was seen in the rate of leucine respiration although they were higher in the surface waters, peaking at the DCM.

DOM addition experiments indicated the bacterial community was unsuitable to determine the DOM functionality most likely due to high background DOM concentrations.
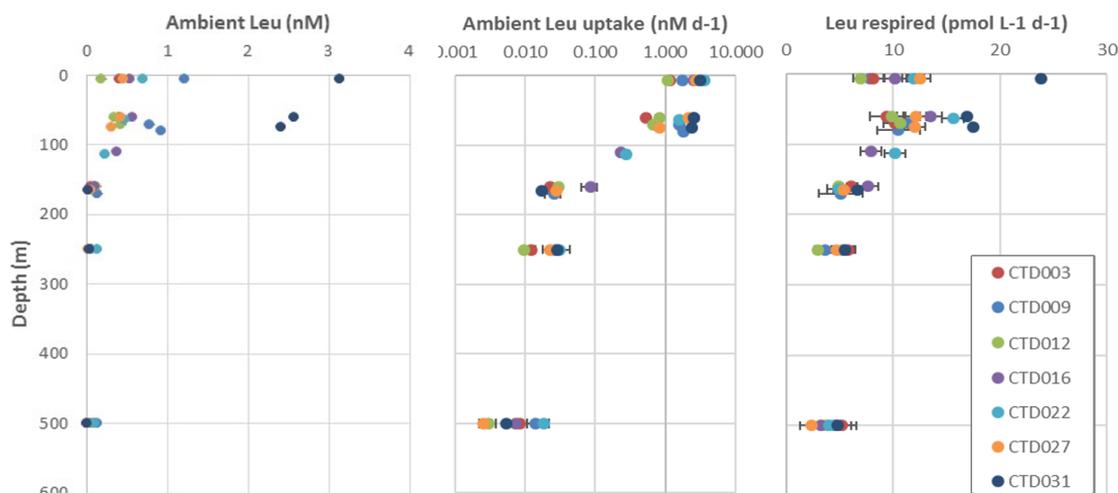
Figure 2.41: Ambient leucine concentrations, rates of uptake and respiration over depth.

2.24.5 References

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2.24.6 Acknowledgements

2.25 Microbial interactions with particles

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2.25.1 Objectives

Microorganisms are master-cyclers of many elements in global oceans. They directly process *ca.* half of the organic carbon produced by marine autotrophs in surface ocean via the so-called microbial loop, where they break down particulate organic matter (POM) into dissolved organic matter (DOM) or remineralised inorganic forms, while incorporating some into their own biomass. The microbial loop also acts on DOM release from phytoplankton and zooplankton. When POM finally sinks out from surface ocean, much is subject to remineralization by diverse microbial assemblages in the ocean's twilight zone.

Although increasing evidence show that sinking particles can be nutrient hotspots that attract microbial colonization and ectoenzymatic activities, and that they initiate the breakdown of POM, microbial production is generally considered higher in the planktonic fraction supported by the trailing plume of nutrient/DOM release from the POM. Recent metagenomic studies reveal distinct microbial community structures within particles, with greater genetic potentials to degrade complex polymeric substances (Azam and Malfatti 2007; Arístegui et al. 2009). However, most are observations drawn from surface ocean, with hardly any studies of the mesopelagic where the extent of remineralisation is crucial to the efficiency of the biological carbon pump. How mesopelagic microorganisms affect POM-DOM dynamics remains poorly known.

The objective of this work component is to characterise the microbial community structure, respiration and remineralisation activities within particles in the mesopelagic – via a combination of microrespiration measurements(Hemsley), incubation experiments with stable-isotope tracers (^{13}C/^{15}N), and various molecular biological analyses – in order to more accurately assess the impact of microbe-particle interactions on biological pump efficiency. The relative contribution from microbial communities associated with fast-sinking, slow-sinking and suspended particles, as well as free-living fractions are investigated. The potential use of oxidised nitrogen (NO_x^-) as an alternative electron acceptor for respiration under possible oxygen tension, ammonium (NH_4^+) release from remineralization of organic matter and chemolithoautoptrophic CO_2 fixation due to nitrification are further assessed in parallel in the various particle-fractions.

2.25.2 Particle Sampling

Marine Snow Catchers (MSC)

At each sampled station, samples of different particle-fractions (and planktonic free-living fractions) were collected with 95-L Marine Snow Catchers, targeting 10 m and 100 m below mixed layer depth (MLD), and 250 m and 500 m, matching the depths of 4 out of 5 PELAGRA deployments (see report by Saw). During each MSC deployment (Table 2.42), at least 3 MSCs were deployed consecutively to the same target depth, with one MSC subsequently dedicated for molecular ecological analyses while the remaining two were combined for microrespiration and incubation experiments. For most MSCs deployed, the actual deployment depth was determined with the RBR Concerto (the same used for Red Camera Frame). Once recovered on deck, the mid-column of each MSC was sampled immediately for ammonium (10 mL), inorganic nutrients (15 mL), dissolved organic carbon and nitrogen (45 mL) and particulate organic carbon and nitrogen (POC/N, 4L), and additionally for metatranscriptomics (10 L) in the MSC dedicated for molecular ecology. The MSCs were left undisturbed on deck for ca. 2 hours to let sinking particles concentrate at the base

of the MSCs. Water samples with 'non-sinking particles' (NS) that remained suspended in the main MSC column were then collected from the mid-column water tap for microbial diversity and metatranscriptomics analyses (see later section on Molecular Ecological Analyses), POC/N and incubation experiments (see section below). Additional water subsamples were collected and then gravity-filtered through 3 μm-pore-sized filters for experiments with 'free-living' (FL) fractions. Once samples for NS and FL fractions had been collected, water from the MSC columns was drained and the base of the MSC detached. The MSC bases were then transferred gently to the constant temperature controlled laboratory, and the particles were let settled. The 'fast-sinking' (FS) particle-fractions were operationally defined as the materials settled at the very bottom of the MSC base (∼1.5-2 L by volume) after this period, while the 'slow-sinking' (SS) fractions constituted the particulate materials above yet within the base. Usually the FS fraction was sampled first with a siphon pump, hovering up most visible particles plus surrounding water at the base very gently, in attempt to minimise the fast-sinking particles being resuspended due to disturbances from sampling. Afterwards, only the top 2-3 L of the MSC base were sampled for slow-sinking particles with a siphon pump, to minimise overlap between FS and SS particle fractions.

Altogether, 42 MSCs were deployed in total for process studies, at 13 sampled depths amongst the two sampled stations, though with only 2 depths at the low-productivity station (see Table 2.42). Amongst these, MSCs 115-118 were particularly intended for the characterisation of sinking particles, including their sizes, sinking velocities, POC/N contents and their specific associated microrespiration rates (Please see separate reports by Hemsley and Iversen), while subsamples were also taken for ammonium and nutrient measurements, as well as DNA analyses.

PELAGRA

Sinking particles collected by the PELAGRA traps that carried formalin-free cups were subsampled for both incubation experiments, microrespirations and molecular ecological analyses (Table 2.43). These 'live' cups were opened for sediment collections in the final 3 hours of deployment. In PELAGRA deployments prior to Event 301, the live cups were pre-filled with unfiltered deep-sea water previously collected at 1000 m at P3. In the final deployments (events 301, 302 and 304), the live cups were prefilled with sterile-filtered (0.2 μm pore-sized) seawater previously collected at 70 m (for P2) and at 500 m (for P6 and P9). Upon recovery on deck, the live cups were carefully transported to the deck lab. Subsamples were first taken for photophysiology analyses via FRRf (5 ml) (Moore), and few visible discrete particles, e.g. fecal pellets, were picked for microrespiration measurements (Hemsley). Afterwards, materials within cups were gently mixed, then subsampled for bulk microrespiration measurements (Hemsley), C/N stable isotope analyses of POM (50 mL) (Stowasser), molecular analyses (150 mL) and incubation experiments (300-800 mL). Subsamples for ammonium and nutrients analyses were also taken prior to incubation experiments. A total of 16 live samples had been taken at the site P3 over 3 visits during this cruise (Table 2.43).

2.25.3   Incubation Experiments

To assess microbial respiration within various particle fractions, microrespiration measurements with oxygen microsensors were conducted on all four particle-fractions collected from the MSCs – *fast-sinking (FS), slow-sinking (SS), non-sinking suspended (NS)* and *free-living (FL)* – and compared with measurements made prior to the 2h settling on deck (see separate report by Hemsley). In parallel, the potential use of nitrate/ nitrite as alternative electron acceptors for respiration under oxygen tension within particles (and consequent production of N_2O) were examined via incubation experiments with ^{15}N-stable isotope tracers. Briefly, 3 parallel incubation experiments were set up for each particle-fraction, which were amended with respective ^{15}N-labeled stable isotope tracers and ^{13}C-bicarbonate listed in Table 3 to target the various nitrate-dependent respiration processes, nitrous oxide production and nitrification (including ammonia oxidation to nitrite, nitrite oxidation

Table 2.42: MSC deployments for Process Studies and Molecular Analyses

Event	Date	Time) (GMT)	Lat (S)	Lon (W)	Station	MSC No.	Depth (target)	Depth (actual)
21	15/11/2017	21:30	52 41.50	40 07.46	P3 test(A)	MSC002	50	
22	15/11/2017	21:56	52 41.49	40 07.46	P3 test(A)	MSC003	50	
23	15/11/2017	22:09	52 41.49	40 07.46	P3 test(A)	MSC004	50	
24	15/11/2017	22:24	52 41.49	40 07.46	P3 test(A)	MSC005	50	
48	17/11/2017	11:18	52 41.39	40 08.05	P3A	MSC011	150	
49	17/11/2017	12:51	52 41.39	40 08.05	P3A	MSC012	150	139
50	17/11/2017	13:11	52 41.39	40 08.05	P3A	MSC013	150	141
51	17/11/2017	13:30	52 41.39	40 08.05	P3A	MSC014	150	140
73	18/11/2017	14:46	52 41.9	40 10.1	P3A	MSC023	250	231
74	18/11/2017	15:06	52 41.9	40 10.1	P3A	MSC024	250	230
75	18/11/2017	15:26	52 41.9	40 10.1	P3A	MSC025	250	231
90	19/11/2017	13:45	52 44.95	40 11.96	P3A	MSC031	500	456
91	19/11/2017	14:23	52 44.95	40 11.96	P3A	MSC032	500	456
93	19/11/2017	15:23	52 44.9	40 11.9	P3A	MSC033	500	455
124	24/11/2017	07:24	56 24.0	41 13.0	P2A	MSC043	70	67
125	24/11/2017	07:42	56 24.0	41 13.0	P2A	MSC044	70	67
126	24/11/2017	07:57	56 24.0	41 13.0	P2A	MSC045	70	67
140	25/11/2017	12:10	56 38.0	40 55.0	P2A	MSC057	160	147
141	25/11/2017	12:25	56 38.0	40 55.0	P2A	MSC058	160	145
142	25/11/2017	12:40	56 38.0	40 55.0	P2A	MSC059	160	146
167	30/11/2017	11:27	52 42.53	40 04.6	P3B	MSC064	500	
168	30/11/2017	12:00	52 42.53	40 04.6	P3B	MSC065	500	454
169	30/11/2017	12:33	52 42.53	40 04.6	P3B	MSC066	500	454
185	01/12/2017	10:53	52 42.28	40 06.1	P3B	MSC073	250	229
186	01/12/2017	11:14	52 42.28	40 06.1	P3B	MSC074	250	229
187	01/12/2017	11:34	52 42.28	40 06.1	P3B	MSC075	250	230
222	03/12/2017	09:12	52 46.4	40 03.1	P3B	MSC086	160	150
223	03/12/2017	09:26	52 46.4	40 03.1	P3B	MSC087	160	150
224	03/12/2017	09:40	52 46.4	40 03.1	P3B	MSC088	160	149
231	04/12/2017	11:26	52 41.25	40 20.66	P3B	MSC089	70	67
232	04/12/2017	11:41	52 41.25	40 20.66	P3B	MSC090	70	67
233	04/12/2017	11:50	52 41.25	40 20.66	P3B	MSC091	70	67
289	10/12/2017	11:10	52 41.7	40 19.4	P3C	MSC107	500	452
290	10/12/2017	11:40	52 41.7	40 19.4	P3C	MSC108	500	453
291	10/12/2017	12:13	52 41.7	40 19.4	P3C	MSC109	500	452
308	11/12/2017	09:28	52 43.0	40 14.3	P3C	MSC115	60	
309	11/12/2017	09:42	52 43.0	40 14.3	P3C	MSC116	60	
310	11/12/2017	09:55	52 43.0	40 14.3	P3C	MSC117	60	
311	11/12/2017	10:02	52 43.0	40 14.3	P3C	MSC118	60	
326	12/12/2017	18:59	52 38.6	40 12.6	P3C	MSC121	75	78
327	12/12/2017	19:09	52 38.6	40 12.6	P3C	MSC122	165	163
328	12/12/2017	19:24	52 38.7	40 12.6	P3C	MSC123	75	77
329	12/12/2017	19:35	52 38.7	40 12.6	P3C	MSC124	75	78

Table 2.43: List of PELAGRA deployments with live samples collected

Date	Station	Event	Deployment	Pelagra Trap	Target depth (m)
22/11/2017	P3A	79	Pelagra012	P9	250
22/11/2017	P3A	80	Pelagra013	P6	150
22/11/2017	P3A	81	Pelagra014	P4	100
01/12/2017	P3B	157	Pelagra018	P7	500
01/12/2017	P3B	158	Pelagra019	P9	250
01/12/2017	P3B	159	Pelagra020	P6	150
01/12/2017	P3B	165	Pelagra013	P4	100
05/12/2017	P3B	212	Pelagra024	P7	500
05/12/2017	P3B	213	Pelagra025	P9	250
05/12/2017	P3B	214	Pelagra026	P6	150
05/12/2017	P3B	215	Pelagra027	P4	100
05/12/2017	P3B	216	Pelagra028	P2	90
09/12/2017	P3C	261	Pelagra030	P9	250
14/12/2017	P3C	301	Pelagra035	P9	250
14/12/2017	P3C	302	Pelagra036	P6	160
14/12/2017	P3C	304	Pelagra038	P2	90

to nitrate), along with CO_2 fixation. Stable isotope tracers were first added into 500 mL water samples and evenly mixed, before distributing into 12x 28 mL combusted glass serum vials and crimp-sealed. One vial for each experiment was fixed immediately with 100 μL of saturated mercuric chloride as the T0 subsample. All remaining vials were then secured in opaque roller tanks and incubated on a rolling table to mimic sinking conditions, at *in situ* temperature ($\sim$2°C) for 8-21 hours. In addition, a 10 mL-subsample and a 15 mL- subsample were taken for each experiment for the measurements of initial ammonium and nutrient concentrations.

At the end of incubation experiments, 3 glass vials were preserved with 100 μL of saturated mercuric chloride solution for later stable isotope analyses for N_2O, NO_x^- and NH_4^+ on a GC-IRMS back in a shorebased laboratory, 3 were distributed for ammonium and nutrient measurements, and 3 were filtered onto combusted and weighed glass-fibre filters (GF/F) for the analyses of POC/N. The remaining 2 subsamples were fixed with paraformaldehyde solution (1% final concentration), incubated at 4°C for 8-14 h before filtering onto 0.2 μm polycarbonate membrane filters for CARD-FISH analyses (see below) in a shore-based laboratory.

In addition, a 45 mL subsample was collected in acid-washed 50 ml tubes for each particle-fraction, without stable isotope tracer amendments, for dissolved organic carbon and nitrogen analyses. The water subsamples were filtered through combusted GF/F filters into a new acid-washed tube, then acidified with concentrated hydrochloric acid to pH 2, stored at room temperature in the dark before analyses on a TOC/TDN analyser back in Southampton. Ammonium concentrations were measured onboard ship following the protocol by Holmes et al. (1999), and nutrient analyses were conducted on a nutrient autoanalyser (Stinchcomb).

For PELAGRA samples, the total volumes of samples were much less than the MSC samples, such that only a subset of experiments could be conducted (only Experiments A and C, or C only from Table 2.43).

Furthermore, in order to put into context ammonium concentrations measured in MSC samples relative to overall water column, ammonium concentrations were additionally measured in samples collected at the 12 sampled depths during CTD casts 005, 012, 017, 021, 027, 030, all of which were at site P3 except for CTD012 at the low-productivity station (P2A or LP).

Table 2.44: Incubation Experiments with ^{15}N- and ^{13}C- Stable Isotope Tracers

	Amendment	Major targeted process(es)
A	$^{15}NO_3^- + ^{14}NO_2^- + H^{13}CO_3^-$	Nitrate reduction to nitrite
B	$^{15}NO_2^- + ^{14}NH_4^+ + H^{13}CO_3^-$	Denitrification/ anammox/ DNRA/ nitrite oxidation/ N_2O production
C	$^{15}NH_4^+ + H^{13}CO_3^-$	Anammox/ nitrification/ N_2O production
D	Control (no amendment)	

2.25.4 Sampling for Molecular Ecological Analyses

DNA/RNA Sampling

Subsamples for nucleic acids (DNA and RNA) extractions were collected from the initial T0 subsamples as well as all particle-fractions of the sampled MSCs, to allow later microbial diversity studies and functional transcriptomics/ metatranscriptomics analyses, respectively. To differentiate between NS and FL microbial fractions, a 10 L water subsample collected from the MSC mid-column (after 2 h settling on deck) was sequentially filtered through 100 µm- and 3 µm- pore-sized membrane filters and eventually through a 0.22 µm-pore-sized cylindrical Sterivex filter (Merck Millipore) with a peristaltic pump. Microorganisms concentrated on both 100- and 3- µm size-fractions are considered as the NS fraction, while those collected on the 0.22 µm-pore-sized filters are the FL fraction. For SS, the ca. 3 L samples were also size-fractionated during filtration into the 100-/3-/0.22-µm size-fractions; while for FS, the 1 L subsamples were only filtered through 3 µm and 0.22 µm pore-sized filters. All filters were then incubated in *RNAlater* solutions (ThermoFisher) for 8-12h at 4$^{\text{o}}$C, after which *RNAlater* solutions were discarded and filters were stored at -80$^{\text{o}}$C until nucleic acids extractions back in a shorebased laboratory.

From the PELAGRA live traps, $\sim$100-150 mL of each subsample was size-fractionated, first onto a 3 µm pore-sized, 47-mm diameter polycarbonate membrane filter in a polycarbonate filtration unit, and the filtrate was subsequently filtered onto 0.2 µm pore-sized 47-mm diameter polycarbonate membrane filters in a second filtration unit. Both membrane filters were subsequently treated with *RNAlater* as described above, and then stored at -80$^{\text{o}}$C until further processing onshore.

Samples were also collected from the 3 RESPIRE deployments (see report by Laurenceau) after recovery on deck, from which 100-150 ml subsamples drawn from each trap were filtered onto 3 µm and 0.22 µm pore-sized membrane filters, and were treated as above for MSC and PELAGRA DNA/RNA samples.

Catalysed Reporter Deposition-Fluorescence In Situ Hybridisation (CARD-FISH)

For all MSC fractions, PELAGRA and RESPIRE sampled for DNA/RNA, a small subsample (35-125 mL) was collected in parallel for later CARD-FISH analyses onshore, to identify and quantify specific microbial cells actively colonizing particles by targeting their unique 16S-RNAs. Briefly, these water subsamples were size-fractionated onto polycarbonate membrane filters. The fixed samples were first filtered through 3 µm pore-sized, 47-mm diameter polycarbonate membrane filters in a filtration unit, and the filtrate was subsequently filtered onto 0.2 µm pore-sized 47-mm diameter polycarbonate membrane filters. Both filters were air-dried and then stored frozen at -80$^{\text{o}}$C until further analyses back onshore. Meanwhile, subsamples from the incubation experiments were directly filtered onto 0.2 µm filters (25 mm diameter) without size-fractionation. The filters were then dried and stored as described above.

2.25.5 Provisional Results and Planned Analyses

Ammonium concentrations, as expected, were found the highest at the base of the mixed layer and in the upper mesopelagic, coinciding with the sharpest decline in total particle volumes and
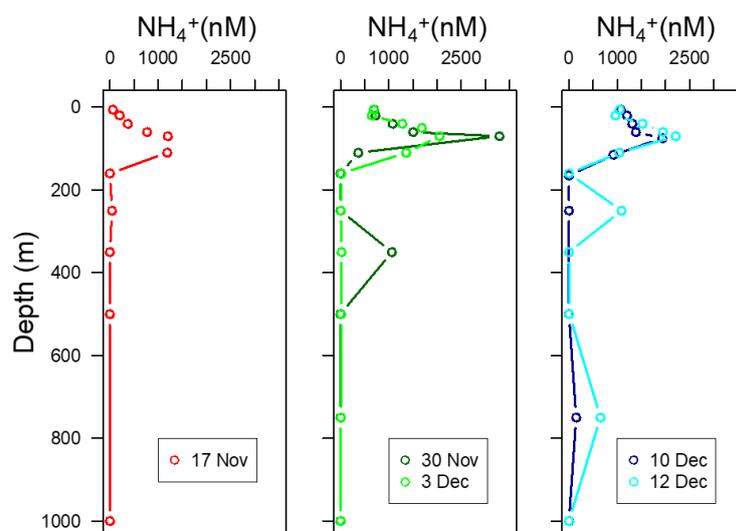
Figure 2.42: Ammonium Concentrations measured in CTD samples at P3 during the 3 visits.

abundance. Concentrations dropped sharply to below detection limit deeper into the mesopelagic. During the three visits to site P3, ammonium level increased to a maximum of over 3 μM in the 2nd visit, first focussing at the base of the mixed layer yet later developed into over 1 μM throughout the mixed layer during the 3rd visit (Fig. 2.42). This agrees well with declining surface diatom bloom conditions, as NH_4^+ is a direct remineralisation product from organic matter. Meanwhile, high NH_4^+ also spread further below the mixed layer, with occasional mid-depth pulses that showed dynamic secondary peaks in particle abundance spreading deeper into the mesopelagic, as observed in the glider backscatter data (Fig. 2.43). 'Net' NH_4^+ production rates measured from the various particle fractions seemed to indicate high remineralisation activities across all particle-fractions (and free-living) in the upper mesopelagic in our first visit, while activity was dominated by fast-sinking particle fraction deeper into the mesopelagic at 500 m (Fig. 2.44). However, over the 3-week period, active remineralisation at the same depth had spread across all particle fractions. Meanwhile, high NH_4^+ has already accumulated after few weeks of active remineralisation in the upper mesopelagic, such that the system seemed to have shifted from 'net' NH_4^+ production mode to 'net' loss, likely indicating more active nitrification, while active remineralisation might have waned. These postulations could be verified by nitrification, assimilation and nitrate/nitrite reduction rate measurements via stable isotope analyses of NO_x^-, NH_4^+ and POM from our incubation experiments back in the UK. In addition, community structure analyses (16S amplicon sequencing and CARD-FISH) and metatranscriptomics analyses would be able to shed light on the different biogeochemical functions likely conducted by the microbial communities residing on the different particle fractions. These rate measurements and molecular analyses are to be further evaluated with microrespiration measurements and particle flux dynamics as observed with optical data from red camera frames (Iversen and Lampitt) and gliders (Carvahlo and Hensen). Comparison will also be made between measurements made on the PELAGRA live trap samples and the MSC particle fractions, to better understand the microbial alterations and remineralisation activities on sinking particles, and between particle-associated and pelagic microbial activities.
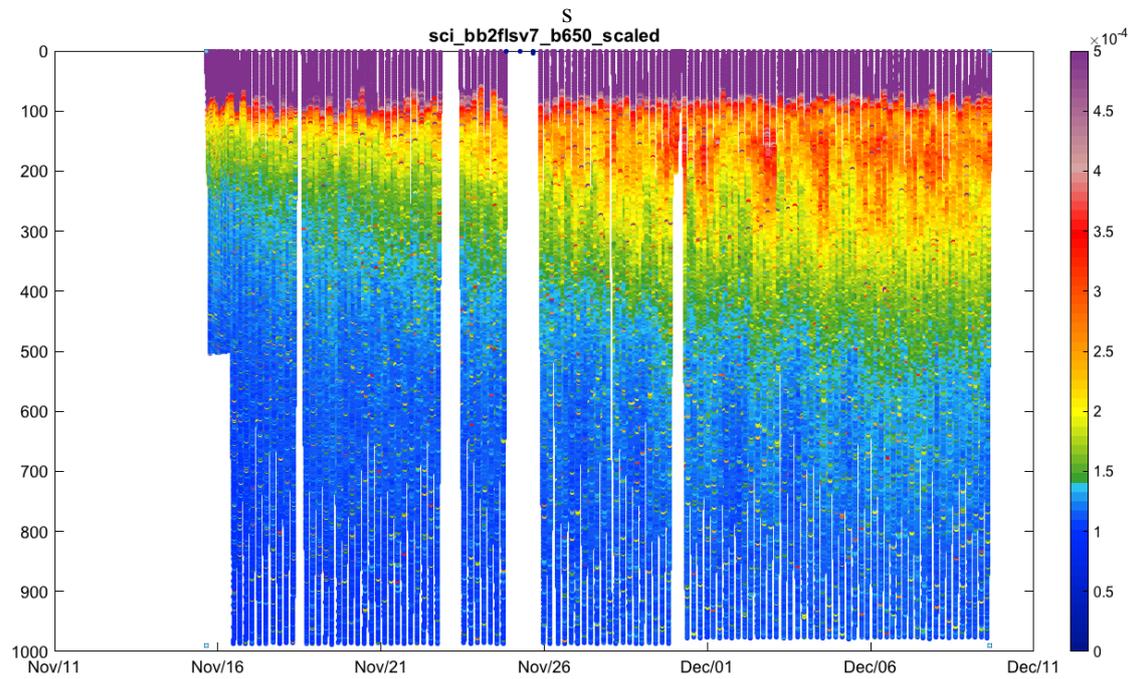
Figure 2.43: Backscatter at 650 nm as measured on the glider from Nov16 to Dec 10 (F. Carvalho)
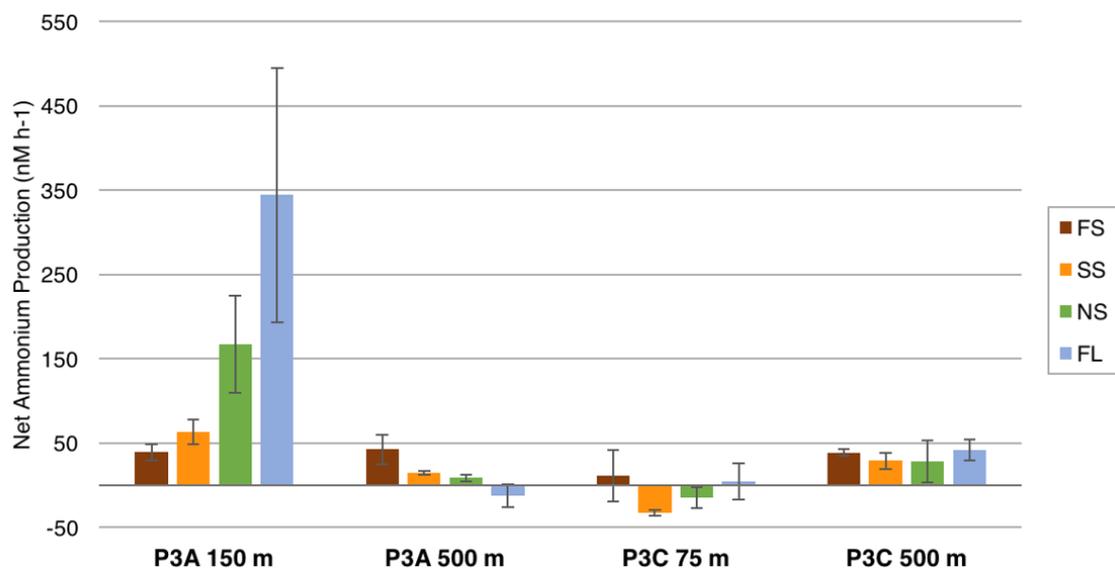
Figure 2.44: Net ammonium production rates measured during the 1st and 3rd visits to site P3, in the upper and mid mesopelagic depths. Error bars show standard errors of the mean. FS= fast-sinking, SS=slow-sinking, NS=non-sinking suspended and FL=free-living.

2.25.6 References

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Holmes, R. M., Aminot, A., Kerouel, R., Hooker, B. A. and Peterson, B. J. (1999). A simple and precise method for measuring ammonium in marine and freshwater ecosystems. Canadian Journal of Fisheries and Aquatic Sciences 56(10): 1801-1808

2.26 Microrespiration

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2.26.1 Objectives

The aim of this research is to quantify respiration and remineralisation on sinking material in the mesopelagic.

2.26.2 Methods

All micro-respiration measurements were taken using the Unisense micro-respiration system, including microelectrodes, stirrer platforms, which can hold the electrodes and 750 µL glass chambers for the samples. A chiller and tank were used to contain the system. This needed to be located in the salinometer room, as it is temperature controlled to approximate 20°C, to prevent large changes in temperature, as oxygen saturation is easily affected by small fluctuations in temperature.

Mircoelectrodes of oxygen, nitric oxide and nitrous oxide were used. Three stirrer systems were used, each with the ability to hold eight mirco-respiration chambers. The electrodes were connected to the Unisense ampmeter, which were connected to a laptop for logging purposes. The Unisense programme Rate in the Sensor Suit was used to record changes in the three parameters.

Calibration of the mircoelectrode sensors

The oxygen electrode was calibrated as a two-point linear calibration using bubbled seawater kept in the chiller tank at the same temperature as the experiment for a 100% point. For the zero point of the calibration an oxidising solution of 0.2 g sodium hydroxide and 1 g ascorbic acid dissolved in 50 mL of MilliQ was placed in the Unisense calibration chamber, left for two hours and then recorded.

The nitrous oxide sensor zero point was in MilliQ water kept at the same temperature as the chiller tank. A 100 µmol solution was made by bubbling 2% nitrous oxide/nitrogen gas into 300 mL of filtered seawater kept at the same temperature as the water bath. The nitric oxide sensor was calibrated to zero in MilliQ water at the same temperature as the chiller. Helium gas was then bubbled through 1mol sodium hydroxide solution and into MilliQ to deoxygenate the sample. Subsequent bubbling of 5% nitric oxide through the sodium hydroxide, removes nitrate. The MilliQ can then be used as an approximate 80 µmol sample. It is difficult to determine exactly as there is sparse literature on NO solubility.

Snow Catcher Samples

Samples were taken from Snow Catcher deployments. Three Snow Catchers were deployed at one depth, per deployment, one for molecular biology, and the other two for rate processes. They were left to settle for at least two hours, to allow the fast and slow sinking fractions to separate into the bottom tray. The fractions used in the incubation chambers were a time zero sample, the suspended, slow and fast fractions from the snow catcher after 2 hours of settling and the free living fraction.

A time zero sample was taken for respiration and POC filtering once the snow catcher was on deck. After two hours the Catchers were emptied, with samples from the suspended fraction taken for respiration measurements and POC filtering and incubation experiments (see Section 2.25). The top of the catcher was then emptied, and the bottom tray taken into the cold room for inspection. Due to movement of the water when it was taken into the cold room it was left again for approximately 30 min to allow the fast sinking fraction to settle.

A portion of the fast sinking pellets and aggregates were transferred to Petri dishes via mouth pipettes for photographs to be taken for later analysis of volume and size. These were then carefully

transferred into the micro-respiration chambers, using a mouth pipette, with small glass stirrers in the bottom to allow suspension of the particles. A portion of the slow sinking fraction was also transferred into respiration chambers. A further portion was filtered for POC. Suspended water from the catchers was gravity filtered through a 3 micron filter to obtain the free living fraction, with some of this transferred to the micro-respiration chambers. Blanks of 0.2 μm filtered seawater was also taken for the micro-respiration chambers.

All measurements were done in at least triplicates, sometimes more depending on the number of sinking particles. After the respiration rate was obtains (typically taking 6-12 hours) the fast sinking fractions were filtered onto a pre-weighed filter for POC analysis. Sometimes rates were slow and therefore measurements over a longer time period was required. However, this was not always possible due to time constraints and snowcatcher deployments. The collected particles for the fast sinking fraction were then filtered onto triple weighed GF/F filters for POC analysis.

PELARGA samples

Sinking material was collected from the formalin free cups from PELAGRA sediment traps, which were opened in the last 3 hours of deployment for live material. Some of this material was transferred into micro-respiration chambers for triplicate rate measurements. Samples for other analysis were also taken, please refer to the Sections 2.25 and 2.28.

RESPIRE samples

A small portion of the material collected by RESPIRE was transferred to mirco-respiration chambers, triplicates for each depth. Once POC has been analysed a comparison between the RESPIRE and micro-respiration chambers can be made. For more information on the RESPIRE traps please refer to Section 2.27.

Example data

The data from the microsensors is available immediately, however the POC is needed to calculate carbon specific respiration. Figure 2.45 shows oxygen consumption from the fast sinking fraction at three depths between 1st December 2017 and 4th December 2017. The rates decrease depth most likely due to reduced material found in the snow catcher. The rate of consumption at 70 m between all three chambers was on average, 2.7 μmol L^{-1} h^{-1}. At 160 m the rates were 1.28 μmol L^{-1} h^{-1} and at 250 m 1.2μmol L^{-1} h^{-1}.
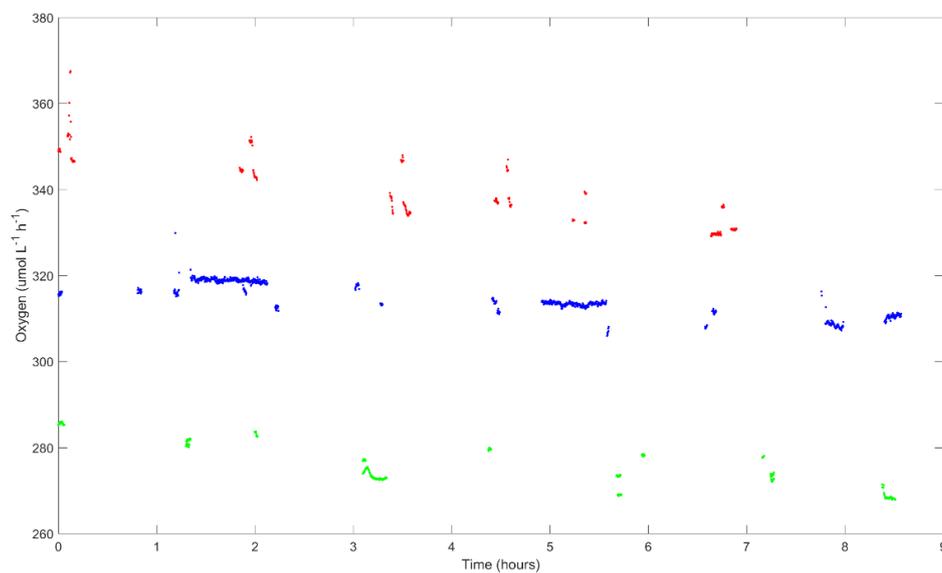
Figure 2.45: Oxygen concentration in microrespiration chambers over time for fast sinking particles collected at 70 m (red), 160 m (blue) and 250 m (green).

2.27 RESPIRE trap

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2.27.1 Objectives

The main objective of deploying the RESPIRE traps during COMICS1 was to explore in situ rates of bacterial remineralisation on sinking particles in the mesopelagic zone. RESPIRE traps are equipped with an indented rotating sphere (IRS) which collects sequentially the sinking particles during the first period of the deployment (collection period), and deposit them into a virtually closed incubation chamber (<0.6 mm gap between IRS and trap cylinder walls), where an oxygen optode (Aanderaa 3830 series) measures dissolved oxygen concentration. The rotation of the sphere is programmed to stop after a given amount of time (end of the collection), and marks the beginning of the incubation time. Oxygen concentration is measured during the whole deployment (collection + incubation) and the rate of its decrease during the incubation period is a metric of particle remineralisation related to particle-attached bacteria.

The two functional RESPIRE traps were deployed at nominal depths of 100 and 150 m (150 and 250 m on the third deployment), below the mixed layer depth and out of the influence of internal waves to avoid temperature variations potentially affecting oxygen measurements.

2.27.2 Preparation of the RESPIRE traps prior to each deployment

Each trap was soaked overnight with 2% detergent (15-30% anionic and 5-15% non-anionic surfactant), flushed with deionised water, then cleaned with 2% HCl during 48h, and finally Thoroughly rinsed with MilliQ water. The settings determining sphere rotation frequency and collection and incubation durations, were chosen accordingly to primary productivity features and total deployment duration constrained by favourable weather windows. In order to collect individual particles to limit particle coagulation (potential bias for particle-attached respiration measurements), and transfer it inside the incubation chamber, the rotation frequency of the sphere was set to one complete rotation (accomplished in 50 seconds) every 10 minutes. Dissolved oxygen concentration was measured by the optode inside the incubation chamber every 5 minutes for the duration of the deployment to monitor evolution of respiration rates between the collection and incubation phases.

In order to reach an initial dissolved oxygen concentration inside the incubation chamber close to the in situ concentration, water was sampled less than 3 hours before deployment from the planned depths of deployment using 20-L Niskin bottles mounted on a CTD rosette. Water was collected from the CTD rosette in 10% HCl cleaned 20-L carboys and clean tubing, filtered on a 1 μm Millipore cartridge filter to remove swimmers, and stored in a temperature controlled room and in darkness. Less than one hour before deployment the traps were gently filled with their respective in situ sampled water and overflowed ensuring limited bubble production.

2.27.3 Sampling after recovery

After recovery, water was gently drained from the trap collection cylinder keeping only the content of the incubation chamber. The whole content of the chamber (1.6L) was collected in a 5L 10% HCl cleaned bottle equipped with a clean funnel (the bottom plate was removed and washed with 2 μm filtered seawater to collect remaining particles; Fig. 2.46), filtered onto pre-combusted 25-mm GF/F filters, and rinsed with MilliQ water for particulate matter content determination required to normalise dissolved oxygen measurements. A small fraction of the water collected was sampled for complimentary analyses:

Figure 2.46: Particles remaining at the surface of the bottom plate after drainage of the incubation chamber (100 m trap, deployment 1)

- bacteria microscopy counting and DNA (Section 2.25),
- nutrients: nitrates, phosphates and dissolved silica (Section 2.16),
- micro-respiration incubation experiments (Section 2.26)
- Fast-Repetition-Fluorometer (FRF) (Mark Moore)
- Particle imaging (Morten Iversen)

2.27.4 Deployment summary

We carried out three deployments. For technical details see Section 2.27.5). A brief description of the location and environmental conditions follows here.

Deployment 1 (P3A)
During the first deployment, the array drifted in surface biomass levels of approx. 2-3 μg Chl L^{-1} according to NASA MODIS Aqua data (Fig. 2.47).

Deployment 2 (P3B)
The RESPIRE traps drifted in a much lower surface biomass during the second deployment as shown by satellite composite image (Fig. 2.48), and confirmed by the very few particles that accumulated in the incubation chamber over the whole deployment. This is consistent with other observations suggesting a particle field deeper than 150 m and a bloom decline at P3.
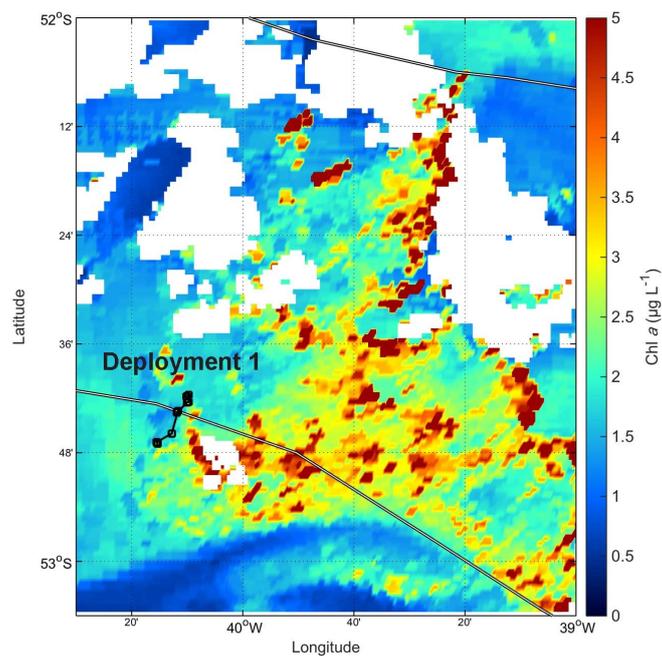
Figure 2.47: Location of the array on a composite mean Chl a product between the 15th and 21st Nov 2017 (NASA MODIS-Aqua).
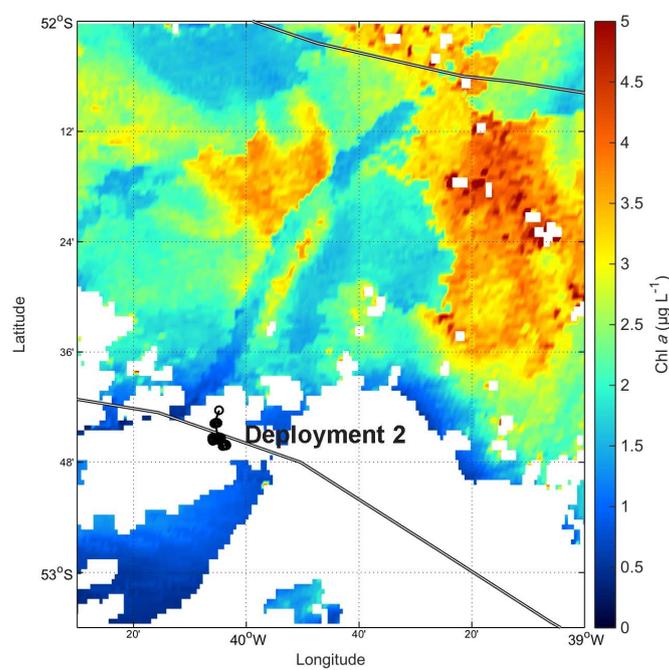
Figure 2.48: Location of the array on a composite mean Chl a product between the 26th Nov and 2nd Dec.2017 (NASA MODIS-Aqua).
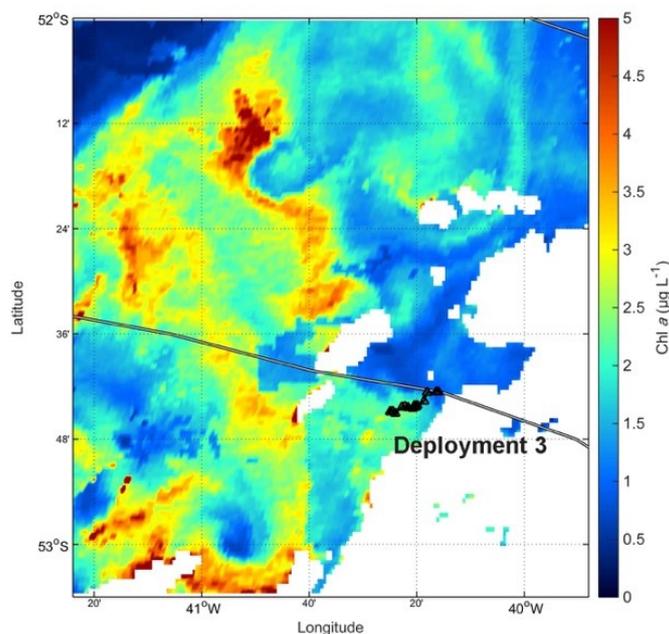
Figure 2.49: Location of the array on a composite mean Chl a product between the 7th and 13th Dec 2017 (NASA MODIS-Aqua).

Deployment 3 (P3C)

During deployment 3 the array drifted in a moderate biomass level (Fig. 2.49). The two traps were deployed at 150 and 250 m to aim for particle collection in deeper layers. A large flux of fecal pellets (mostly from krill) was collected at 250 m.

2.27.5 Technical report

REspiration of Sinking Particles In the subsuRface ocEan (RESPIRE) particle interceptors were deployed during the first COMICS voyage off South Georgia (RRS Discovery, 7 Nov- 21 Dec 2017). RESPIRE traps were deployed on a free-drifting surface-tethered array (Fig. 2.50 and 2.51) for an average duration of 3 days depending on weather constraints and biomass productivity on site driving particle collection.

The 3 traps, controllers and two frames were lent by the Institute for Marine and Antarctic Studies (P. Boyd, IMAS, Tasmania, Australia). The mooring line was designed by the NOC technical team and the surface buoy lent by the Woods Hole Oceanographic Institute.

A total of three RESPIRE traps was embarked with several technical issues inherited from a previous voyage and that could not be solved prior to the COMICS cruise for timing reasons. Two optode - controller cables were damaged and needed to be changed. Because of time constraints only the Aanderaa connectors (optode end) were replaced with new items. The Impulse connectors (controller end) were used ones and recycled on newly built cables. One Impulse connector was corroded but arrived already spliced to an Aanderaa cable. The other Impulse connector was incorrectly supplied as a female connector instead of a male. The two splices were also not wired correctly and the two cables had to be disassembled are re-wired onboard. Because of the male Impulse connector missing, one cable had to be connected directly to the controller and potted through the end cap as a penetrator using a Polyurethane resin pack (Electrolube, type UR5041) to ensure waterproofness.

A flashing light and a flag were manufactured on board by an NMF technician and installed on the surface buoy on route to the study site. Because of a missing mooring GPS tracking system,

Figure 2.50: Surface buoy equipped with 4 penguin tags, flashing light and high-visibility flag.

Table 2.45: Date and times of RESPIRE deployments and recoveries (GMT).

	Deployment 1 (P3A)	Deployment 2 (P3B)	Deployment 3 (P3C)
Controller activation	Trap 1: 18/11/17 - 19:44	Trap 1: 30/11/17 - 13:34	Trap 1: 11/12/17 - 21:21
	Trap 2: 18/11/17 - 19:46	Trap 2: 30/11/17 - 13:39	Trap 2: 11/12/17 - 21:29
Deployment	18/11/17 - 21:00	30/11/17 - 13:48	11/12/17 - 22:10
	ID#: RESPIRE002	ID#: RESPIRE003	ID#: RESPIRE004
Recovery	21/11/17 - 8:30	03/12/17 - 11:47	14/12/17 - 11:30
	ID#: RESPIRERecover	ID#: RESPIRERecover	ID#: RESPIRErescover
End of mission (P,M)*	Trap 1: 21/11/17 - 8:43 (M)	Trap 1: 02/12/17 - 23:00 (P)	Trap 1: 14/12/17 - 6:00 (P)
	Trap 2: 21/11/17 - 8:50 (M)	Trap 2: 02/12/17 - 23:00 (P)	Trap 2: 14/12/17 - 6:00 (P)

tags normally designed to locate penguins at sea were placed on the mooring as an alternative location tracking system. 4 to 6 tags were placed on the surface buoy on each deployment (Fig. 2.50) and programmed to transmit their location sequentially according to the following pattern:

- start transmission 3 hours after activation
- during the first 60 hours:
  - transmit every 15 minutes during three hours
  - remain silent during 9 hours
- after 60 hours: transmit continuously every 15 minutes

To cover the largest time range of transmission, the tags were activated respectively 9, 6, and 3 hours before deployment and the last one at deployment time. A test deployment of the Toroid buoy was conducted on the 16 Nov 2017 (event ID# RESPIRE001) to check functionality of the tags and ensure that they can be used as a reliable means to track the array. The tags transmitted as programmed confirming they were fit for purpose and the array could be located.

Depths of deployment and temperature variations were monitored using a temperature and pressure sensor (RBR Canada) set to a sampling period of 10 seconds and placed on the shallowest frame (deployments 1-2: nominal depth of 100 m on deployment; deployment 3: nominal depth of 150 m). Temperature inside the trap was also provided by the optode and could be compared with the RBR sensor for validation purposes.

Deployment and recovery dates and times are reported in Table 2.45.
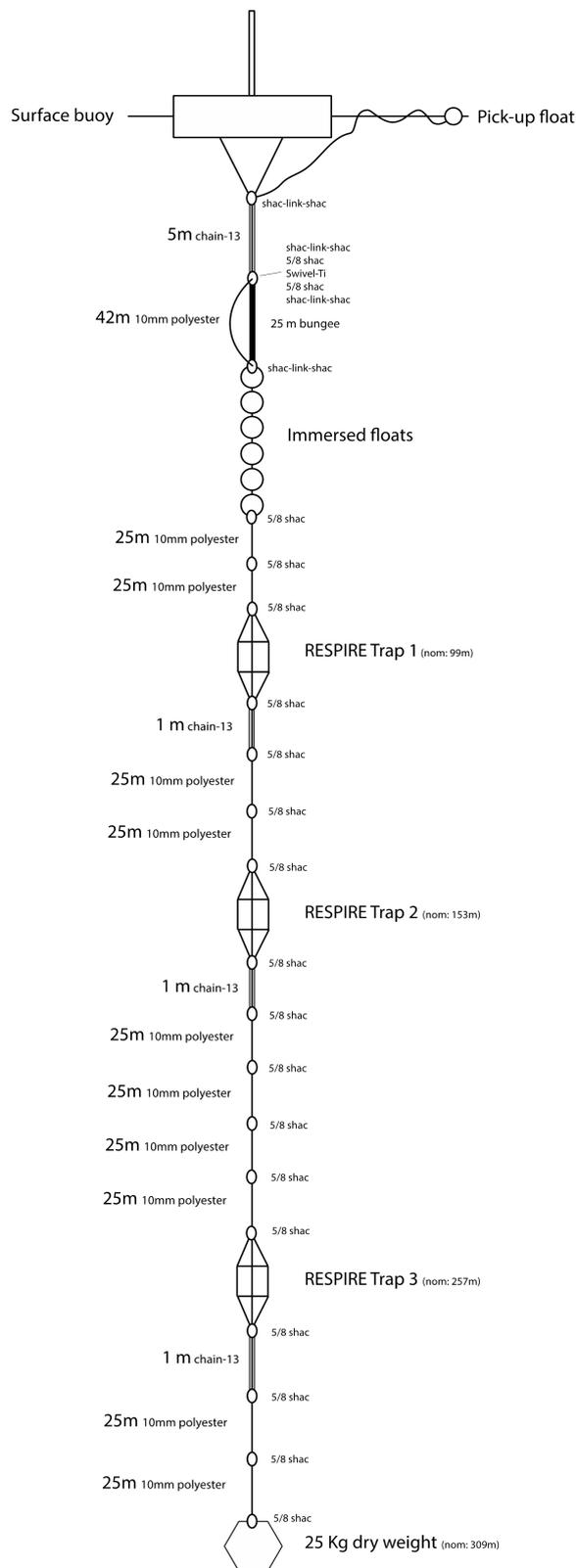
Figure 2.51: Design of the surface tethered free-drifting array used for RESPIRE trap deployments.

Figure 2.52: On-deck operations during the first deployment.

Deployment 1 - P3A

The first deployment occurred just prior to a storm and deck operations ended when weather started to worsen (Fig. 2.52).
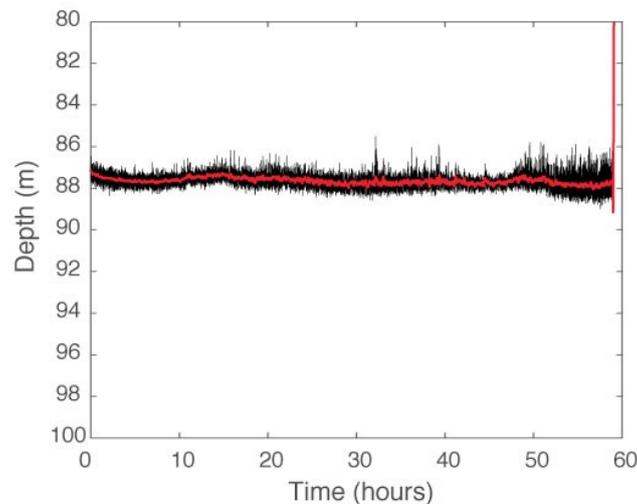
Figure 2.53: Depth recorded by the RBR pressure sensor placed on the shallowest trap (100 m nominal) during Deployment 1. The depth displayed does not account for the atmospheric pressure and has to be corrected (10 m subtracted from the depth displayed).

One length of 10-mm nylon rope 42 m long followed by 10 x 10 mm nylon rope lengths of 25 m were wound on to the North Sea deck winch including all shackles and links, in preparation for deployment. The drifting array was deployed anchor first using the port pedastal crane with a block to take the line outboard through the A frame. The final release was done by holding the top link on the pellet floats on a rope slightly starboard whilst releasing the buoy, bungee and 42m safety line on a sea catch (Fig. 2.51). The rope was then cut releasing the array from the ship. On the second and third deployment the safety rope was taped to the bungee in equidistant loops to reduce entanglement.

All three traps were deployed the first time at nominal depths of 100, 150 and 250 m for a

duration of 3 days. Positions of the drifting array from the penguin tags are presented in Table 2.46. The third trap (connected to the controller featuring the penetrator) did not record any oxygen data over the whole deployment. Latter inspection of the motherboard suggested a faulty reed switch (activated by a magnet) preventing the controller from functioning independently from a computer communication. Shorting the switch did not restore the ability to communicate with the controller and no further repair could be made onboard. Two RESPIRE traps were deployed for the remainder of the voyage.

The bungee dampened efficiently wave effects and kept the traps within a range of approximately 3m of vertical excursions (Fig. 2.53). The depth recorded by the pressure sensor had an approximate 20 m difference with the nominal depth. Checking the different sections of the mooring line revealed no evidence that could explain this difference.

Recovery of the array was conducted early in the morning with no issue after being located easily using the tracking system and flashing light.

Table 2.46: Position of the mooring array from penguin tags during the first deployment (P3A; 18/11 to 21/11/17). *Location quality from best to worst: 3, 2, 1.

Loc. date (GMT)	Lon	Lat	Loc. quality*	Error radius (m)
18/11/2017 19:12	-40.17852	-52.70592	1	856
18/11/2017 20:16	-40.16937	-52.6964	3	160
18/11/2017 20:26	-40.16309	-52.6935	3	159
18/11/2017 20:53	-40.18467	-52.69116	2	280
19/11/2017 01:07	-40.16226	-52.70831	1	509
19/11/2017 01:11	-40.1624	-52.70653	3	234
19/11/2017 02:09	-40.1675	-52.70783	3	183
19/11/2017 08:20	-40.19733	-52.72644	3	145
19/11/2017 08:20	-40.19479	-52.72372	3	221
19/11/2017 08:20	-40.17268	-52.73106	1	1481
19/11/2017 08:23	-40.19129	-52.72606	2	423
19/11/2017 08:24	-40.19876	-52.73056	1	750
19/11/2017 09:22	-40.16724	-52.73824	1	823
19/11/2017 09:22	-40.20201	-52.73182	1	964
19/11/2017 09:24	-40.20097	-52.73518	2	251
19/11/2017 09:25	-40.19806	-52.72742	1	533
19/11/2017 18:00	-40.21222	-52.74912	2	405
19/11/2017 18:01	-40.21607	-52.75743	2	287
19/11/2017 18:32	-40.21677	-52.76011	2	266
19/11/2017 19:44	-40.20535	-52.7638	1	596
19/11/2017 20:15	-40.21332	-52.76492	3	248
19/11/2017 20:27	-40.21349	-52.76661	2	268
20/11/2017 01:49	-40.21648	-52.78211	2	373
20/11/2017 09:05	-40.24064	-52.78738	2	275
20/11/2017 09:05	-40.24147	-52.78963	2	424
20/11/2017 09:11	-40.23753	-52.78626	2	395
20/11/2017 09:11	-40.23346	-52.7888	1	564
20/11/2017 09:27	-40.24349	-52.78632	1	1086
20/11/2017 09:27	-40.21959	-52.78379	1	1216
20/11/2017 09:30	-40.24584	-52.78689	1	677
20/11/2017 09:31	-40.23542	-52.78869	1	944
20/11/2017 17:33	-40.25211	-52.77149	1	511
20/11/2017 18:21	-40.25322	-52.7809	2	310
20/11/2017 19:13	-40.25657	-52.78201	3	225
20/11/2017 19:13	-40.25551	-52.78298	3	170
20/11/2017 20:01	-40.26753	-52.78427	2	272
20/11/2017 20:03	-40.25741	-52.78203	3	162

Figure 2.54: On-deck operations during the second deployment in calm seas.

Deployment 2 - P3B

The second deployment was conducted in good weather conditions (Fig. 2.54) and no complications or incidents of note. Locations of the drifting array from penguin tags are presented in Table 2.47.

The second deployment was also for a duration of 3 days. Vertical motions of the array from the pressure sensor are shown in Fig. 2.55. Vertical displacement of the array did not exceed 2 m for the duration of the deployment.

Recovery of the drifting array was also conducted in favourable weather conditions and no issues were encountered.

Table 2.47: Position of the mooring array from penguin tags during the second deployment (P3B; 30/11 to 03/12/17). *Location quality from best to worst: 3, 2, 1.

Loc. date (GMT)	Lon	Lat	Loc. quality*	Error radius (m)
30/11/2017 09:49	-40.08205	-52.70807	1	555
30/11/2017 10:29	-40.06218	-52.71211	2	380
30/11/2017 10:29	-40.06897	-52.71338	2	402
30/11/2017 10:34	-40.07691	-52.7122	2	387
30/11/2017 10:37	-40.05739	-52.71627	2	378
30/11/2017 10:51	-40.06692	-52.70934	1	662
30/11/2017 10:54	-40.07339	-52.6991	2	424
30/11/2017 11:27	-40.12153	-52.70486	1	687
30/11/2017 12:12	-40.08009	-52.70613	3	143
30/11/2017 21:05	-40.09451	-52.72958	3	179
30/11/2017 21:07	-40.09513	-52.72756	2	276
30/11/2017 21:29	-40.09584	-52.72589	2	280
30/11/2017 21:29	-40.08851	-52.72785	3	175
30/11/2017 22:22	-40.08965	-52.73112	1	781
30/11/2017 22:30	-40.08497	-52.72763	2	491
30/11/2017 22:33	-40.08976	-52.72929	3	159
30/11/2017 22:46	-40.11408	-52.73461	2	495
30/11/2017 23:42	-40.08556	-52.72845	3	233
01/12/2017 00:12	-40.10141	-52.72555	1	507
01/12/2017 00:26	-40.07461	-52.72676	2	259
01/12/2017 00:26	-40.09055	-52.72921	3	216
01/12/2017 10:00	-40.08333	-52.75553	2	256
01/12/2017 10:01	-40.08834	-52.75528	2	256

Table 2.47: continued

Loc. date (GMT)	Lon	Lat	Loc. quality*	Error radius (m)
01/12/2017 10:12	-40.08478	-52.7561	3	189
01/12/2017 10:12	-40.08374	-52.75777	3	165
01/12/2017 10:12	-40.08273	-52.75867	3	215
01/12/2017 10:22	-40.07852	-52.75541	3	176
01/12/2017 10:23	-40.08858	-52.75619	3	248
01/12/2017 10:24	-40.08614	-52.75681	3	145
01/12/2017 10:24	-40.0826	-52.75735	3	171
01/12/2017 10:25	-40.08061	-52.75455	3	193
01/12/2017 10:26	-40.08135	-52.75627	3	192
01/12/2017 11:09	-40.08308	-52.75571	2	402
01/12/2017 11:10	-40.09333	-52.75333	2	409
01/12/2017 11:54	-40.07521	-52.75532	3	185
01/12/2017 12:02	-40.07872	-52.75535	1	506
01/12/2017 21:18	-40.10061	-52.76349	2	275
01/12/2017 21:19	-40.10137	-52.75967	2	494
01/12/2017 21:50	-40.09379	-52.75719	2	282
01/12/2017 21:50	-40.09709	-52.75821	2	332
01/12/2017 22:07	-40.09764	-52.75988	2	253
01/12/2017 22:08	-40.0792	-52.75725	1	561
01/12/2017 22:09	-40.09572	-52.75964	2	270
01/12/2017 22:24	-40.09043	-52.759	1	522
01/12/2017 22:25	-40.0855	-52.75931	1	610
01/12/2017 22:31	-40.09067	-52.75983	1	909
01/12/2017 22:33	-40.09476	-52.75857	2	296
01/12/2017 23:21	-40.0941	-52.75831	2	323
01/12/2017 23:48	-40.0899	-52.7596	3	179
02/12/2017 00:06	-40.10093	-52.75831	3	163
02/12/2017 00:16	-40.08128	-52.75325	2	326
02/12/2017 01:05	-40.05013	-52.7508	1	951
02/12/2017 09:35	-40.08825	-52.76136	2	253
02/12/2017 09:35	-40.09685	-52.76255	2	258
02/12/2017 09:53	-40.08894	-52.75823	2	281
02/12/2017 09:55	-40.09869	-52.76083	3	187
02/12/2017 09:55	-40.09976	-52.75555	3	205
02/12/2017 09:55	-40.09557	-52.75936	3	174
02/12/2017 10:06	-40.09808	-52.76275	2	264
02/12/2017 10:08	-40.1078	-52.76072	2	334
02/12/2017 10:08	-40.08766	-52.75769	3	187
02/12/2017 10:48	-40.08931	-52.76196	2	344
02/12/2017 11:28	-40.05141	-52.76606	1	911
02/12/2017 12:26	-40.08005	-52.7596	1	634
02/12/2017 13:12	-40.0838	-52.76221	2	254
02/12/2017 21:06	-40.07446	-52.76927	2	455
02/12/2017 21:07	-40.07101	-52.76371	3	247
02/12/2017 21:47	-40.0722	-52.76959	2	311
02/12/2017 21:48	-40.07547	-52.76891	2	321
02/12/2017 22:22	-40.07047	-52.77036	3	224
02/12/2017 22:22	-40.06854	-52.77024	3	148
02/12/2017 22:23	-40.06526	-52.76945	3	228
02/12/2017 22:46	-40.0589	-52.77744	1	1004
02/12/2017 23:22	-40.05969	-52.76926	3	209
02/12/2017 23:22	-40.06219	-52.76803	3	165
02/12/2017 23:23	-40.05749	-52.76669	2	267
02/12/2017 23:42	-40.06041	-52.76812	2	291
02/12/2017 23:42	-40.06041	-52.76779	3	210
02/12/2017 23:42	-40.059	-52.76824	3	214
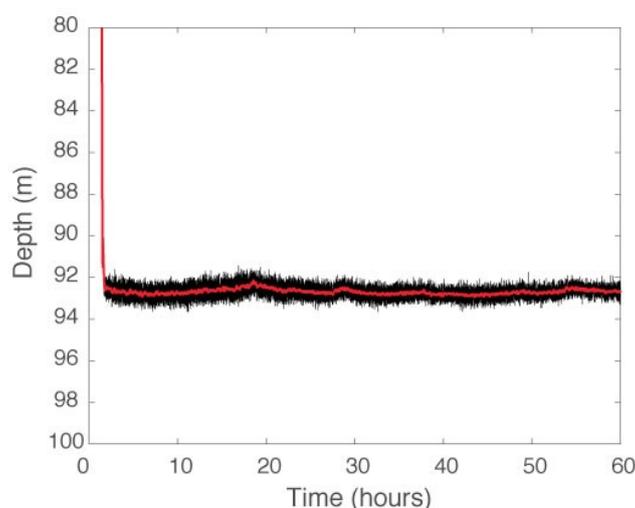
Figure 2.55: Depth recorded by the RBR pressure sensor placed on the shallowest trap (100 m nominal) during Deployment 2. The depth displayed does not account for the atmospheric pressure and has to be corrected (10 m subtracted from the depth displayed).

Deployment 3 - P3C

The third deployment was conducted without any issue in very calm seas (Fig. 2.56).

The third deployment also lasted three days. Locations from penguin trackers are presented in Table 2.48. Vertical movements did not exceed 3 meters during the third deployment (Fig. 2.57), despite very rough conditions encountered toward the ends of the 3 days.

Recovery was conducted in the morning of the 14th December in moderately hard conditions (approx. 30 knots wind and 4-5 m waves), but the crew managed the operations without any complication.

Table 2.48: Position of the mooring array from penguin tags during the third deployment (P3C; 11/12 to 14/12/17). *Location quality from best to worst: 3, 2, 1.

Loc. date (GMT)	Lon	Lat	Loc. quality*	Error radius (m)
11/12/2017 16:40	57.39122	-68.09865	1	1172
11/12/2017 21:01	-40.39902	-52.74516	2	304
11/12/2017 21:04	-40.29695	-52.69003	1	575
11/12/2017 21:18	-40.40796	-52.74702	3	232
11/12/2017 21:18	-40.43831	-52.75023	1	757
11/12/2017 22:14	-40.39349	-52.72915	1	1140
11/12/2017 22:17	-40.41461	-52.74728	3	214
11/12/2017 22:18	-40.41604	-52.74861	3	215
11/12/2017 22:53	-40.39971	-52.75097	3	190
12/12/2017 05:19	-40.39572	-52.73782	2	346
12/12/2017 05:29	-40.38882	-52.74076	1	601
12/12/2017 05:29	-40.37446	-52.73958	1	1312
12/12/2017 08:03	-40.37878	-52.73246	1	631
12/12/2017 08:03	-40.37691	-52.75113	2	393
12/12/2017 08:04	-40.38686	-52.73948	2	473
12/12/2017 08:10	-40.38446	-52.73493	1	1117
12/12/2017 08:15	-40.37832	-52.74222	2	436
12/12/2017 08:15	-40.37865	-52.73891	3	200
12/12/2017 08:16	-40.37491	-52.74435	2	405
12/12/2017 08:44	-40.36497	-52.7374	2	355

Table 2.48: continued

Loc. date (GMT)	Lon	Lat	Loc. quality*	Error radius (m)
12/12/2017 08:45	-40.36629	-52.74127	2	364
12/12/2017 08:45	-40.38173	-52.73661	2	305
12/12/2017 09:06	-40.37058	-52.73866	2	333
12/12/2017 09:43	-40.36548	-52.73678	2	467
12/12/2017 09:43	-40.3605	-52.73954	3	190
12/12/2017 09:58	-40.36993	-52.73816	3	221
12/12/2017 10:22	-40.34571	-52.74141	3	170
12/12/2017 17:27	-40.40497	-52.74024	1	1204
12/12/2017 17:28	-40.33402	-52.73079	1	621
12/12/2017 19:26	-40.34329	-52.73302	2	283
12/12/2017 20:27	-40.33267	-52.72891	1	1074
12/12/2017 20:49	-40.33473	-52.73751	2	348
12/12/2017 20:50	-40.33782	-52.73889	2	281
12/12/2017 20:52	-40.33983	-52.73664	3	208
12/12/2017 20:53	-40.33523	-52.73762	3	173
12/12/2017 21:06	-40.33862	-52.73599	3	186
12/12/2017 21:06	-40.33146	-52.73602	3	221
12/12/2017 21:07	-40.33632	-52.73908	3	219
12/12/2017 22:06	-40.34112	-52.73698	3	220
12/12/2017 22:29	-40.32546	-52.73887	1	1451
12/12/2017 22:30	-40.33514	-52.74534	1	1452
13/12/2017 05:05	-40.29946	-52.73495	1	1326
13/12/2017 05:06	-40.3102	-52.72777	3	194
13/12/2017 05:08	-40.30272	-52.72975	2	258
13/12/2017 08:04	-40.29287	-52.71862	2	392
13/12/2017 08:04	-40.29863	-52.71949	2	273
13/12/2017 08:05	-40.29447	-52.72255	1	1152
13/12/2017 09:10	-40.30594	-52.71594	1	666
13/12/2017 09:11	-40.30256	-52.71419	2	270
13/12/2017 09:12	-40.29873	-52.71244	2	286
13/12/2017 09:12	-40.28698	-52.71093	1	712
13/12/2017 09:26	-40.30508	-52.71561	1	557
13/12/2017 09:26	-40.30973	-52.72087	1	777
13/12/2017 09:26	-40.27792	-52.71354	1	997
13/12/2017 09:27	-40.28681	-52.71504	1	504
13/12/2017 09:46	-40.3017	-52.7115	3	171
13/12/2017 09:57	-40.2982	-52.70959	2	432
13/12/2017 17:15	-40.27579	-52.70883	2	388
13/12/2017 17:15	-40.27978	-52.70596	2	330
13/12/2017 17:18	-40.28195	-52.70504	1	886
13/12/2017 17:19	-40.2809	-52.70862	1	568
13/12/2017 18:55	-40.27432	-52.7106	2	448
13/12/2017 18:57	-40.31004	-52.71777	1	971
13/12/2017 20:27	-40.27502	-52.71509	2	409
13/12/2017 20:29	-40.27221	-52.71023	3	245
13/12/2017 20:35	-40.27614	-52.70938	2	300
13/12/2017 20:36	-40.26899	-52.70957	2	293
13/12/2017 20:37	-40.27438	-52.70871	1	618
13/12/2017 20:38	-40.27095	-52.7086	2	340
13/12/2017 21:54	-40.26681	-52.71083	3	226
13/12/2017 22:03	-40.26444	-52.70795	2	289
13/12/2017 22:16	-40.26689	-52.71071	1	665
13/12/2017 22:20	-40.26999	-52.71148	1	717

Figure 2.56: End of the third deployment in very calm seas. The photography shows the release of the immersed floats and the surface buoy.
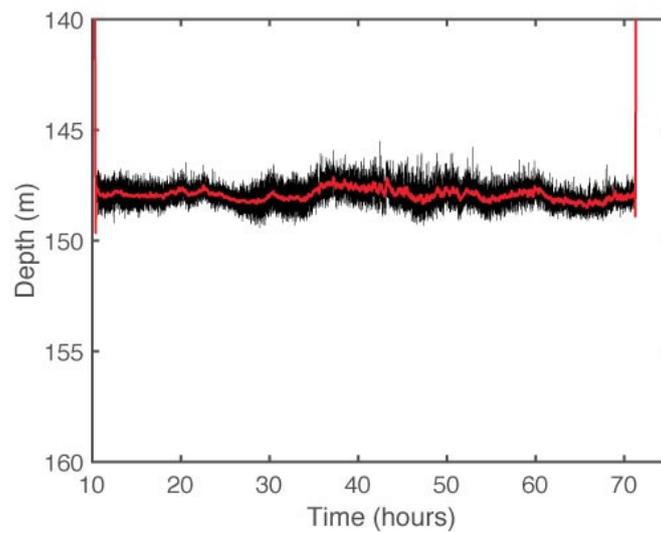

Figure 2.57: Depth recorded by the RBR pressure sensor placed on the shallowest trap (150 m nominal) during Deployment 3. The depth displayed does not account for the atmospheric pressure and has to be corrected (10 m subtracted from the depth displayed).

2.28 PELAGRA sediment trap

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2.28.1 Overview

The objective of this component of the COMICS programme was to make direct measurements of downward particle flux between the base of the upper mixed layer and 500 m depth, a depth layer over which the most rapid attenuation in flux is usually observed. The intention was to deploy traps for periods of several days at predetermined depth at both the P3 (Fe+) and P2 (Fe-) sites. Two types of PELAGRA were used: Standard traps with 4 collecting funnels and Camera traps with two collecting funnels, two openings for Gel cups and the P-Cam particle imaging system. Standard cups contained formalin preservative, the Gel cups contained Gel and some cups were free of any preservative (live cups).
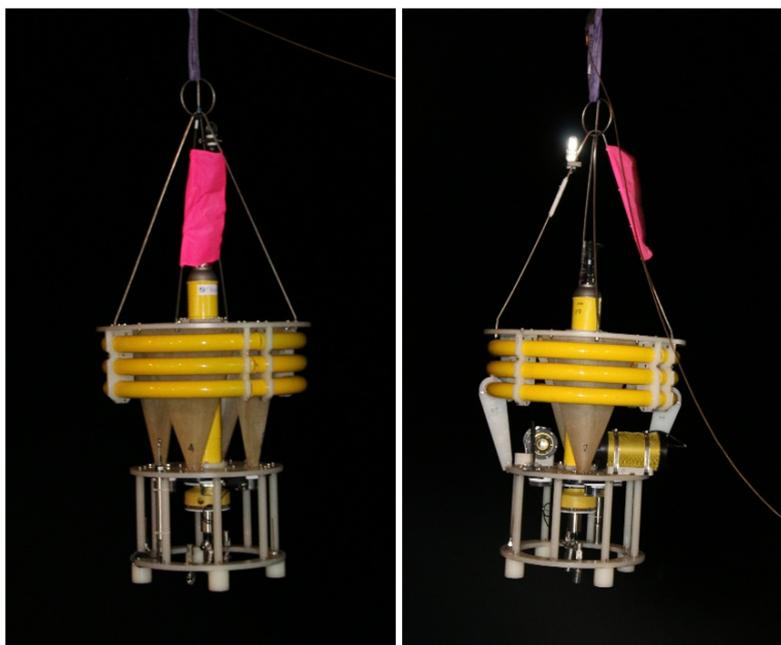
Figure 2.58: Standard PELAGRA with four funnels (left) and Camera PELAGRA with two funnels, optical particle system and two gel cups (right).

2.28.2 Preparation

Cups were filled just before deployment via the funnel in order to reduce the presence of trapped air in the cups. Formalin cups were filled with a solution prepared from seawater from below 500 m depth to which had been added 5 g L^{-1} analar NaCl and concentrated borax-buffered formalin to a final concentration of 5%. Live cups were in general filled with unfiltered >500 m seawater with no salt addition. For the final deployment, the water was filtered.

2.28.3 Sample processing

Immediately on recovery formalin and live samples were photographed.
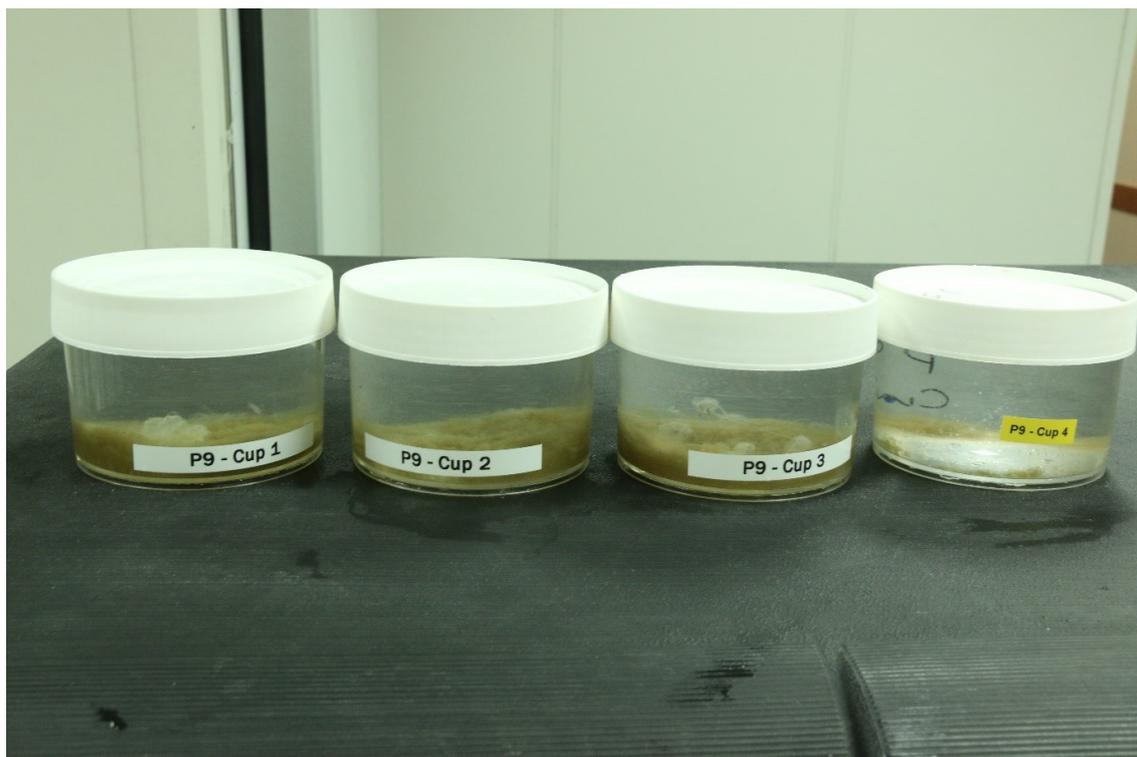
Figure 2.59: Example of photographs of recovered samples. In this case, the samples were from event 261 deployed on 5.12.17 at a depth of 250m for three consecutive 24 hour periods (Formalin Cups 1,2 & 3) followed by a live cup for 3 hours (Cup 4).

Formalin Samples

Gelatinous organisms were removed from the samples immediately after recovery and preserved separately. The remainder was decanted in 1-L plastic jars and 3 mL of concentrated formalin added in case the initial formalin concentration had decreased by diffusion during deployment. On recovery an aroma of formalin was usually apparent in the cups and the brine solution could be seen in the lower half of the sample cups indicating that preservation was successful.

2 mL of gently mixed suspensate was placed in a 2.97 mL Utermöhl chamber, topped up with filtered seawater and examined under 10x magnification using a Brunel inverted microscope. Photographs were taken at random to provide an initial impression of the types of material deposited, the changes with depth and time. After examination the Utermöhl samples were added back to the 1-L bottles.

Live Samples

These were used for a variety of analyses. See Sections 2.25, 2.26 and 2.18 for further information.

Gel Samples

Two of the PELAGRA sediment traps (P4 and P7) were equipped with camera systems (P-Cam, see below) and gel traps. Two of the four collection funnels were removed to avoid any disturbance of the particles collected in the gel traps. The gel traps were equipped with a viscous gel that preserved the structure, shape and size of the fragile particles settling into it. The particles collected in the gel were photographed at three different magnifications:

1. with a 12 mega-pixel Basler camera equipped with a 16 mm lens from Edmund Optics and even backlight illumination to provide overview images,
2. with a 12 mega-pixel Basler camera equipped with a 50 mm lens and even backlight illumi-
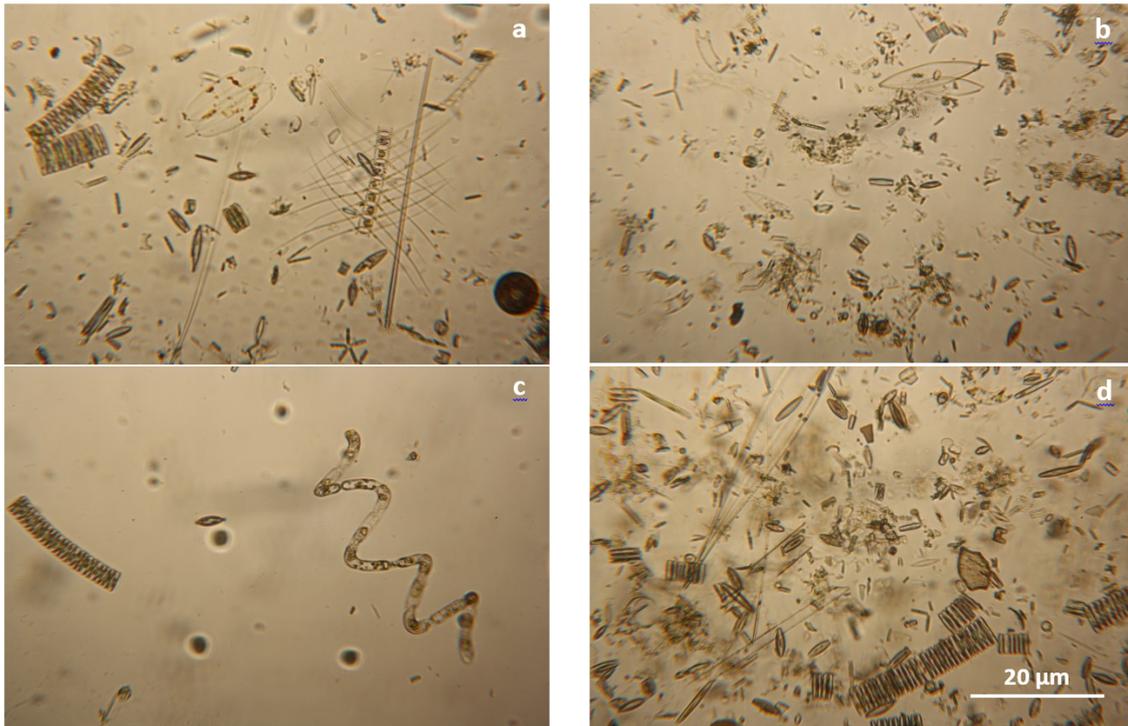
Figure 2.60: Photomicrograph examples of PELAGRA material. These were from (a) 100 m depth on the 20th November; P4, deployment 3, event 81. (b) 500 m depth on the 20th November; P7, deployment 3, event 78. (c) 100 m depth on the 12th December; P4, deployment 7, event 303. (d) 500 m depth on the 12th December; P7, deployment 7, event 300.

nation to provide obtain images with a magnification similar to that provided by the P-Cams, and

3. high resolution images of individual aggregates and particles made with a Brunel inverted microscope at 10x magnification.

2.28.4 P-Cam

We deployed the P-Cam (PELAGRA Camera) on two of the PELAGRA sediment traps (P4 and P7). The P-Cam was timed to take ten images with two seconds intervals every hour. The image sequences from the P-Cams provide in situ particle size-distribution, abundance, and size- and type-specific settling velocities. The P-Cams consisted of a Canon EOS 6D digital SLR camera equipped with a 50 mm macro lens and a Canon Speedlite 600EX RT flash gun. The camera and the flash gun were perpendicular to each other to provide illumination from the right side of the captured images. We used a Hahnel Giga T Pro II remote timer to control the flash timing. The camera was put in manual mode and the settings were adjusted to have an ISO of 2500, a shutter speed of 1/160 seconds, an aperture of f/32, and the lens focus was put to 1.5 feet. The flash was also in manual mode and put for straight flash direction and a flash output of 1/8.

The pixel size of the images changed depending on whether the particles were in the front or back of the field of depth. We determined a pixel size of 33 μm per pixel in the front of the depth of field (as seen from the camera) and a pixel size of 61 μm per pixel at the back of the depth of field. This suggested an average pixel size of 47 μm per pixel. The field of view for each image was 157 mm width, 101 mm height, and 135 mm depth.
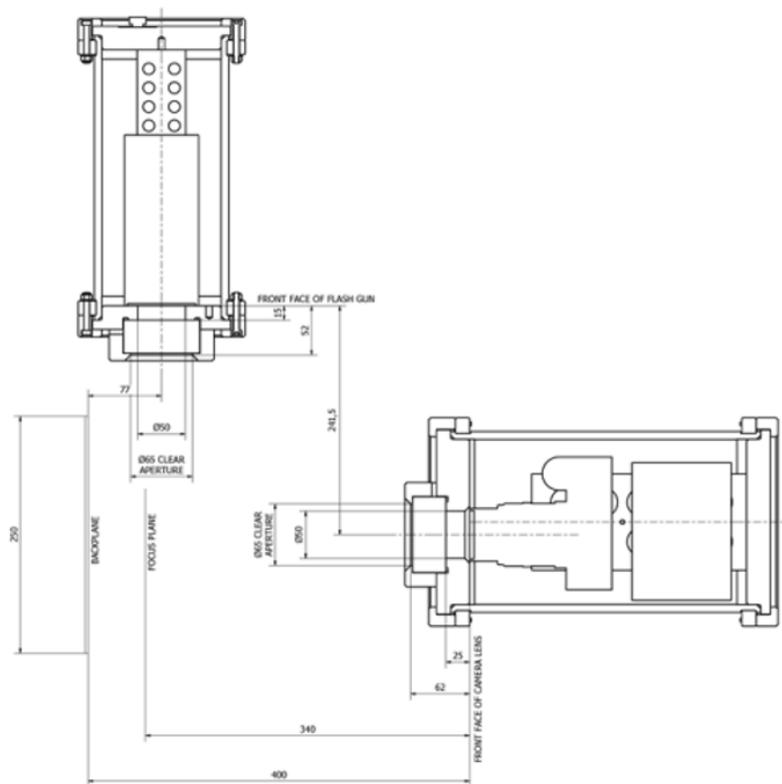
Figure 2.61: Overview figure of the PELAGRA Cam configuration. The pressure housing in the lower right part of the image contained the camera and the upper left pressure housing contained the flash gun.

PELAGRA Drift tracks during COMICS#1
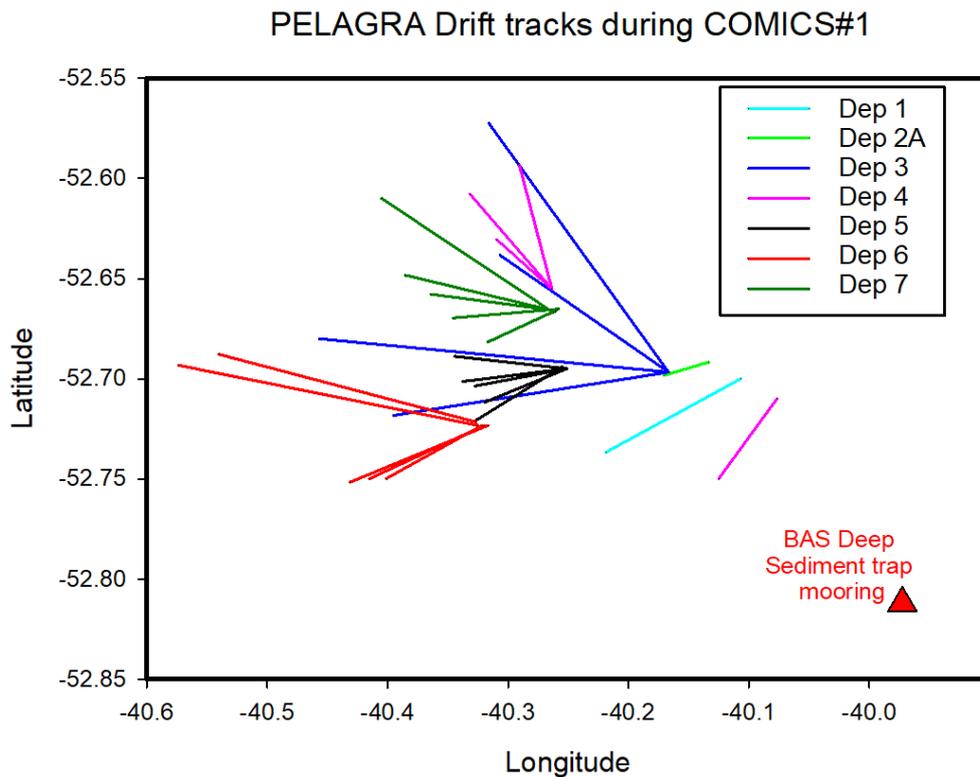
Figure 2.62: Trajectories of the 7 Series of PELAGRA deployments.

2.28.5 Deployment summary

38 PELAGRA deployments were made during the cruise. Including the ballast tests starting on 15th November, 7 deployment series were carried out with great success providing material for a wide range of chemical, isotopic and microscopic analyses to characterise the particle flux regime at this time of the decline of a massive phytoplankton bloom. During Deployment series 3 the surface traps drifted northwest and the deeper traps drifted west. In subsequent deployment series the surface traps drifted in a more southerly direction than the deeper traps. On return to NOC, samples will be picked for "swimmers", split into subsamples and analysed in a variety of ways.

2.28.6 Technical report

Kevin Saw*, Richard Lampitt*, Morten Iversen[+]

Summary

Five Pelagra traps were on board for DY086: P2, P4, P6, P7 and P9. P4 and P7 each carry two conventional sediment funnels, two non-funnelled collectors for gel sampling and a camera/flash system for capturing time-lapse images of sinking particles. P2, P6 and P9 each carry four conventional sediment funnels. All traps were furnished with the upgraded LED flashing light beacon that was successfully trialled on DY077 (PAP) earlier in the year, but otherwise unchanged.

The broad strategy for DY086 was to make simultaneous deployments of all five traps at depths at just below the mixed layer (initially estimated to be about 50 m), 110 m, 150 m, 250 m and 500 m.

Ballast trial deployment series 1 (15 November 2017)

All traps were deployed to test they were ballasted correctly:

P7 (camera trap)

Station:	P3A, event 2
Target depth:	500 m
Target temp:	1.9°C
In situ density:	1030.00 kg m^{-3}
Sampling strategy:	Cups G1, 2, G3 and 4 open 16/11/17 08:00, close 16/11/17 14:00
Added ballast:	3566 g
Piston posn Mbp:	115
Deployment time:	1511/17 13:00
Deployment posn:	52° 42.00' S, 40° 06.42' W

P7 was under-ballasted by 46 piston counts but stabilized at 500 m before the cups opened. However, the cups failed to close at the programmed time and were recovered open; no useable samples were obtained. Investigations into why the cups failed to close revealed no apparent issues; all cups opened and closed normally when tested on deck.
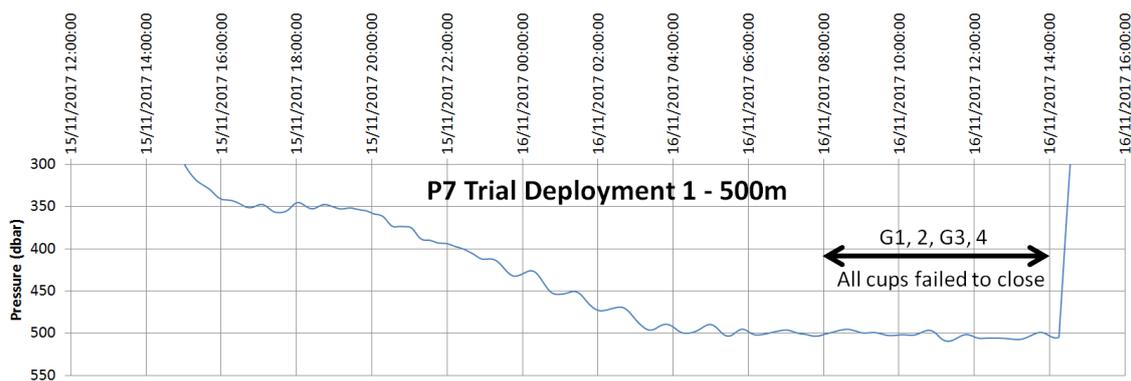
P9 (standard trap)

Station:	P3A, event 3
Target depth:	250 m
Target temp:	1.6°C
In situ density:	1028.68 kg m^{-3}
Sampling strategy:	Cups 1, 2, 3 and 4 open 16/11/17 08:00, close 16/11/17 14:00
Added ballast:	3967 g
Piston posn Mbp:	115
Deployment time:	15/11/17 13:15
Deployment posn:	52° 42.06' S, 40° 06.36' W

P9 was perfectly ballasted and the cups opened and closed as planned. Good samples were obtained. This plot shows corrected Idronaut pressure which was offset by +13 dbar at stabilisation depth.
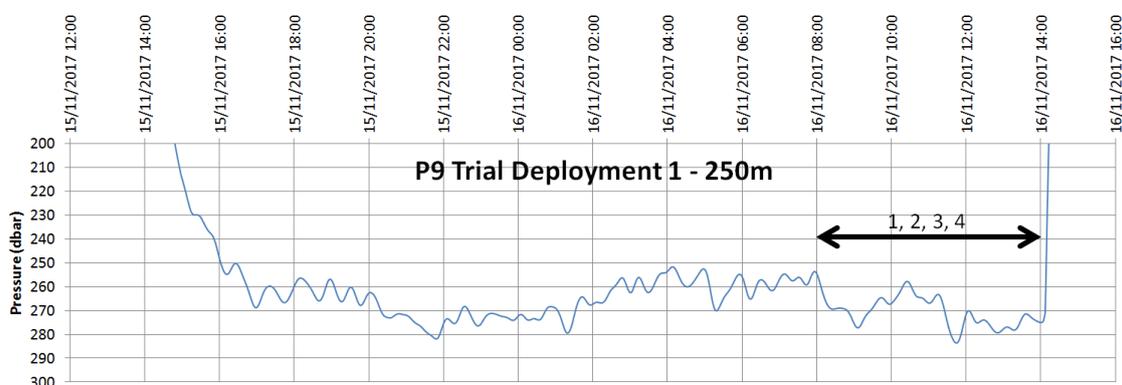
P6 (standard trap)

Station:	P3A, event 4
Target depth:	150 m
Target temp:	0.8°C
In situ density:	1028.00 kg m^{-3}
Sampling strategy:	Cups 1, 2, 3 and 4 open 16/11/17 08:00, close 16/11/17 14:00
Added ballast:	3605 g
Piston posn Mbp:	115
Deployment time:	15/11/17 13:30
Deployment posn:	52° 42.12' S, 40° 06.36' W

P6 was under-ballasted and didn't sink.

P4 (camera trap)

Station:	P3A, event 5
Target depth:	150 m
Target temp:	0.8°C
In situ density:	1028.00 kg m^{-3}
Sampling strategy:	Cups G1, 2, G3 and 4 open 16/11/17 08:00, close 16/11/17 14:00
Added ballast:	3206 g
Piston posn Mbp:	115
Deployment time:	15/11/17 13:45
Deployment posn:	52° 42.00' S, 40° 06.24' W

P4 was under-ballasted and returned directly to the surface after the depressor weight released.

P2 (standard trap)

Station:	P3A, event 6
Target depth:	150 m
Target temp:	0.8°C
In situ density:	1028.00 kg m^{-3}
Sampling strategy:	Cups 1, 2, 3 and 4 open 16/11/17 08:00, close 16/11/17 14:00
Added ballast:	3533 g
Piston posn Mbp:	115
Deployment time:	15/11/17 14:00
Deployment posn:	52° 42.00' S, 40° 06.24' W

P2 was under-ballasted and returned directly to the surface after the depressor weight released.

Ballast trial deployment series 2 (17 November 2017)

P6, P4 and P2 were redeployed to re-check adjusted ballasting:

P6 (standard trap)

Station:	P3A, event 44
Target depth:	150 m
Target temp:	0.8°C
In situ density:	1028.00 kg m^{-3}
Sampling strategy:	Cups 1, 2, 3 and 4 open 17/11/17 19:00, close 17/11/17 22:00
Added ballast:	3635 g
Piston posn Mbp:	115
Deployment time:	17/11/17 10:00
Deployment posn:	52° 41.46' S, 40° 07.56' W

Despite an additional 30 g of ballast, P6 was still under-ballasted and returned directly to the surface. It was also noted that the reason P6 failed to sink at all on the first deployment was likely to have been because the sample cups were not completely filled. From this point onwards it was decided to fit the sample cups empty and then fill them by holding them in the 'open' position and pouring the brine/formalin into the funnels. This ensured no air space remained. It was also decided to increase the depressor weight mass to 1 kg using the small ballast weights.

P4 (camera trap)

Station:	P3A, event 45
Target depth:	150 m
Target temp:	0.8°C
In situ density:	1028.00 kg m^{-3}
Sampling strategy:	Cups G1, 2, G3 and 4 open 17/11/17 19:00, close 17/11/17 22:00
Added ballast:	3257 g
Piston posn Mbp:	115
Deployment time:	17/11/17 10:15
Deployment posn:	52° 41.52' S, 40° 07.68' W

Despite an additional 20 g of ballast, P4 was still under-ballasted and returned directly to the surface.

P2 (standard trap)

Station:	P3A, event 46
Target depth:	150 m
Target temp:	0.8°C
In situ density:	1028.00 kg m^{-3}
Sampling strategy:	Cups 1, 2, 3 and 4 open 17/11/17 19:00, close 17/11/17 22:00
Added ballast:	3599 g
Piston posn Mbp:	115
Deployment time:	17/11/17 10:30
Deployment posn:	52° 41.52' S, 40° 07.80' W

Despite an additional 30 g of ballast, P2 was still under-ballasted and returned directly to the surface. During recovery, P2 was subject to several heavy snatch loads that caused a previously welded repair on one leg of the lifting frame to break. This was subsequently repaired using a threaded/clamped sleeve:

Ballast trial deployment series 2a (17 November 2017)

P6 and P4 were recovered quickly and redeployed with adjusted ballast. P2 was also recovered quickly but not redeployed at this time pending repair to lifting frame.

P6 (standard trap)

Station:	P3A, event 52
Target depth:	150 m
Target temp:	0.8°C
In situ density:	1028.00 kg m^{-3}
Sampling strategy:	Cups 1, 2, 3 and 4 open 17/11/17 19:00, close 17/11/17 22:00
Added ballast:	3665 g
Piston posn Mbp:	115
Deployment time:	17/11/17 14:00
Deployment posn:	52° 41.40' S, 40° 08.04' W

Despite an additional 30 g of ballast, P6 was still under-ballasted and returned directly to the surface.

P4 (camera trap)

Station: P3A, event 56
Target depth: 150 m
Target temp: 0.8°C
In situ density: 1028.00 kg m^{-3}
Sampling strategy: Cups G1, 2, G3 and 4 open 17/11/17 19:00, close 17/11/17 22:00
Added ballast: 3287 g
Piston posn Mbp: 115
Deployment time: 17/11/17 16:30
Deployment posn: 52° 41.52' S, 40° 07.98' W

With an additional 30 g of ballast, P4 eventually stabilised at 130 m with Mbp = 127 counts. This plot shows corrected Idronaut pressure which was offset by +5 dbar at stabilisation depth.
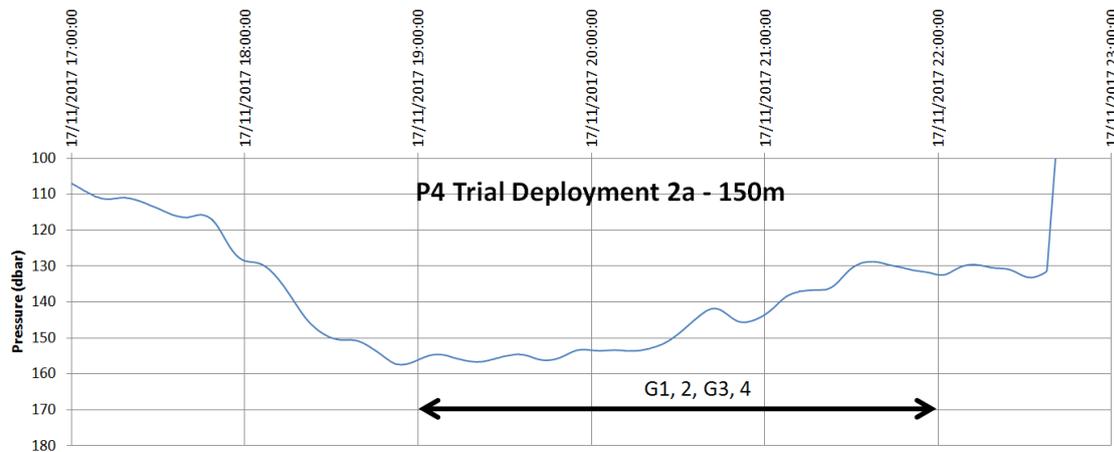
Deployment series 3 (18 November 2017)
P7 (camera trap)

Station: P3A, event 78
Target depth: 500 m
Target temp: 1.9°C
In situ density: 1030.00 kg m^{-3}
Sampling strategy: Cup G1 open 19/11/17 19:00, close 20/11/17 19:00
                      Cup 2 open 19/11/17 19:00, close 21/11/17 19:05
                      Cup G3 open 20/11/17 19:05, close 22/11/17 01:10
                      Cup 4 open 21/11/17 19:10, close 22/11/17 01:10
Added ballast: 3566 g
Piston posn Mbp: 70
Deployment time: 18/11/17 23:00
Deployment posn: 52° 41.82' S, 40° 10.02' W

Cups G3 and 4 failed to close as all the cups had done on deployment 1. This was further investigated and although it wasn't definite there was a suspicion that the carousel bearing may have had a slight tight spot. The bearing clamp screws were loosened slightly in the hope that the tight spot would be freed up for future deployments. Stabilisation was achieved at ~525 m with Mbp = 81 counts.
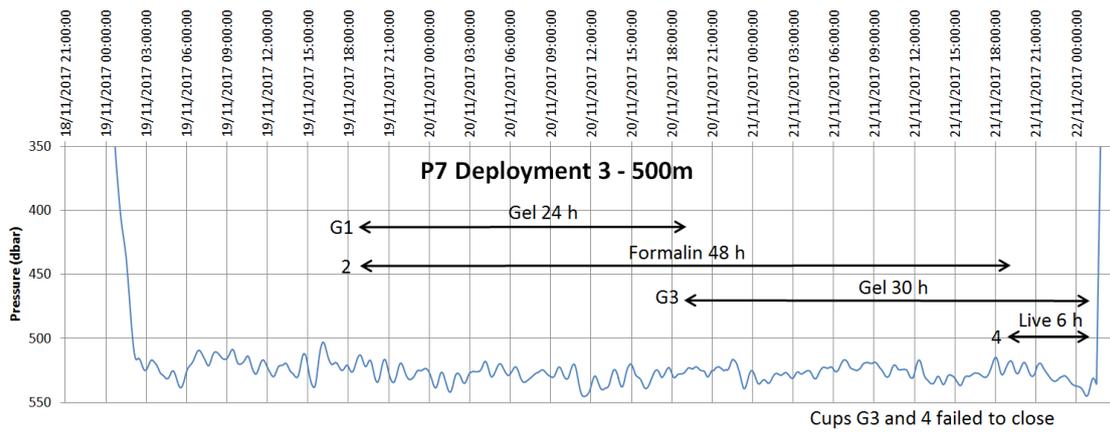
P9 (standard trap)

Station:	P3A, event 79
Target depth:	250 m
Target temp:	1.6°C
In situ density:	1028.68 kg m^{-3}
Sampling strategy:	Cup 1 open 19/11/17 19:00, close 20/11/17 19:00
	Cup 2 open 20/11/17 19:05, close 21/11/17 19:05
	Cup 3 open 21/11/17 19:10, close 22/11/17 22:10
	Cup 4 open 21/11/17 22:15, close 22/11/17 01:15
Added ballast:	3967 g
Piston posn Mbp:	123
Deployment time:	18/11/17 23:15
Deployment posn:	52° 41.82' S, 40° 10.02' W

Stabilisation was achieved at 260 m with Mbp = 136 counts. This plot shows corrected Idronaut pressure which was offset by +13 m at stabilisation depth.
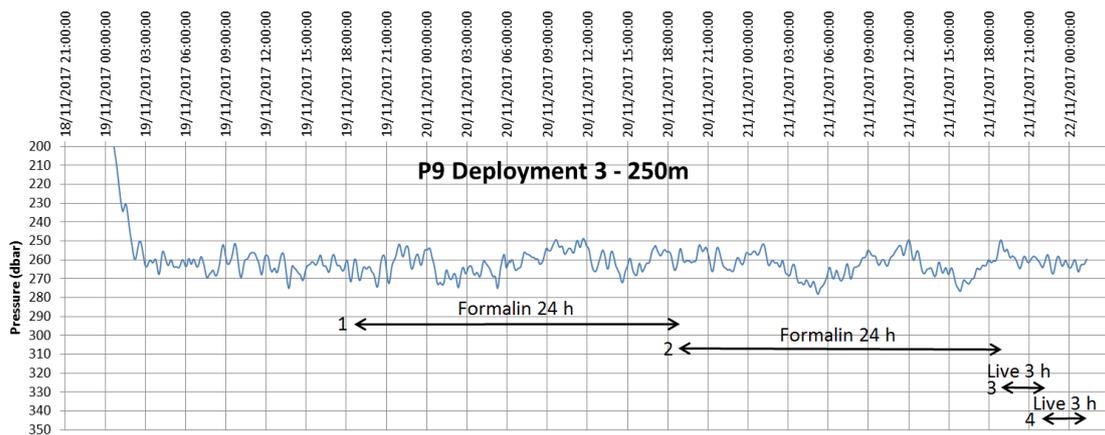
P6 (standard trap)

Station:	P3A, event 80
Target depth:	150 m
Target temp:	0.8°C
In situ density:	1028.00 kg m^{-3}
Sampling strategy:	Cup 1 open 19/11/17 19:00, close 20/11/17 19:00
	Cup 2 open 20/11/17 19:05, close 21/11/17 19:05
	Cup 3 open 21/11/17 19:10, close 22/11/17 22:10
	Cup 4 open 21/11/17 22:15, close 22/11/17 01:15
Added ballast:	3685 g
Piston posn Mbp:	115
Deployment time:	18/11/17 23:30
Deployment posn:	52° 41.82' S, 40° 10.02' W

Stabilisation was achieved at ~130 m with Mbp = 121 counts. This plot shows corrected Idronaut pressure which was offset by -9 dbar at stabilisation depth.

P6 Deployment 3 - 150m
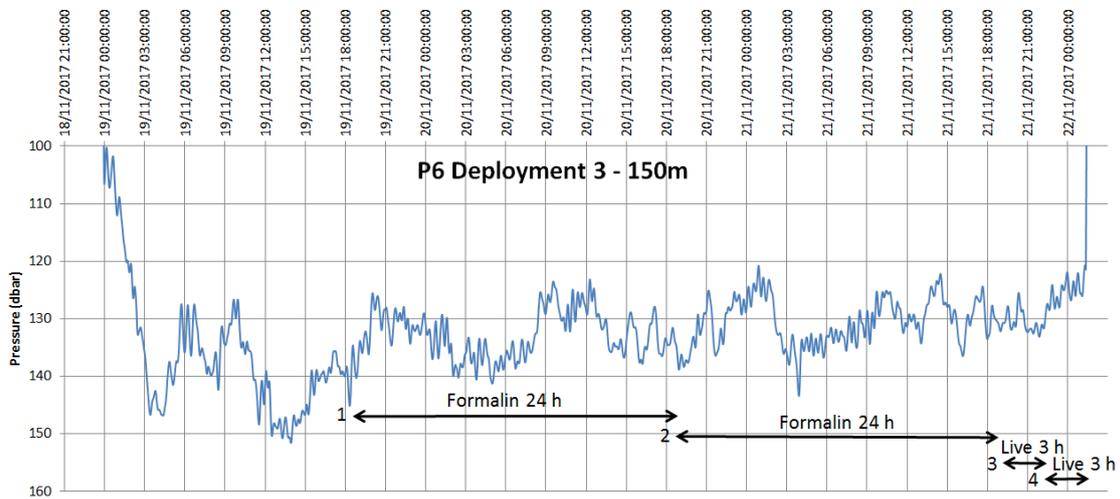
P4 (camera trap)

Station:	P3A, event 81
Target depth:	100 m
Target temp:	1.2°C
In situ density:	1027.60 kg m^{-3}
Sampling strategy:	Cup G1 open 19/11/17 19:00, close 20/11/17 19:00
	Cup 2 open 19/11/17 19:00, close 21/11/17 19:05
	Cup G3 open 20/11/17 19:05, close 22/11/17 01:10
	Cup 4 open 21/11/17 19:10, close 22/11/17 01:10
Added ballast:	3287 g
Piston posn Mbp:	115
Deployment time:	18/11/17 23:45
Deployment posn:	52° 41.82' S, 40° 10.02' W

P4 surfaced 6 hours sooner than intended. This meant that cup G3 and 4 were compromised. The early surfacing was due to a setup error on the APEX float; Mtd was entered as '4045' instead of '4420'. Stabilisation was achieved at ~105 m with Mbp = 156 counts. This plot shows corrected Idronaut pressure which was offset by +7 dbar at stabilisation depth.
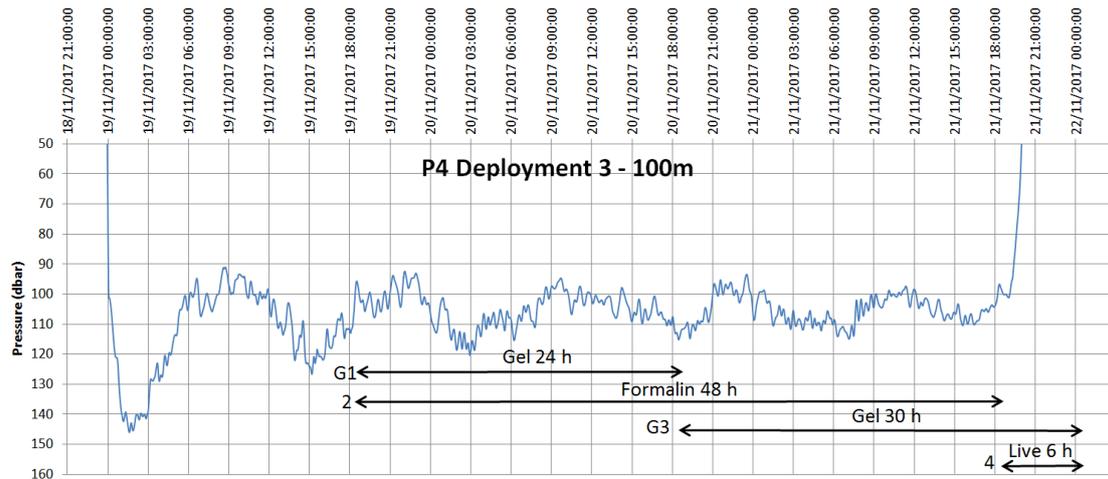
P2 (standard trap)

Station:	P3A, event 82
Target depth:	50 m
Target temp:	1.95°C
In situ density:	1027.27 kg m^{-3}
Sampling strategy:	Cup 1 open 19/11/17 19:00, close 20/11/17 19:00
	Cup 2 open 20/11/17 19:05, close 21/11/17 19:05
	Cup 3 open 21/11/17 19:10, close 22/11/17 22:10
	Cup 4 open 21/11/17 22:15, close 22/11/17 01:15
Added ballast:	3541 g (-114 g for frame repair, + 6 g for brine adjustment)
Piston posn Mbp:	115
Deployment time:	19/11/17 02:00
Deployment posn:	52° 41.22' S, 40° 09.90' W

P2 was slightly over ballasted and began to stabilise at ~115 m. The buoyancy engine adjusted to gain buoyancy but over-compensated and P2 returned to the surface. From this deployment it was clear that sigma-theta was within the +/-0.01 range from 65 m to the surface, i.e. the value of sigma-theta was near constant between these depths. It was realised that it would be hopeless trying to follow an isopycnal at such shallow depths. It was therefore decided that future deployments would be set to isobaric (Mbd = 5).

Deployment series 3a (20 November 2017)
P2 (standard trap) - isobaric

Station:	P3A, event 92
Target depth:	50 m
Target temp:	1.95°C
In situ density:	1027.27 kg m^{-3}
Sampling strategy:	Cup 1 open 19/11/17 19:00, close 20/11/17 19:00
	Cup 2 open 19/11/17 19:05, close 21/11/17 19:05
	Cup 3 open 21/11/17 19:10, close 22/11/17 22:10
	Cup 4 open 21/11/17 22:15, close 22/11/17 01:15
Added ballast:	3541 g (-114 g for frame repair, + 6 g for brine adjustment)
Piston posn Mbp:	115
Deployment time:	20/11/17 15:00 (redeployed)
Deployment posn:	52° 44.94' S, 40° 11.94' W

P2 was again slightly over ballasted and again the buoyancy engine over-compensated, despite

being set to isobaric, and returned directly to the surface.

Deployment series 3b (21 November 2017)
P2 (standard trap) - isobaric

Station:	P3A, event 107
Target depth:	50 m
Target temp:	1.95°C
In situ density:	1027.27 kg m^{-3}
Sampling strategy:	Cups 1, 2, 3 and 4 open 21/11/17 19:15, close 22/11/17 01:15
Added ballast:	3511 g (-30 g)
Piston posn Mbp:	115
Deployment time:	21/11/17 12:30 (redeployed)
Deployment posn:	52° 45.06' S, 40° 12.24' W

P2 was slightly under ballasted and returned directly to the surface before the buoyancy engine could compensate.

Deployment series 4 (29 November 2017)

At this point all traps had had successful deployments. Added ballast was to remain as previously used and any adjustments would be made by changing the park piston position, Mbp.

For deployment 4, an error was made in reading the CTD data and all values for Mbp were erroneous. However, with the exception of P4 (which was eventually redeployed successfully), all traps managed to stabilise at their intended depths.

P7 (camera trap)

Station:	P3B, event 157
Target depth:	500 m
Target temp:	2.0°C
In situ density:	1030.01 kg m^{-3}
Sampling strategy:	Cup G1 and 2 open 30/11/17 15:00, close 1/12/17 15:00
	Cup G3 and 4 open 1/12/17 15:15, close 1/12/17 18:15
Added ballast:	3566 g
Piston posn Mbp:	163
Deployment time:	29/11/17 23:00
Deployment posn:	52° 39.30' S, 40° 15.88' W

Stabilisation was achieved at ~490 m with Mbp = 79 counts.
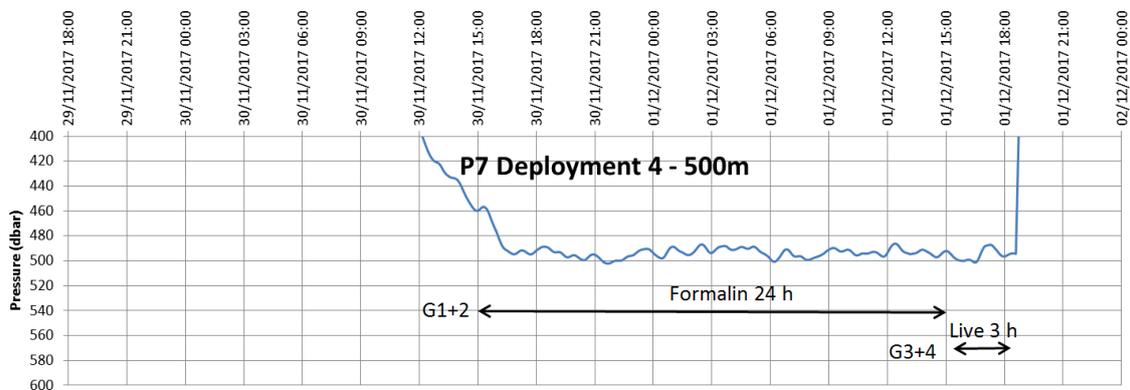
P9 (standard trap)

Station:	P3B, event 158
Target depth:	250 m
Target temp:	1.5°C
In situ density:	1028.66 kg m^{-3}
Sampling strategy:	Cup 1 and 3 open 30/11/17 15:00, close 1/12/17 15:00
	Cup 2 and 4 open 1/12/17 15:05, close 1/12/17 18:05
Added ballast:	3967 g
Piston posn Mbp:	174
Deployment time:	29/11/17 23:30
Deployment posn:	52° 39.30' S, 40° 15.88' W

Stabilisation was achieved at ∼240 m with Mbp = 137 counts.
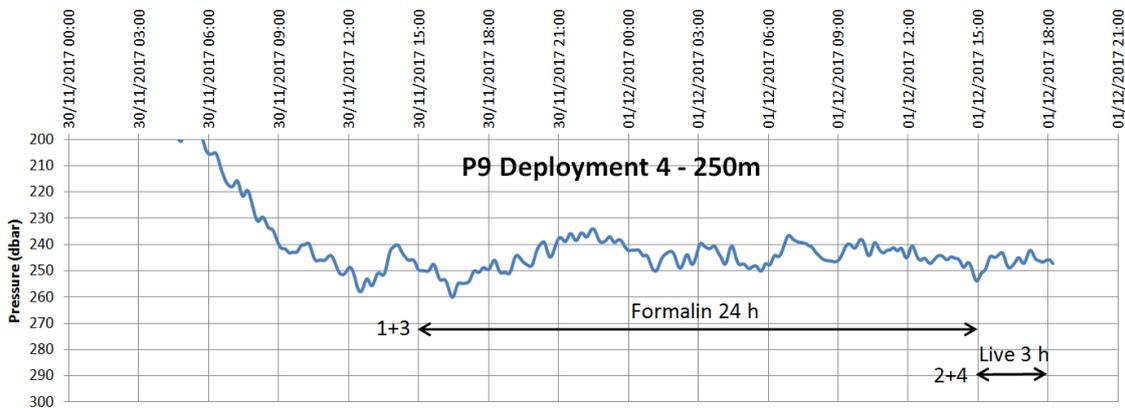
P6 (standard trap)

Station:	P3B, event 159
Target depth:	150 m
Target temp:	0.88°C
In situ density:	1028.01 kg m^{-3}
Sampling strategy:	Cup 1 and 3 open 30/11/17 15:00, close 1/12/17 15:00
	Cup 2 and 4 open 1/12/17 15:05, close 1/12/17 18:05
Added ballast:	3685 g
Piston posn Mbp:	95
Deployment time:	29/11/17 23:30
Deployment posn:	52° 39.30' S, 40° 15.88' W

P6 stabilised at ∼140 m with Mbp = 106 counts. This plot shows corrected Idronaut pressure which was offset by -10 dbar at stabilisation depth.
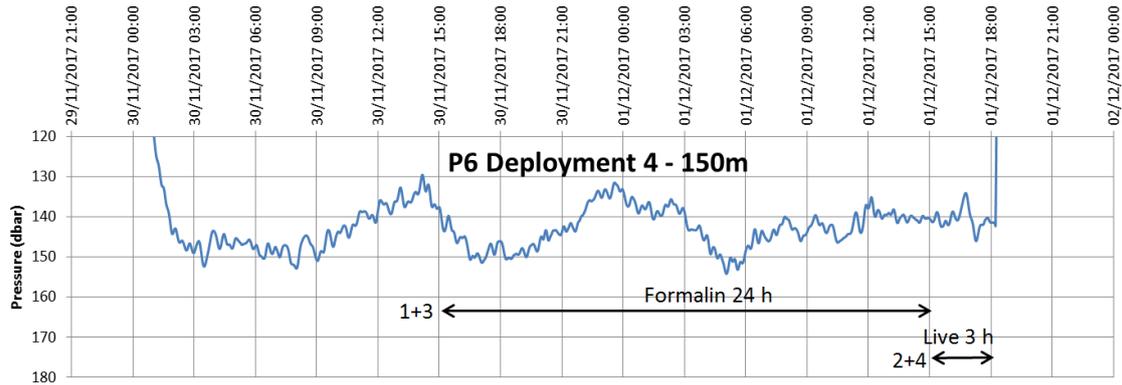
P4 (camera trap) - isobaric

Station:	P3B, event 160
Target depth:	100 m
Target temp:	1.1°C
In situ density:	1027.62 kg m^{-3}
Sampling strategy:	Cup G1 and 2 open 30/11/17 15:00, close 1/12/17 15:00
	Cup G3 and 4 open 1/12/17 15:15, close 1/12/17 18:15
Added ballast:	3287 g
Piston posn Mbp:	137
Deployment time:	29/11/17 23:45
Deployment posn:	52° 39.30' S, 40° 15.88' W

P4 was under ballasted and returned directly to the surface.

P2 (standard trap) - isobaric

Station:	P3B, event 161
Target depth:	75 m
Target temp:	1.7°C
In situ density:	1027.43 kg m^{-3}
Sampling strategy:	Cup 1 and 3 open 30/11/17 15:00, close 1/12/17 15:00
	Cup 2 and 4 open 1/12/17 15:05, close 1/12/17 18:05
Added ballast:	3541 g
Piston posn Mbp:	106
Deployment time:	30/11/17 00:00
Deployment posn:	52° 39.30' S, 40° 15.88' W

P2 appeared to be ballasted OK and stabilised for a while at ~75 m. However it was driven to the surface after about 12 hours by what appears to be an internal wave; the buoyancy engine was unable to compensate quickly enough.

Deployment series 4a (30 November 2017)
P4 (camera trap) - isobaric

Station:	P3B, event 165
Target depth:	100 m
Target temp:	1.1°C
In situ density:	1027.62 kg m^{-3}
Sampling strategy:	Cup G1 and 2 open 30/11/17 15:00, close 1/12/17 15:00
	Cup G3 and 4 open 1/12/17 15:15, close 1/12/17 18:15
Added ballast:	3287 g
Piston posn Mbp:	115
Deployment time:	30/11/17 08:30
Deployment posn:	52° 42.60' S, 40° 04.62' W

Despite being slightly over ballasted, P4 stabilised at ~105 m with Mbp = 146 counts. During this deployment the Idronaut CTD pressure sensor malfunctioned and reported erroneous pressure data from this point forwards. (P4 plots from here on show APEX pressure data).
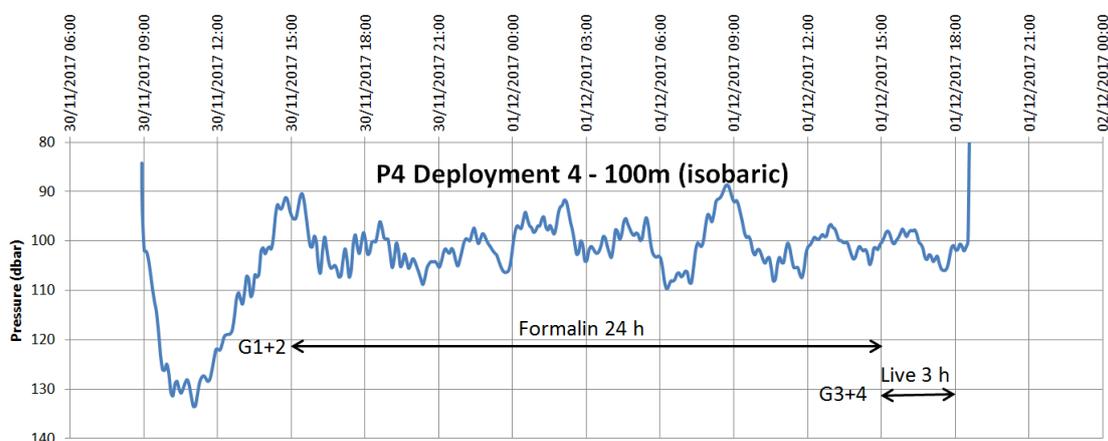
Deployment series 5 (30 November 2017)

During previous deployments it was becoming apparent that communications with the NOC Iridium server were unreliable. With Teledyne's permission, the primary and alternate servers were switched to make Teledyne's server primary. This improved the timeliness of Iridium messages.

P7 (camera trap)

Station:	P3B, event 212
Target depth:	500 m
Target temp:	2.0°C
In situ density:	1030.01 kg m^{-3}
Sampling strategy:	Cup G1 and 2 open 3/12/17 15:00, close 4/12/17 15:00
	Cup G3 and 4 open 4/12/17 15:15, close 4/12/17 18:15
Added ballast:	3566 g
Piston posn Mbp:	75
Deployment time:	2/12/17 23:00
Deployment posn:	52° 41.70' S, 40° 15.12' W

P7 stabilised at ~510 m with Mbp = 76 counts.
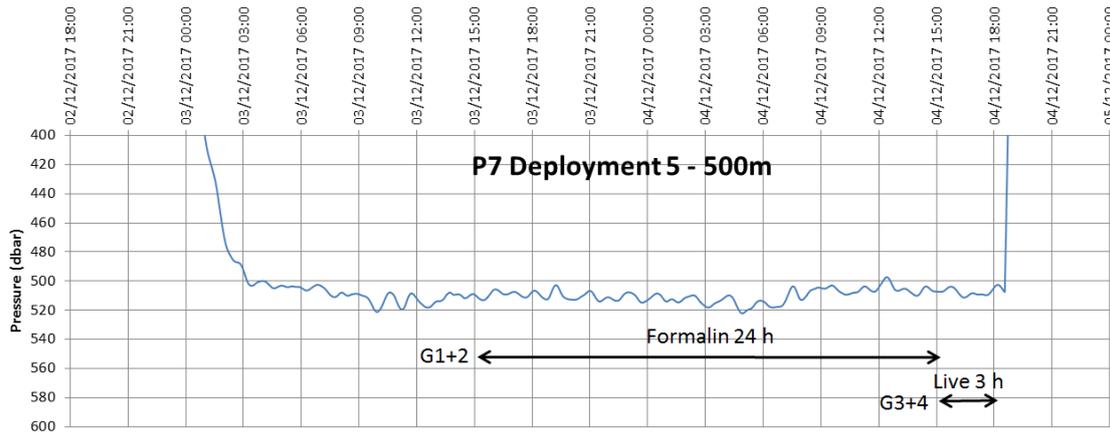
P9 (standard trap)

Station: P3B, event 213
Target depth: 250 m
Target temp: 1.5°C
In situ density: 1028.66 kg m^{-3}
Sampling strategy: Cup 1 and 3 open 3/12/17 15:00, close 4/12/17 15:00
                         Cup 2 and 4 open 4/12/17 15:05, close 4/12/17 18:05
Added ballast: 3967 g
Piston posn Mbp: 130
Deployment time: 2/12/17 23:15
Deployment posn: 52° 41.70' S, 40° 15.12' W

P9 stabilised at ∼240 m with Mbp = 146 counts. This plot shows corrected Idronaut pressure which was offset by +11 m at stabilisation depth.
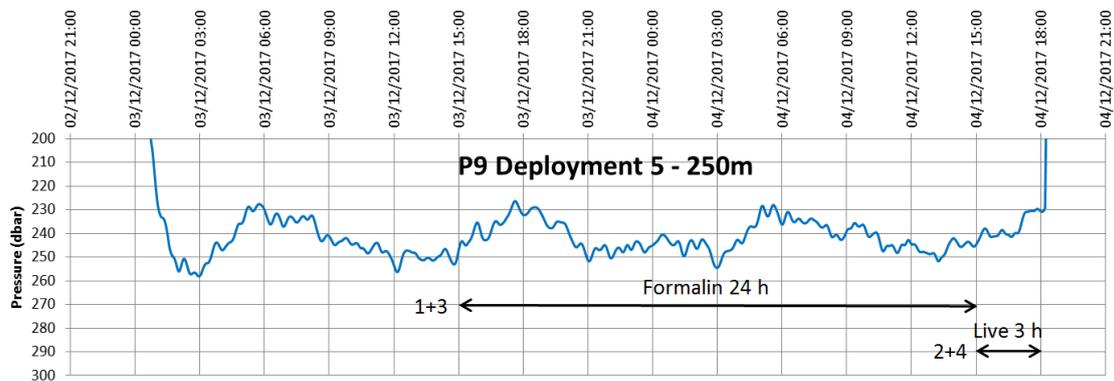
P6 (standard trap)

Station:	P3B, event 214
Target depth:	150 m
Target temp:	0.88°C
In situ density:	1028.01 kg m^{-3}
Sampling strategy:	Cup 1 and 3 open 3/12/17 15:00, close 4/12/17 15:00
	Cup 2 and 4 open 4/12/17 15:05, close 4/12/17 18:05
Added ballast:	3685 g
Piston posn Mbp:	85
Deployment time:	2/12/17 23:30
Deployment posn:	52° 41.70' S, 40° 15.12' W

P6 stabilised at ∼145 m with Mbp = 107 counts. This plot shows corrected Idronaut pressure which was offset by -10 m at stabilisation depth.
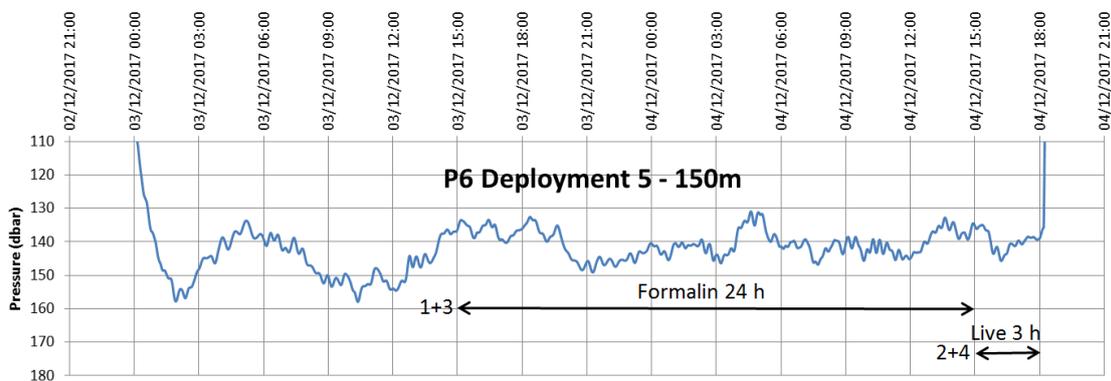
P4 (camera trap)

Station:	P3B, event 215
Target depth:	110 m
Target temp:	1.1°C
In situ density:	1027.62 kg m^{-3}
Sampling strategy:	Cup G1 and 2 open 3/12/17 15:00, close 4/12/17 15:00
	Cup G3 and 4 open 4/12/17 15:15, close 4/12/17 18:15
Added ballast:	3287 g
Piston posn Mbp:	135
Deployment time:	2/12/17 23:45
Deployment posn:	52° 41.70' S, 40° 15.12' W

P4 stabilised at ∼95 m with Mbp = 150 counts.

P2 (standard trap) - isobaric

Station:	P3B, event 216
Target depth:	90 m
Target temp:	1.7°C
In situ density:	1027.43 kg m^{-3}
Sampling strategy:	Cup 1 and 3 open 3/12/17 15:00, close 4/12/17 15:00
	Cup 2 and 4 open 4/12/17 15:05, close 4/12/17 18:05
Added ballast:	3541 g
Piston posn Mbp:	115
Deployment time:	3/12/17 00:00
Deployment posn:	52° 41.70' S, 40° 15.12' W

P4 Deployment 5 - 110m
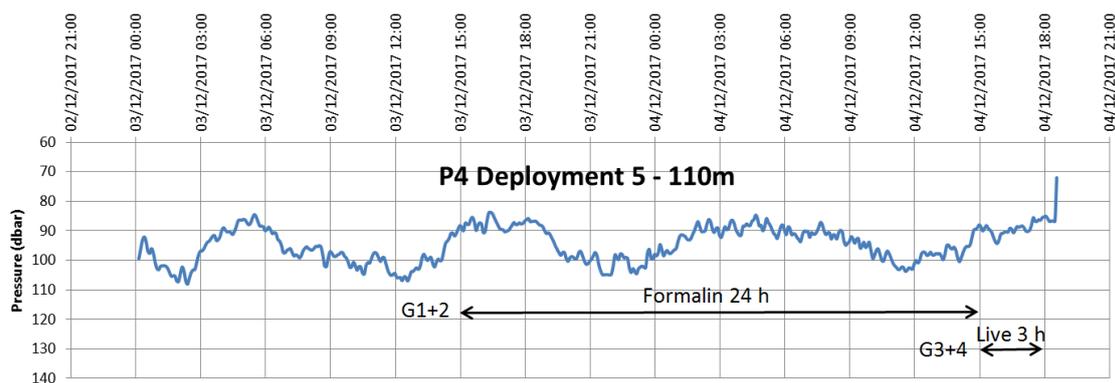
P2 stabilised at ~95 m with Mbp = ~135 counts.

P2 Deployment 5 - 90m (isobaric)
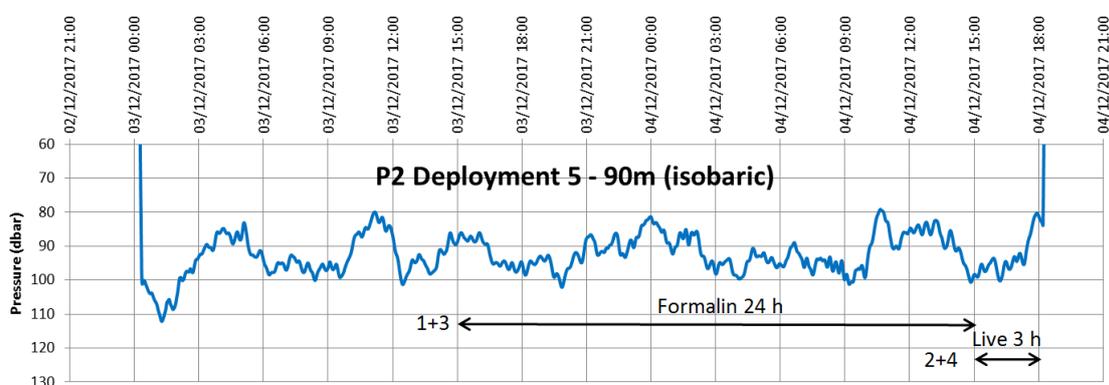
Deployment series 6 (5 December 2017)
P7 (camera trap)

Station:	P3B, event 260
Target depth:	500 m
Target temp:	2.0°C
In situ density:	1030.01 kg m^{-3}
Sampling strategy:	Cup 2 open 6/12/17 15:00, close 7/12/17 15:00
	Cup G3 open 7/12/17 15:05, close 7/12/17 18:05
	Cup 4 open 8/12/17 15:10, close 9/12/17 15:10
	Cup G1 open 9/12/17 15:15, close 9/12/17 18:15
Added ballast:	3566 g
Piston posn Mbp:	72
Deployment time:	5/12/17 19:00
Deployment posn:	52° 43.26' S, 40° 19.56' W

P7 stabilised at 520 m with Mbp = 78 counts.
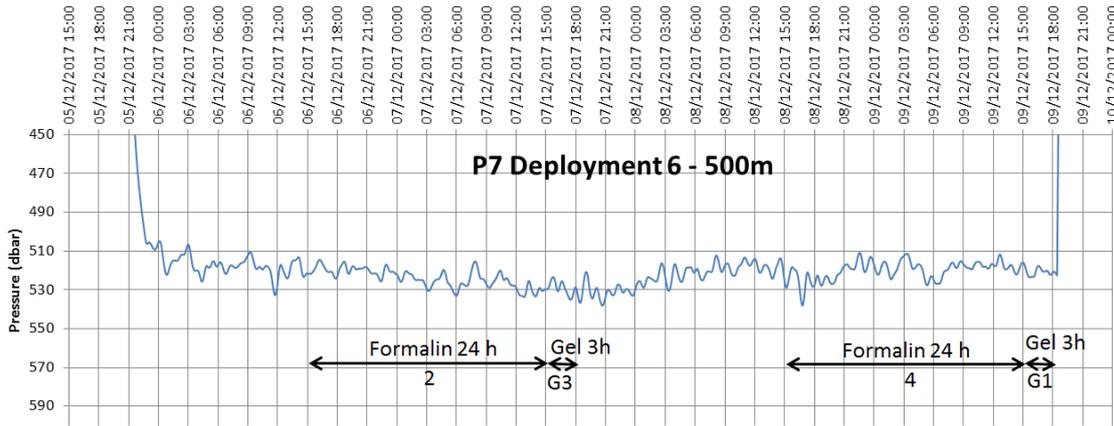
P9 (standard trap)

Station:	P3B, event 261
Target depth:	250 m
Target temp:	1.5°C
In situ density:	1028.66 kg m^{-3}
Sampling strategy:	Cup 1 open 6/12/17 15:00, close 7/12/17 15:00
	Cup 2 open 7/12/17 15:05, close 8/12/17 15:05
	Cup 3 open 8/12/17 15:10, close 9/12/17 15:10
	Cup 4 open 9/12/17 15:15, close 9/12/17 18:15
Added ballast:	3967 g
Piston posn Mbp:	142
Deployment time:	5/12/17 19:15
Deployment posn:	52° 43.26' S, 40° 19.56' W

P9 stabilised at ∼240 m with Mbp = 142 counts. This plot shows corrected Idronaut pressure which was offset by +11 m at stabilisation depth.
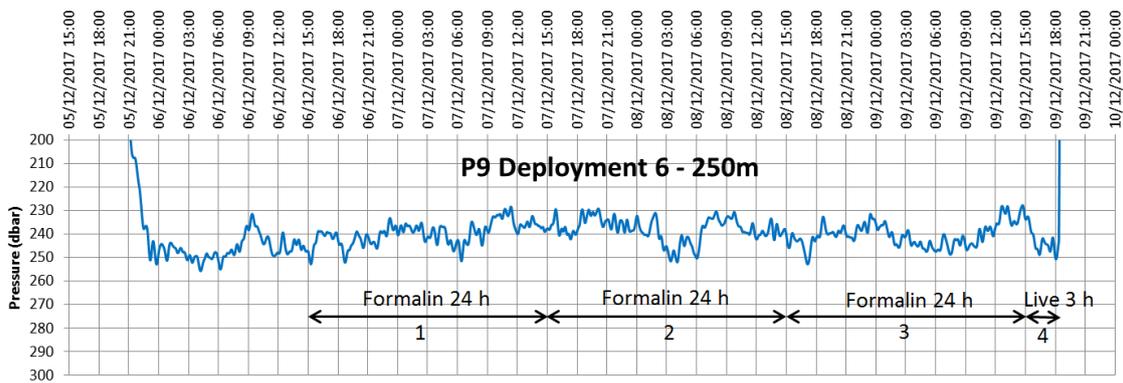
P6 (standard trap)

Station:	P3B, event 262
Target depth:	150 m
Target temp:	0.88°C
In situ density:	1028.01 kg m^{-3}
Sampling strategy:	Cup 1 open 6/12/17 15:00, close 7/12/17 15:00
	Cup 2 open 7/12/17 15:05, close 8/12/17 15:05
	Cup 3 open 8/12/17 15:10, close 9/12/17 15:10
	Cup 4 open 9/12/17 15:15, close 9/12/17 18:15
Added ballast:	3685 g
Piston posn Mbp:	100
Deployment time:	5/12/17 19:30
Deployment posn:	52° 43.26' S, 40° 19.56' W

P6 stabilised at ∼136 m with Mbp = 110 counts. Cup 2 appeared to under-sample compared to other traps and cup 4 was open on recovery. This plot shows corrected Idronaut pressure which was offset by -10 m at stabilisation depth.
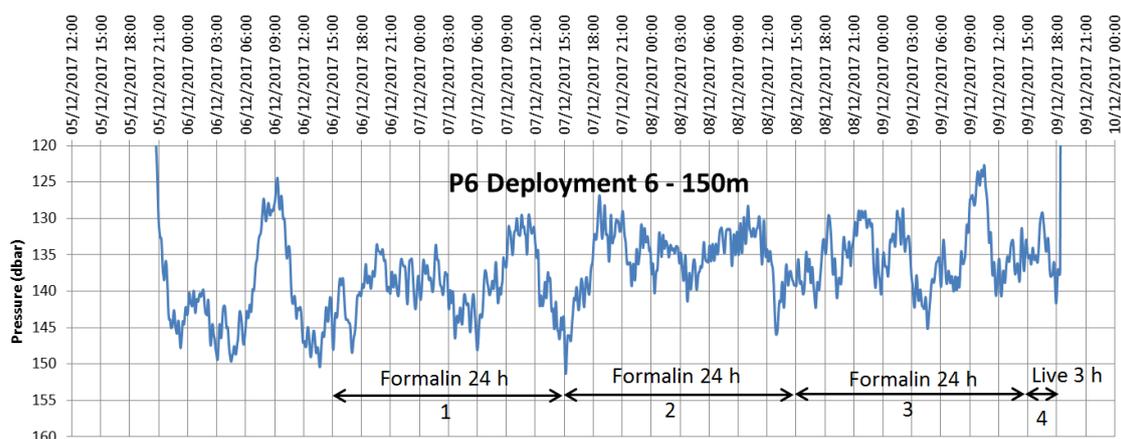
P4 (camera trap)

Station:	P3B, event 263
Target depth:	110 m
Target temp:	1.1°C
In situ density:	1027.62 kg m^{-3}
Sampling strategy:	Cup 2 open 6/12/17 15:00, close 7/12/17 15:00
	Cup G3 open 7/12/17 15:05, close 7/12/17 18:05
	Cup 4 open 8/12/17 15:10, close 9/12/17 15:10
	Cup G1 open 9/12/17 15:15, close 9/12/17 18:15
Added ballast:	3287 g
Piston posn Mbp:	130
Deployment time:	5/12/17 19:45
Deployment posn:	52° 43.26' S, 40° 19.56' W

Idronaut pressure was not functioning and the APEX float only recorded data until 09:00 on 8/12/17. However, the temperature data strongly suggests that depth stability was maintained throughout the deployment. P4 stabilised at ∼88 m with Mbp = 153 counts.
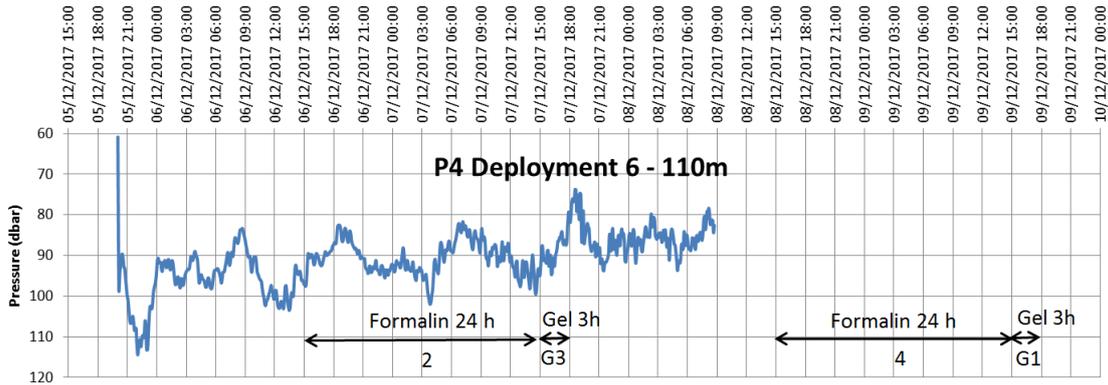
P2 (standard trap) - isobaric

Station:	P3B, event 264
Target depth:	90 m
Target temp:	1.7°C
In situ density:	1027.43 kg m^{-3}
Sampling strategy:	Cup 1 open 6/12/17 15:00, close 7/12/17 15:00
	Cup 2 open 7/12/17 15:05, close 8/12/17 15:05
	Cup 3 open 8/12/17 15:10, close 9/12/17 15:10
	Cup 4 open 9/12/17 15:15, close 9/12/17 18:15
Added ballast:	3541 g
Piston posn Mbp:	115
Deployment time:	5/12/17 20:00
Deployment posn:	52° 43.26' S, 40° 19.56' W

P2 stabilised at ∼91 m with Mbp = ∼149 counts. Cup 4 was open on recovery.
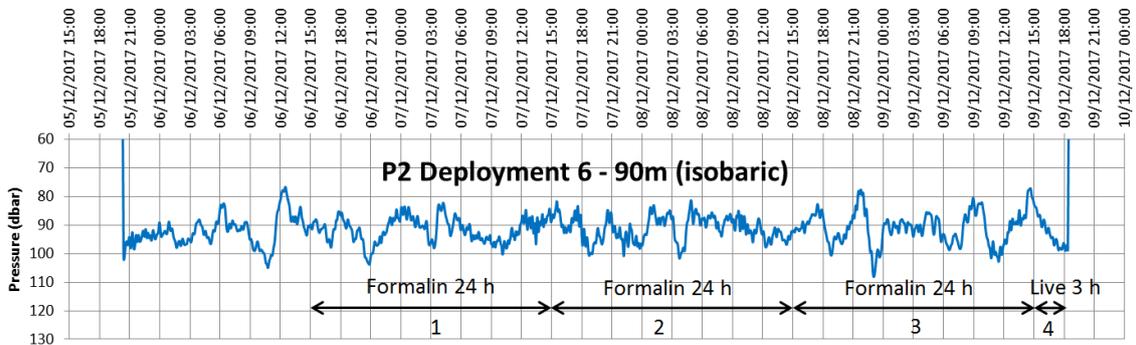
Deployment series 7 (10 December 2017)
P7 (camera trap)

Station:	P3C, event 300
Target depth:	500 m
Target temp:	2.0°C
In situ density:	1030.01 kg m^{-3}
Sampling strategy:	Cup 2 open 11/12/17 07:00, close 12/12/17 07:00
	Cup G3 open 12/12/17 07:05, close 12/12/17 10:05
	Cup 4 open 13/12/17 07:10, close 14/12/17 07:10
	Cup G1 open 14/12/17 07:15, close 14/12/17 10:15
Added ballast:	3566 g
Piston posn Mbp:	72
Deployment time:	10/12/17 21:00
Deployment posn:	52° 40.08' S, 40° 15.84' W

P7 stabilised at ~495 m with Mbp=87 counts.
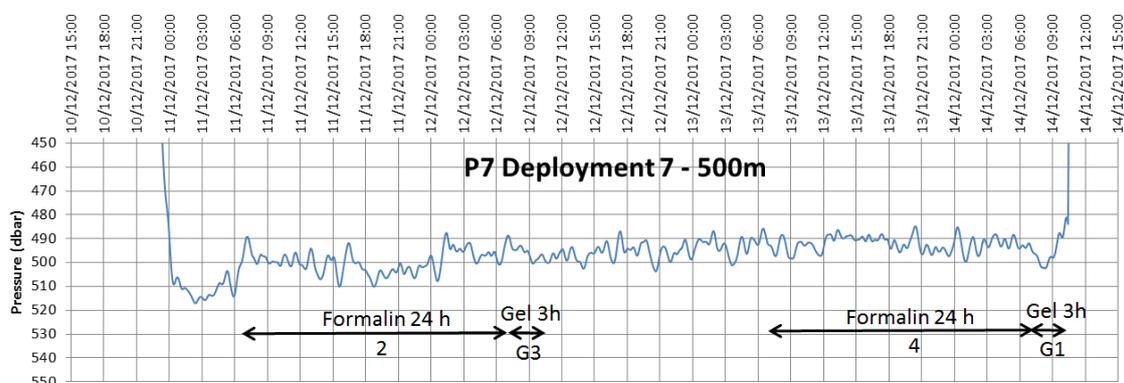
P9 (standard trap)

Station:	P3C, event 301
Target depth:	250 m
Target temp:	1.5°C
In situ density:	1028.66 kg m^{-3}
Sampling strategy:	Cup 1 open 11/12/17 07:00, close 12/12/17 07:00
	Cup 2 open 12/12/17 07:05, close 13/12/17 07:05
	Cup 3 open 13/12/17 07:10, close 14/12/17 07:10
	Cup 4 open 14/12/17 07:15, close 14/12/17 10:15
Added ballast:	3967 g
Piston posn Mbp:	142
Deployment time:	10/12/17 21:15
Deployment posn:	52° 40.02' S, 40° 15.72' W

The Idronaut CTD logger only recorded data until 15:00 on 12/12/17 and the APEX until 12:00 on 13/12/17; APEX pressure data is shown here. However, the temperature data strongly suggests that depth stability was maintained throughout the deployment. P9 stabilised at ~250 m with Mbp = 125 counts.

P9 Deployment 7 - 250m
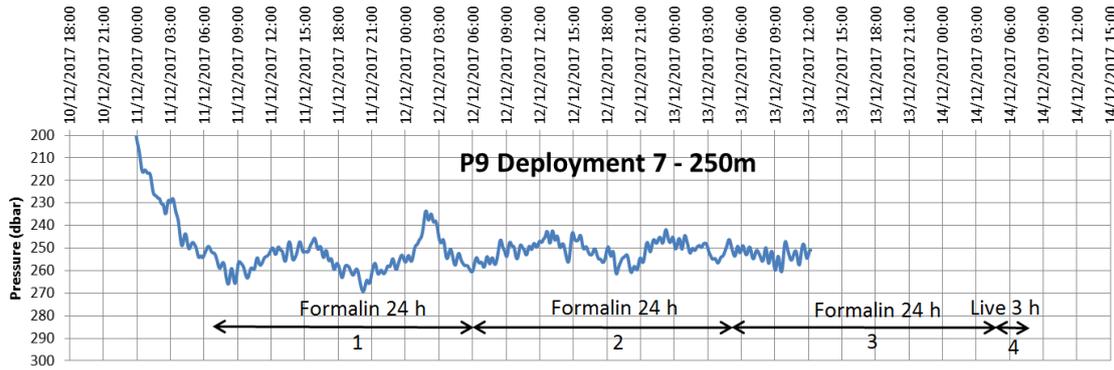
P6 (standard trap)

Station:	P3C, event 302
Target depth:	160 m
Target temp:	0.88°C
In situ density:	1028.01 kg m^{-3}
Sampling strategy:	Cup 1 open 11/12/17 07:00, close 12/12/17 07:00
	Cup 2 open 12/12/17 07:05, close 13/12/17 07:05
	Cup 3 open 13/12/17 07:10, close 14/12/17 07:10
	Cup 4 open 14/12/17 07:15, close 14/12/17 10:15
Added ballast:	3685 g
Piston posn Mbp:	90
Deployment time:	10/12/17 21:30
Deployment posn:	52° 40.02' S, 40° 15.66' W

P6 stabilised at ∼155 m with Mbp = 96 counts. This plot shows corrected Idronaut pressure which was offset by -10 m at stabilisation depth.

P6 Deployment 7 - 160m
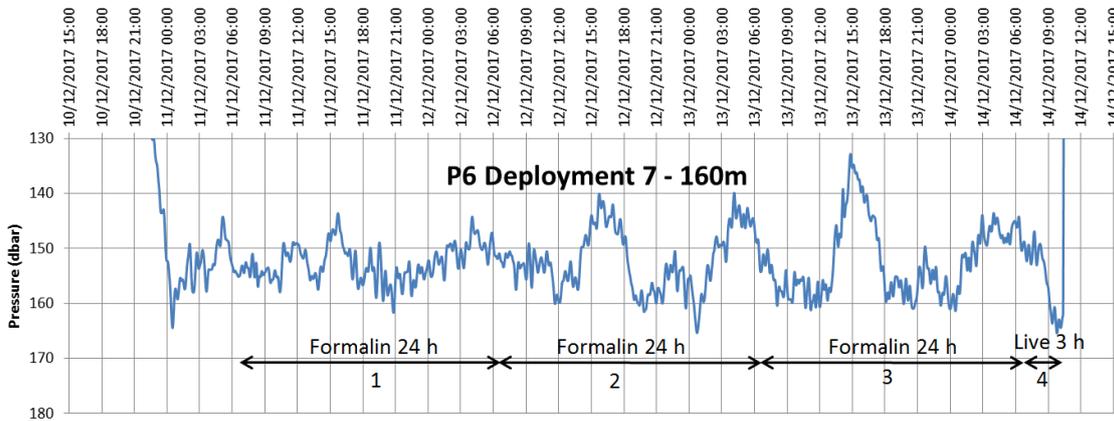
P4 (camera trap)

Station:	P3C, event 303
Target depth:	125 m
Target temp:	1.1°C
In situ density:	1027.62 kg m^{-3}
Sampling strategy:	Cup 2 open 11/12/17 07:00, close 12/12/17 07:00
	Cup G3 open 12/12/17 07:05, close 12/12/17 10:05
	Cup 4 open 13/12/17 07:10, close 14/12/17 07:10
	Cup G1 open 14/12/17 07:15, close 14/12/17 10:15
Added ballast:	3287 g
Piston posn Mbp:	118
Deployment time:	10/12/17 21:45
Deployment posn:	52° 39.96' S, 40° 15.54' W

Idronaut pressure was not functioning and the APEX float only recorded data until 10:48 on 13/12/17. However, the temperature data strongly suggests that depth stability was maintained throughout the deployment. P4 stabilised at ∼112 m with Mbp = ∼146 counts.

On recovery it was apparent that none of the sample cups appeared to have opened and the burnwire had not released. Consequently, P4 was sitting very low in the water and this explains why it was not transmitting. All timers are being taken back to NOC for a full investigation.
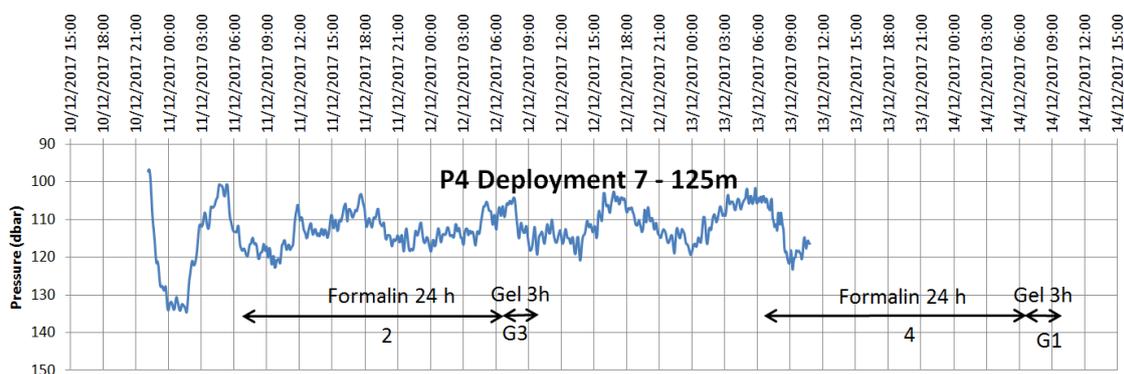
P2 (standard trap) - isobaric

Station:	P3C, event 304
Target depth:	90 m
Target temp:	1.7°C
In situ density:	1027.43 kg m^{-3}
Sampling strategy:	Cup 1 open 11/12/17 07:00, close 12/12/17 07:00
	Cup 2 open 12/12/17 07:05, close 13/12/17 07:05
	Cup 3 open 13/12/17 07:10, close 14/12/17 07:10
	Cup 4 open 14/12/17 07:15, close 14/12/17 10:15
Added ballast:	3541 g
Piston posn Mbp:	130
Deployment time:	10/12/17 22:00
Deployment posn:	52° 39.90' S, 40° 15.48' W

P2 stabilised at ∼92 m with Mbp = 150 counts.
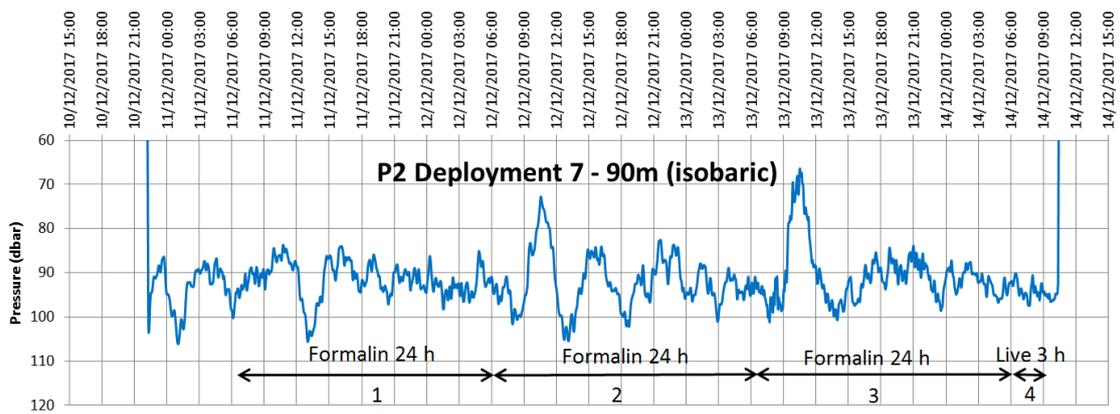
Table 2.49: PELAGRA deployment details

Station	Depl. series	Trap and target depth	Deployment					Recovery				
			Event	Date	Time	Lat (S)	Lon (W)	Event	Date	Time	Lat (S)	Lon (W)
P3A	1 (trial)	P7 - 500m	2	15/11/2017	13:10:00	52.7	40.107	37	16/11/2017	18:30:00	52.737	40.218
P3A	1 (trial)	P9 - 250m	3	15/11/2017	13:23:00	52.701	40.106	38	16/11/2017	18:46:00	52.737	40.218
P3A	1 (trial)	P6 - 150m	4	15/11/2017	13:52:00	52.702	40.106	19	15/11/2017	20:25:00	52.692	40.124
P3A	1 (trial)	P4 - 150m	5	15/11/2017	13:56:00	52.7	40.104	17	15/11/2017	20:00:00	52.696	40.118
P3A	1 (trial)	P2 - 150m	6	15/11/2017	14:07:00	52.7	40.104	18	15/11/2017	20:11:00	52.694	40.12
P3A	2 (trial)	P6 - 150m	44	17/11/2017	10:06:00	52.691	40.126	47	17/11/2017	12:00:00	52.69	40.134
P3A	2 (trial)	P4 - 150m	45	17/11/2017	10:19:00	52.692	40.128	53	17/11/2017	14:39:00	52.69	40.134
P3A	2 (trial)	P2 - 150m	46	17/11/2017	10:37:00	52.692	40.13	54	17/11/2017	15:00:00	52.69	40.134
P3A	2a (trial)	P6 - 150m	52	17/11/2017	14:08:00	52.69	40.134	59	18/11/2017	02:39:00	52.703	40.15
P3A	2a (trial)	P4 - 150m	56	17/11/2017	16:38:00	52.692	40.133	60	18/11/2017	03:20:00	52.698	40.17
P3A	3	P7 - 500m	78	18/11/2017	23:17:00	52.697	40.167	114	22/11/2017	06:22:00	52.68	40.457
P3A	3	P9 - 250m	79	18/11/2017	23:26:00	52.697	40.167	113	22/11/2017	05:31:00	52.718	40.395
P3A	3	P6 - 150m	80	18/11/2017	23:40:00	52.697	40.167	115	22/11/2017	07:50:00	52.573	40.316
P3A	3	P4 - 100m	81	18/11/2017	23:52:00	52.697	40.167	116	22/11/2017	14:00:00	52.638	40.307
P3A	3	P2 - 50m	82	19/11/2017	02:10:00	52.687	40.165	88	20/11/2017	11:40:00	52.82	40.183
P3A	3a	P2 - 50m	92	20/11/2017	15:06:00	52.749	40.199	100	21/11/2017	04:18:00	52.732	40.218
P3A	3b	P2 - 50m	107	21/11/2017	12:37:00	52.751	40.204	112	22/11/2017	02:32:00	52.75	40.195
P3B	4	P7 - 500m	157	29/11/2017	23:17:00	52.655	40.264	199	02/12/2017	01:30:00	52.608	40.332
P3B	4	P9 - 250m	158	29/11/2017	23:34:00	52.655	40.264	200	02/12/2017	02:34:00	52.594	40.291
P3B	4	P6 - 150m	159	29/11/2017	23:40:00	52.655	40.264	198	02/12/2017	00:30:00	52.631	40.31
P3B	4	P4 - 100m	160	29/11/2017	23:53:00	52.655	40.264	163	30/11/2017	05:36:00	52.657	40.277
P3B	4	P2 - 75m	161	30/11/2017	00:08:00	52.655	40.264	182	01/12/2017	03:49:00	52.68	40.238

Table 2.49: PELAGRA deployment details

Station	Depl. series	Trap and target depth	Deployment					Recovery				
			Event	Date	Time	Lat (S)	Lon (W)	Event	Date	Time	Lat (S)	Lon (W)
P3B	4a	P4 - 100m	165	30/11/2017	08:46:00	52.71	40.077	197	01/12/2017	22:57:00	52.75	40.125
P3B	5	P7 - 500m	212	02/12/2017	23:00:00	52.695	40.252	242	04/12/2017	20:25:00	52.689	40.344
P3B	5	P9 - 250m	213	02/12/2017	23:15:00	52.695	40.252	243	04/12/2017	20:53:00	52.701	40.338
P3B	5	P6 - 150m	214	02/12/2017	23:15:00	52.695	40.252	244	04/12/2017	21:21:00	52.704	40.328
P3B	5	P4 - 110m	215	02/12/2017	23:15:00	52.695	40.252	245	04/12/2017	21:45:00	52.712	40.319
P3B	5	P2 - 90m	216	03/12/2017	00:00:00	52.695	40.252	246	04/12/2017	22:25:00	52.721	40.326
P3B	6	P7 - 500m	260	05/12/2017	19:00:00	52.721	40.326	284	09/12/2017	23:37:00	52.688	40.54
P3B	6	P9 - 250m	261	05/12/2017	19:15:00	52.721	40.326	283	09/12/2017	23:09:00	52.693	40.573
P3B	6	P6 - 150m	262	05/12/2017	19:30:00	52.721	40.326	285	10/12/2017	00:37:00	52.75	40.401
P3B	6	P4 - 110m	263	05/12/2017	19:45:00	52.721	40.326	281	09/12/2017	21:40:00	52.75	40.415
P3B	6	P2 - 90m	264	05/12/2017	20:00:00	52.721	40.326	282	09/12/2017	22:01:00	52.752	40.431
P3C	7	P7 - 500m	300	10/12/2017	21:00:00	52.668	40.264	337	14/12/2017	15:49:00	52.61	40.405
P3C	7	P9 - 250m	301	10/12/2017	21:15:00	52.667	40.262	336	14/12/2017	15:03:00	52.648	40.385
P3C	7	P6 - 160m	302	10/12/2017	21:30:00	52.667	40.261	335	14/12/2017	13:54:00	52.658	40.364
P3C	7	P4 - 125m	303	10/12/2017	21:45:00	52.666	40.259	338	14/12/2017	19:46:00	52.682	40.317
P3C	7	P2 - 90m	304	10/12/2017	22:00:00	52.665	40.258	334	14/12/2017	13:28:00	52.67	40.346

2.29 Marine Snow Catcher

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2.29.1 Overview

Profiles of suspended, slow-sinking and fast-sinking particles were collected using the Marine Snow Catcher (MSC) between 15th Nov – 15th Dec 2017 during COMICS cruise DY086 aboard the RRS Discovery.

2.29.2 Particle collection

At each superstation, three particle profiles were collected with 4-5 depths chosen based on the mixed layer depth. Typically, these depths were, MLD+10m, MLD+50m, MLD+100m, 250m and 500m. Opportunistically, other depths (intermediate or 1000 m) were also sampled. All MSCs for an individual profile were deployed within 2 hours of each other, though variability between profiles collected during each superstation was low.

A full description of the MSC and its assumptions are described in Riley et al. (2012) and Giering et al. (2016). We did, however, alter the sampling strategy for the fast-sinking particles to reduce user bias. Briefly, for t_{zero} and suspended particles 5 L each were collected from a tap positioned in the middle of the top section. After a 2-h settling period, the suspended particle sample was taken from the middle tap, and the tap was left running until the upper half of the top section was empty (approximately 5 min). The bottom tap on the top section was then opened by approximately 30° to allow the top section to drain slowly, reducing resuspension of slow-sinking material. Draining the bottom half of the MSC typically took 30 min. We placed trays on the bottom (18.5 cm diameter, 4 cm height, total volume approximately 1000 mL). Particles in the water above the tray were considered slow-sinking, and were removed by carefully siphoning the water off (4-5 L). A lid was then placed on the tray, and the tray was removed.

Concentrations of suspended, slow-sinking and fast-sinking particles ($p_{suspended}$, p_{slow} and p_{fast}, respectively) are calculated as follows:

$$p_{suspended} = p_{top} \tag{2.7}$$

$$p_{slow} = \frac{(p_{bottom} - p_{top}) \cdot V_{base}}{V_{MSC}} \tag{2.8}$$

$$p_{fast} = \frac{(p_{tray} - p_{bottom}) \cdot V_{tray}}{A_{tray} \cdot h_{MSC}} \tag{2.9}$$

where p is the particle concentration in the top, bottom or tray (p_{top}, p_{bottom} and p_{tray}, respectively), V_{base} is the volume of the base section (8 L), V_{tray} is the volume of the tray (typically 1 L), V_{MSC} is the volume of the MSC (95 L), A_{tray} is the area of the tray (0.026 m^2), and h_{MSC} is the height of the MSC (1.58 m). The fraction of the tray that was analysed for a particular parameter was 5-30% of the tray volume, depending on the parameter.

2.29.3 Sample preparation
Dry weight, particular organic carbon and nitrogen, stable isotopes
Samples were filtered onto pre-combusted (24 h at 450°C), pre-weighed GF/F filters (nominal pore-size 0.7 μm, 25 mm diameter, Whatman), briefly rinsed with pH-adjusted MilliQ water (180

μL 25% ammonium in 1 L MilliQ), dried in the oven (overnight at 50°C), and stored in a dark place. Blanks were prepared by filtering 1000 mL MilliQ and preparing the filter as described above. For t_{zero}, suspended and slow-sinking particles, 1000 mL were filtered in duplicates. For fast-sinking particles, 150-350 mL were filtered in duplicates.

Particulate inorganic carbon
Samples were filtered onto polycarbonate filters (0.8-μm pore size; Whatman) and briefly rinsed with pH-adjusted MilliQ water (pH 8.5; 180 μL 25% ammonium in 1 L MilliQ) to remove any salt. For t_{zero}, suspended and slow-sinking particles, 500 mL were filtered each. For fast-sinking particles, 50-100 mL were filtered. Blanks were prepared by filtering 500 mL of MilliQ through a filter and preparing the filter as described. Filters were placed into 50 mL corning tubes, dried (overnight at 50°C) and stored.

Biogenic silica
Samples were filtered onto polycarbonate filters (0.8-μm pore size; Whatman) and briefly rinsed with pH-adjusted MilliQ water (pH 8.5; 180 μL 25% ammonium in 1 L MilliQ) to remove any salt. For t_{zero}, suspended and slow-sinking particles, 500 mL were filtered each. For fast-sinking particles, 50-100 mL were filtered. Blanks were prepared by filtering 500 mL of MilliQ through a filter and preparing the filter as described. Filters were placed into 15 mL corning tubes, dried (overnight at 50°C) and analyzed on board as described by Stinchcombe.

Chlorophyll a
Samples were filtered onto GF/F filters (nominal pore-size 0.7 μm, 25 mm diameter, Whatman), placed into glass vials filled with 6 mL acetone (90%, HPLC), and pigments extracted for 24 h at 4°C. Fluorescence was analyzed on board as described by Ainsworth.

Photosynthetic health (Fv:Fm)
15-50 mL of sample water were filled into corning tubes and stored in darkness at 4°C until analysis (typically within 12 h after sample collection). Fv:Fm was determined on board as described by Moore.

Microbial community composition
1.8 mL sample were transferred into cryovials and stored in darkness at 4°C until fixation with 100 μL paraformaldehyde (20%) (typically within 12 hours of sample collection). Fixed samples were frozen in liquid nitrogen -80°C until on-shore analysis.

Microplankton community composition
50-200 mL sample were transferred into glass bottles, fixed with a final concentration of 3.6% formaldehyde (buffered with di-sodium tetraborate). Samples were stored in darkness in a cool place until onshore analysis.

Table 2.50: Marine Snow Catcher deployments and sampling details

Event	Deployment	MSC	Site	Description	Date (GMT)	Time fired (GMT)	Time t_0 (GMT)	Lat	Lon	Depth (m)	Echo depth (m)	SST (°C)	Air temp (°C)	Wind (knots)	Sea State (Bft)	Comments
020	MSC001		P3Test	Biogeochemistry/ Respiration	15/11/2017	21:14	21:25	52 41.48	40 7.47	50						Trays - no markings, not acid washed
021	MSC002		P3Test	Zooplankton incubations	15/11/2017	21:41	21:47	52 41.48	40 7.47	30						misfired
022	MSC003	3	P3Test	Molecular	15/11/2017	21:54	22:00	52 41.48	40 7.47	50						
023	MSC004	4	P3Test	Respiration, Molecular	15/11/2017	22:11	22:15	52 41.48	40 7.47	50						
024	MSC005		P3Test	Biogeochemistry/ Respiration	15/11/2017	22:26	22:30	52 41.48	40 7.47	50						
029	MSC006	1	P3A	Fluxes	16/11/2017	8:00	8:10	52 41.42	40 7.5	60	3787	2.5	0.2	16	4	slight leak
030	MSC007	4	P3A	Fluxes	16/11/2017	8:18	8:30	52 41.42	40 7.5	100	3786	2.5	0.3	15.5	4	
031	MSC008	3	P3A	Fluxes	16/11/2017	8:34	-	52 41.42	40 7.5	150	3787	2.5	0.2	8	3	misfired, o-ring popped out
032	MSC009	3	P3A	Fluxes	16/11/2017	8:53	-	52 41.42	40 7.5	150	3797	2.51	0.3	7.4	3	misfired, o-ring popped out
033	MSC010	2	P3A	Fluxes	16/11/2017	9:14	9:20	52 41.42	40 7.5	150	3786	2.51	0.3	10	3	
048	MSC011	2	P3A	Molecular	17/11/2017	12:25	12:30	52 41.89	40 8.09	150						MSC1 on labels
049	MSC012	1	P3A	Rates	17/11/2017	12:57	13:05	52 41.89	40 8.09	150						MSC2 on labels
050	MSC013	4	P3A	Rates	17/11/2017	13:15	13:23	52 40.39	40 8.09	150						
051	MSC014	3	P3A	Rates	17/11/2017	-	-	- -	- -	-						leaked. Not sampled
061	MSC015	4	P3A	Fluxes	18/11/2017	03:44	03:50	52 41.82	40 0.13	60	3786	2.68	2.27	9	3	
062	MSC016	2	P3A	Fluxes	18/11/2017	03:57	04:07	52 41.86	40 10.13	150	3786	2.7	2.9	12	3	
066	MSC017	-	P3A	Zooplankton incubations	18/11/2017	08:34	-	52 41.86	40 10.13	350	3787	2.65	2.25	13	4	
067	MSC018	-	P3A	Zooplankton incubations	18/11/2017	08:51	-	52 41.86	40 10.13	30	3787	2.65	2.4	11	4	
068	MSC019	4	P3A	Fluxes	18/11/2017	09:22	09:28	52 41.86	40 10.13	100	3787	2.7	2.6	12.1	4	

Table 2.50: continued

Event	Deployment	MSC	Site	Description	Date (GMT)	Time fired (GMT)	Time t_0 (GMT)	Lat	Lon	Depth (m)	Echo depth (m)	SST (°C)	Air temp (°C)	Wind (knots)	Sea State (Bft)	Comments
069	MSC020	2	P3A	Fluxes	18/11/2017	09:44	09:58	52 41.86	40 10.13	500	3787	2.65	2.7	13	4	
070	MSC021	1	P3A	Fluxes	18/11/2017	10:09	-	52 41.86	40 10.13	250	3787	2.67	2.97	16	5	did not close
071	MSC022	1	P3A	Fluxes	18/11/2017	10:25	10:31	52 41.86	40 10.13	250	3787	2.67	2.77	15	4	
073	MSC023	1	P3A	Molecular	18/11/2017	14:52	15:03	52 41.95	40 10.09	250						
074	MSC024	4	P3A	Respiration	18/11/2017	15:13	15:25	52 41.95	40 10.09	250						
075	MSC025	2	P3A	Respiration	18/11/2017	15:33	15:41	52 41.95	40 10.09	250						
083	MSC026	4	P3A	Zooplankton incubations	20/11/2017	08:54	-	52 44.98	40 11.98	30	3791	2.56	2.42	9	3	
084	MSC027	2	P3A	Fluxes	20/11/2017	09:13	09:24	52 44.99	40 11.98	250	3795	2.6	2.4	8	3	likely fired at 65 m (based on Chl)
085	MSC028	4	P3A	Fluxes	20/11/2017	09:38	09:43	52 44.99	40 11.98	60	3791	2.55	2.36	8	3	
086	MSC029	1	P3A	Fluxes	20/11/2017	10:07	10:29	52 44.99	40 11.98	500	3790	2.54	2.51	9	3	
087	MSC030	3	P3A	Fluxes	20/11/2017	10:32	-	52 44.99	40 11.98	150	3784	2.55	2.48	9	3	leaked. Not sampled
090	MSC031	2	P3A	Molecular	20/11/2017	14:00	14:21	52 44.97	40 11.97	500						
091	MSC032	4	P3A	Rates	20/11/2017	14:34	14:48	52 44.96	40 11.97	500						
092	MSC033	1	P3A	Rates	20/11/2017	15:38	15:8.	52 44.96	40 11.97	500						
096	MSC034	1	P3A	Fluxes	20/11/2017	23:05	23:12	52 46.52	40 20.94	150	3794	2.74	2.3	40	8	
097	MSC035	2	P3A	Fluxes	20/11/2017	23:28	23:35	52 46.52	40 20.94	100	3798	2.73	2.3	35	7	
103	MSC036	2	P3A	Lipids	21/11/2017	09:50	09:55	52 45.09	40 12.26	150	3794	2.64	2.53	16	4	
104	MSC037	1	P3A	Lipids	21/11/2017	10:19	10:26	52 45.09	40 12.23	500	3785	2.65	2.68	16	4	
105	MSC038	3	P3A	Lipids	21/11/2017	10:52	10:55	52 45.09	40 12.23	50	3786	2.66	2.57	20	5	
106	MSC039	4	P3A	Lipids	21/11/2017	11:17	11:25	52 45.09	40 12.23	100	3794	2.67	2.59	17	5	
109	MSC040		P3A	Polonium/ POC/Flux	21/11/2017	17:47	18:00	52 42.1	40 8.38	1000	3800	2.78	2.69	17	5	
119	MSC041		Argo	Production/ Fluxes	23/11/2017	06:50	06:59	53 58.06	41 2.16	150	2634	2.66	0.66	30	4	

Table 2.50: continued

Event	Deployment	MSC	Site	Description	Date (GMT)	Time fired (GMT)	Time t_0 (GMT)	Lat	Lon	Depth (m)	Echo depth (m)	SST (°C)	Air temp (°C)	Wind (knots)	Sea State (Bft)	Comments
123	MSC042	2	P2	Pelagra	24/11/2017	07:10	-	56 24.01	41 12.98	250	3459	1.44	0.46			
124	MSC043	2	P2	Rates/ Molecular	24/11/2017	07:25	-	56 24.01	41 12.1	70	3459					misfired
125	MSC044	2	P2	Rates/ Molecular	24/11/2017	07:30	07:44	56 24.01	41 12.1	70	3459					
126	MSC045	1	P2	Rates	24/11/2017	08:00	-	56 24.01	41 12	70	3459					leaked when recovered
127	MSC046	1	P2	Rates	24/11/2017	08:37	08:44	56 24.01	41 12	70	3459					
128	MSC047	3	P2	Rates	24/11/2017	08:50	08:55	56 24.07	41 12	70	3459					
129	MSC048	4	P2	Fluxes	24/11/2017	09:10	-	56 24.07	41 12	70	3459					misfired
130	MSC049	4	P2	Fluxes	24/11/2017	09:15	09:29	56 24.07	41 12	70	3459					bottom tap open
131	MSC050	4	P2	Fluxes	25/11/2017	07:28	07:35	56 38	40 54.93	110	3649	1.22	0.97	21	5	
132	MSC051	3	P2	Fluxes	25/11/2017	07:54	08:10	56 38	40 54.93	500	3651	1.22	1.08	18	5	
133	MSC052	1	P2	Fluxes	25/11/2017	08:24	08:30	56 38.01	40 54.94	250	3650	1.22	1.28	19	5	
134	MSC053	2	P2	Fluxes	25/11/2017	08:44	08:48	56 38.01	40 54.94	70	3649	1.2	1.32	23	5	
137	MSC054		P2	Zooplankton incubations	25/11/2017	11:06	-	56 38.01	40 54.94	350	3651	1.13	1.84	20	6	Did not release
138	MSC055		P2	Zooplankton incubations	25/11/2017	11:20	-	56 38.01	40 54.94	30						
139	MSC056	1	P2	Zooplankton incubations	25/11/2017	11:37	-	56 38.01	40 54.93	350						
140	MSC057	4	P2	Molecular	25/11/2017	12:13	12:20	56 38.01	40 54.93	160						
141	MSC058	2	P2	Rates	25/11/2017	12:30	12:38	56 38	40 54.93	160						
142	MSC059	3	P2	Rates	25/11/2017	12:44	12:55	56 38	40 54.93	160						
143	MSC060	1	P2	Fluxes	25/11/2017	13:02	13:05	56 38	40 54.93	160						
154	MSC061	1	P3B	Fluxes	29/11/2017	21:52	22:08	52 39.31	40 15.79	250	2251	3.25	3.29	17	4	
155	MSC062	2	P3B	Fluxes	29/11/2017	22:11	22:22	52 39.31	40 15.79	160	2258	3.28	2.92	16	5	
156	MSC063	3	P3B	Fluxes	29/11/2017	22:24	22:28	52 39.31	40 15.79	70	2262	3.26	2.95	16	5	

Table 2.50: continued

Event	Deployment	MSC	Site	Description	Date (GMT)	Time fired (GMT)	Time t_0 (GMT)	Lat	Lon	Depth (m)	Echo depth (m)	SST (°C)	Air temp (°C)	Wind (knots)	Sea State (Bft)	Comments
167	MSC064	1	P3B	Molecular	30/11/2017	11:40	11:58	52 42.53	40 4.58	500	3785	3.29	4.2			
168	MSC065	2	P3B	Rates	30/11/2017	12:11	12:31	52 42.53	40 4.58	500	3785	3.3	4.2			
169	MSC066	3	P3B	Rates	30/11/2017	12:45	13:00	52 42.53	40 4.58	500	3785	3.3	4.2			
170	MSC067	4	P3B	Fluxes	30/11/2017	13:05	13:11	52 42.53	40 4.58	110	3785	3.3	4.2			
176	MSC068	4	P3B	Fluxes	30/11/2017	21:13	21:16	52 42.28	40 6.13	70	3795	3.6	4.25	14	4	
177	MSC069	1	P3B	Zooplankton incubations	30/11/2017	21:26	-	52 42.28	40 6.13	30	3785	3.45	4.25	12	4	
178	MSC070	2	P3B	Fluxes	30/11/2017	21:46	21:58	52 42.28	40 6.13	500	3793	3.52	4.22	10	3	
179	MSC071	1	P3B	Fluxes	30/11/2017	22:09	22:14	52 42.28	40 6.13	250	3793	3.47	4.34	12	4	
180	MSC072	3	P3B	Fluxes	30/11/2017	22:26	22:32	52 42.28	40 6.13	160	3784	3.43	4.54	13	4	check depth. Fired shallow acc. Chl.
185	MSC073	2	P3B	Molecular	01/12/2017	11:01	11:09	52 42.4	40 5.94	250	3793	3.4	4.51	18.6		
186	MSC074	1	P3B	Rates	01/12/2017	11:21	11:31	52 42.4	40 5.94	250	3793	3.4	4.51			
187	MSC075	3	P3B	Rates	01/12/2017	11:41	11:49	52 42.4	40 5.94	250	3793	3.4	4.51			
188	MSC076	4	P3B	Fluxes	01/12/2017	12:01	12:08	52 42.4	40 5.94	110	3793	3.4	4.51			
193	MSC077	4	P3B	Lipids/ Fluxes	01/12/2017	20:40	20:50	52 42.32	40 6.08	500	3786	3.45	2.27	13	4	
194	MSC078	2	P3B	Lipids/ Fluxes	01/12/2017	21:15	21:20	52 42.32	40 6.08	150	3785	3.47	1.79	16	5	
195	MSC079	3	P3B	Lipids/ Fluxes	01/12/2017	21:28	21:40	52 42.32	40 6.03	100	3784	3.47	1.95	13	4	
196	MSC080	1	P3B	Lipids/ Fluxes	01/12/2017	21:44	21:50	52 42.32	40 6.07	50	3785	3.47	1.95	13	4	
206	MSC081	3	P3B	Fluxes	02/12/2017	15:37	15:46	52 41.74	40 15.45	250	3785	3.56	3.58	18	5	
207	MSC082	1	P3B	Fluxes	02/12/2017	15:58	16:07	52 41.74	40 15.15	160	3785	3.51	3.53	19	5	
208	MSC083	2	P3B	Fluxes	02/12/2017	16:13	16:18	52 41.74	40 15.15	110	3785	3.54	3.47	18	5	
209	MSC084	4	P3B	Fluxes	02/12/2017	16:29	16:33	52 41.74	40 15.15	70	3784	3.52	3.43	22	5	
221	MSC085	1	P3B	Zooplankton incubations	03/12/2017	09:04	-	52 46.39	40 3.09	30	3785	3.36	3.24	16		

Table 2.50: continued

Event	Deployment	MSC	Site	Description	Date (GMT)	Time fired (GMT)	Time t_0 (GMT)	Lat	Lon	Depth (m)	Echo depth (m)	SST (°C)	Air temp (°C)	Wind (knots)	Sea State (Bft)	Comments
222	MSC086	3	P3B	Molecular	03/12/2017	09:17	09:25	52 46.39	40 3.09	160	3785	3.36	3.24	16		
223	MSC087	2	P3B	Rates	03/12/2017	09:32	09:38	52 46.39	40 3.09	160	3785	3.36	3.24	16		
224	MSC088	1	P3B	Rates	03/12/2017	09:45		52 46.39	40 3.09	160	3785	3.36	3.24	16		
231	MSC089	1	P3B	Molecular	04/12/2017	11:30	11:35	52 41.25	40 20.05	70	3789	3.45	1.72	26		
232	MSC090	2	P3B	Rates	04/12/2017	11:43	11:48	52 41.25	40 40.65	70	3789					
233	MSC091	3	P3B	Rates	04/12/2017	11:53	11:56	52 41.25	40 40.69	70	3789					
235	MSC092	3	P3B	Fluxes	04/12/2017	17:21	17:25	52 41.25	40 20.64	30	3786	3.65	2.47	12		
236	MSC093	2	P3B	Fluxes	04/12/2017	17:33	17:36	52 41.25	40 20.65	70	3791	3.63	2.45	15		Samples lost
237	MSC094	1	P3B	Fluxes	04/12/2017	17:47	-	52 41.25	40 20.65	80	3793	3.62	2.45	15		Did not fire
238	MSC095	1	P3B	Fluxes	04/12/2017	17:54	17:58	52 41.26	40 20.64	80	3793	3.6	2.21	13		Samples lost
239	MSC096	4	P3B	Fluxes	04/12/2017	18:08	-	52 41.26	40 20.65	100	3793	3.62	2.21	14		Did not fire
240	MSC097	4	P3B	Fluxes	04/12/2017	18:15	18:22	52 41.26	40 20.64	100	3795	3.6	2.22	10	4	Samples lost
248	MSC098		P3B	Zooplankton incubations	05/12/2017	00:10	-	52 43.24	40 19.57	30						
255	MSC099	4	P3B	Fluxes	05/12/2017	16:03	16:18	52 43.25	40 19.56	500	2267	3.56	3.56	28	7	
256	MSC100	1	P3B	Fluxes	05/12/2017	16:28	16:34	52 43.25	40 19.56	170	3786	3.59	3.7	31	7	
257	MSC101	2	P3B	Fluxes	05/12/2017	16:44	16:50	52 43.25	40 19.56	80	3786	3.58	3.62	30	6	
266	MSC102		P3C	Zooplankton incubations	09/12/2017	10:20	10:25	52 43.26	40 19.65	30	3792	3.52	3.18	11	4	
267	MSC103	1	P3C	Fluxes	09/12/2017	10:48	10:59	52 43.26	40 19.65	500	3792	3.5	3.18	13	4	
268	MSC104	2	P3C	Fluxes	09/12/2017	11:12	11:18	52 43.26	40 19.65	150	3792	3.53	3.14	10	4	
269	MSC105	4	P3C	Fluxes	09/12/2017	11:30	11:37	52 43.26	40 19.65	60	3787	3.54	3.14	12	4	
270	MSC106	3	P3C	Fluxes	09/12/2017	11:48	11:58	52 43.26	40 19.65	250	3794	3.55	3.15	10	3	
289	MSC107	1	P3C	Molecular	10/12/2017	11:24	11:39	52 41.71	40 19.41	500	3785	3.76	3.82	12		
290	MSC108	2	P3C	Rates	10/12/2017	11:57	12:15	52 41.71	40 19.41	500	3785					
291	MSC109	3	P3C	Rates	10/12/2017	12:26	12:40	52 41.71	40 19.41	500	3785					

Table 2.50: continued

Event	Deployment	MSC	Site	Description	Date (GMT)	Time fired (GMT)	Time t_0 (GMT)	Lat	Lon	Depth (m)	Echo depth (m)	SST (°C)	Air temp (°C)	Wind (knots)	Sea State (Bft)	Comments
292	MSC110	4	P3C	Lipids	10/12/2017	12:57	13:13	52 41.71	40 19.41	500	3785	3.76	3.8	12		
296	MSC111	3	P3C	Fluxes	10/12/2017	19:26	19:34	52 40.03	40 15.76	160	3787	3.95	4.88	17	4	
297	MSC112	4	P3C	Fluxes	10/12/2017	19:42	19:47	52 40.03	40 15.76	110	3788	4.00	4.95	16	5	
298	MSC113	1	P3C	Fluxes	10/12/2017	19:53	19:56	52 40.03	40 15.76	70	3794	4.01	4.95	19	5	
299	MSC114	2	P3C	Fluxes	10/12/2017	20:05	20:07	52 40.03	40 15.76	30	3791	4.02	4.85	18	5	
308	MSC115	4	P3C	?	11/12/2017	09:30	09:33	52 43	40 14.3	60						
309	MSC116	3	P3C	?	11/12/2017	09:45	09:48	52 43	40 14.3	60						
310	MSC117	1	P3C	?	11/12/2017	09:59	10:08	52 43	40 14.3	60						
311	MSC118	2	P3C	?	11/12/2017	10:15	10:22	52 43	40 14.3	60						
324	MSC119	4	P3C	Zooplankton incubations	12/12/2017	18:37	-	52 38.7	40 12.6	75						
325	MSC120	1	P3C	Rates	12/12/2017	18:37	19:00	52 38.7	40 12.6	75						
326	MSC121	3	P3C	Molecular	12/12/2017	19:10	19:23	52 38.6	40 12.6	75						
327	MSC122	2	P3C	Respiration	12/12/2017	19:14	19:25	52 38.6	40 12.6	165						
328	MSC123	4	P3C	Rates	12/12/2017	19:23	19:35	52 38.7	40 12.6	75						
329	MSC124	1	P3C	Rates	12/12/2017	19:39	19:48	52 38.7	40 12.6	75						
342	MSC125	4	P3C	Lipids/ Fluxes	15/12/2017	11:05	11:18	52 42.1	39 56.98	500	3787	3.83	3.73	27	6	
343	MSC126	1	P3C	Lipids/ Fluxes	15/12/2017	11:28	11:35	52 42.1	39 56.99	165	3787	3.83	3.7	20	5	
344	MSC127	2	P3C	Lipids/ Fluxes	15/12/2017	11:44	11:49	52 42.1	39 56.98	75	3786	3.84	3.7	22	5	
345	MSC128	3	P3C	Lipids/ Fluxes	15/12/2017	11:56	12:00	52 42.1	39 56.98	30	3786	3.84	3.67	21	5	

2.30 ^{234}Th-^{238}U profiles

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2.30.1 Objectives

The Radioactive short-lived Thorium-234 (^{234}Th, $t_{1/2}$ = 24.1 d) can be used to estimate export fluxes into the deep ocean. ^{234}Th is the daughter isotope of naturally occurring 238-Uranium (^{238}U, $t_{1/2}$ = 4.47 x 109 y) which is conservative in seawater and is proportional to salinity in well oxygenated environments. Unlike ^{238}U, ^{234}Th is particle reactive in the water column. As particles with ^{234}Th sink through the water column, a radioactive disequilibrium is formed between ^{238}U and ^{234}Th, which can be used to quantify the rate of carbon and biomineral export from the surface ocean. This is possible with the ratios of POC, PIC or BSi to particulate ^{234}Th activity (Tsunogai et Minagawa, 1976) obtained from large volume samples (e.g. in situ pumps such as SAPS).

2.30.2 Sampling methodology and sampling treatment on board

Samples for Thorium analysis were collected from a stainless steel CTD rosette (total activity) and SAPS (particulate activity) at various stations (see Table 2.51).

Total ^{234}Th from CTD casts

For total ^{234}Th 4 L water samples were collected from 15 depths to 500 m from four stations and from 10 depths from the last station (see Table 2.51). The depths were 5, 10, 15 20, 30, 40, 50, 75, 100, 125, 150, 200, 250, 350 and 500 m for the first four deployments and 5, 10, 20, 30, 50, 75, 100, 150, 250 and 500 m for the last. The reason for selecting lower number of depths during the last total Thorium deployment was the need to calibrate ^{234}Th counting efficiency by sampling 5 mid water samples, away from the surface ocean (at 1000 m), where the secular equilibrium between ^{234}Th and ^{238}U is expected, and lack of time due to weather conditions to carry out another deployment. The plastic bottles used to sample the water were leaking through small holes close to the bottom. Tape was used to stop the leak however some water unavoidably lost during the process. One bottle was totally lost from the first and last deployment (from 125 m in E14 and 50 m in E318; see Table 2.51), therefore 14 and 9 results were respectively obtained from these deployments (see Table 2.51). Upon collection the water bottles were acidified by adding 6 mL nitric acid spiked with a Thorium standard, and left at room temperature for 6-8 h. The bottles were shaken in between each step of the process. After 6-8 h total ^{234}Th was precipitated by adding 6.4 – 7 mL concentrated ammonia, $KMnO_6$ (potassium permanganate), and $MnCl_2$ (manganese dichloride), whilst shaking the bottles in between the steps. After 6-8 h (minimum) the formed precipitate was filtered onto 25 mm ashed GF/F filters. Occasionally some water was lost through filtration (see Table 2.51). The filters were then placed in plastic petri dishes dried in a mild oven. The filters were subsequently wrapped in mylar foil and counted in a Riso beta counter. A procedural blank was carried out using MiiliQ water from the ship.

Particulate ^{234}Th from SAPS

For particulate ^{234}Th 1/4 of the large particles obtained from SAPS (see Section 2.18) were filtered on onto 25 mm ashed GF/F filters and rinsed with MilliQ pH 8 adjusted water. The filters were then placed in plastic petri dishes dried in a mild oven. Afer drying the filters were wrapped in mylar foil and counted in a Riso beta counter. All the preliminary results are shown in Table 2.52.

Table 2.51: Sampling information of total ^{234}Th from CTD casts. Details about the timings of the procedure in accompanying Excel file.

15/11/2017	P3A	14	2	52 42.5	40 06.3	24	1	5	1L only - partly lost during filtration
15/11/2017	P3A	14	2	52 42.5	40 06.3	23	2	10	3L leaky bottle
15/11/2017	P3A	14	2	52 42.5	40 06.3	22	3	15	
15/11/2017	P3A	14	2	52 42.5	40 06.3	21	4	20	
15/11/2017	P3A	14	2	52 42.5	40 06.3	20	5	30	
15/11/2017	P3A	14	2	52 42.5	40 06.3	19	6	40	
15/11/2017	P3A	14	2	52 42.5	40 06.3	18	7	50	3L leaky bottle
15/11/2017	P3A	14	2	52 42.5	40 06.3	17	8	75	3L leaky bottle
15/11/2017	P3A	14	2	52 42.5	40 06.3	16	9	100	3L leaky bottle
15/11/2017	P3A	14	2	52 42.5	40 06.3	15	10	125	lost during filtration
15/11/2017	P3A	14	2	52 42.5	40 06.3	14	11	150	
15/11/2017	P3A	14	2	52 42.5	40 06.3	13	12	200	3.5L leaky bottle
15/11/2017	P3A	14	2	52 42.5	40 06.3	12	13	250	3.5L leaky bottle
15/11/2017	P3A	14	2	52 42.5	40 06.3	11	14	350	
15/11/2017	P3A	14	2	52 42.5	40 06.3	9	15	500	3.5L leaky bottle
21/11/2017	P3A	108	10	52 42.09	40 08.39	2 or 3	15	500	leaky bottles slightly less than 4L filtered
21/11/2017	P3A	108	10	52 42.09	40 08.39	4	14	350	leaky bottles slightly less than 4L filtered
21/11/2017	P3A	108	10	52 42.09	40 08.39	5 or 6	13	250	leaky bottles slightly less than 4L filtered
21/11/2017	P3A	108	10	52 42.09	40 08.39	7 or 8	12	200	leaky bottles slightly less than 4L filtered
21/11/2017	P3A	108	10	52 42.09	40 08.39	9 or 10	11	150	leaky bottles slightly less than 4L filtered
21/11/2017	P3A	108	10	52 42.09	40 08.39	11	10	125	leaky bottles slightly less than 4L filtered
21/11/2017	P3A	108	10	52 42.09	40 08.39	12 or 13	9	100	leaky bottles slightly less than 4L filtered
21/11/2017	P3A	108	10	52 42.09	40 08.39	14	8	75	leaky bottles slightly less than 4L filtered
21/11/2017	P3A	108	10	52 42.09	40 08.39	15 or 16	7	50	leaky bottles slightly less than 4L filtered
21/11/2017	P3A	108	10	52 42.09	40 08.39	17	6	40	leaky bottles slightly less than 4L filtered
21/11/2017	P3A	108	10	52 42.09	40 08.39	18 or 19	5	30	leaky bottles slightly less than 4L filtered
21/11/2017	P3A	108	10	52 42.09	40 08.39	20	4	20	leaky bottles slightly less than 4L filtered

Table 2.51: continued

Date	Station ID	Event	Cast	Lat (S)	Lon (E)	Niskin	Th bottle	Depth (m)	Comments
21/11/2017	P3A	108	10	52 42.09	40 08.39	21	3	15	leaky bottles slightly less than 4L filtered
21/11/2017	P3A	108	10	52 42.09	40 08.39	22 or 23	2	10	leaky bottles slightly less than 4L filtered
21/11/2017	P3A	108	10	52 42.09	40 08.39	24	1	5	leaky bottles slightly less than 4L filtered
25/11/2017	P2A	144	13	56 38.0	40 55.0	3	15	500	leaky bottles slightly less than 4L filtered
25/11/2017	P2A	144	13	56 38.0	40 55.0	4 or 5	14	350	leaky bottles slightly less than 4L filtered
25/11/2017	P2A	144	13	56 38.0	40 55.0	6	13	250	leaky bottles slightly less than 4L filtered
25/11/2017	P2A	144	13	56 38.0	40 55.0	7 or 8	12	200	leaky bottles slightly less than 4L filtered
25/11/2017	P2A	144	13	56 38.0	40 55.0	9	11	150	leaky bottles slightly less than 4L filtered
25/11/2017	P2A	144	13	56 38.0	40 55.0	10	10	125	leaky bottles slightly less than 4L filtered
25/11/2017	P2A	144	13	56 38.0	40 55.0	11 or 12	9	100	leaky bottles slightly less than 4L filtered
25/11/2017	P2A	144	13	56 38.0	40 55.0	13	8	75	leaky bottles slightly less than 4L filtered
25/11/2017	P2A	144	13	56 38.0	40 55.0	14 or 15	7	50	leaky bottles slightly less than 4L filtered
25/11/2017	P2A	144	13	56 38.0	40 55.0	16	6	40	leaky bottles slightly less than 4L filtered
25/11/2017	P2A	144	13	56 38.0	40 55.0	17 or 18	5	30	leaky bottles slightly less than 4L filtered
25/11/2017	P2A	144	13	56 38.0	40 55.0	19	4	20	torn filter 3L filtered
25/11/2017	P2A	144	13	56 38.0	40 55.0	20 or 21	3	15	leaky bottles slightly less than 4L filtered
25/11/2017	P2A	144	13	56 38.0	40 55.0	22 or 23 or 24	2	10	leaky bottles slightly less than 4L filtered
25/11/2017	P2A	144	13	56 38.0	40 55.0	underway	1	5	leaky bottles slightly less than 4L filtered
02/12/2017	P3B	211	20	52 41.7	40 15.06	3 or 4	15	500	leaky bottles slightly less than 4L filtered
02/12/2017	P3B	211	20	52 41.7	41 15.06	5 or 6	14	350	leaky bottles slightly less than 4L filtered
02/12/2017	P3B	211	20	52 41.7	42 15.06	7 or 8	13	250	leaky bottles slightly less than 4L filtered
02/12/2017	P3B	211	20	52 41.7	43 15.06	9 or 10	12	200	leaky bottles slightly less than 4L filtered
02/12/2017	P3B	211	20	52 41.7	44 15.06	11 or 12	11	150	leaky bottles slightly less than 4L filtered
02/12/2017	P3B	211	20	52 41.7	45 15.06	13 or 14	10	125	leaky bottles slightly less than 4L filtered
02/12/2017	P3B	211	20	52 41.7	45 15.06	15	9	100	leaky bottles slightly less than 4L filtered

Table 2.51: continued

Date	Station ID	Event	Cast	Lat (S)	Lon (E)	Niskin	Th bottle	Depth (m)	Comments
02/12/2017	P3B	211	20	52 41.7	45 15.06	16	8	75	leaky bottles slightly less than 4L filtered
02/12/2017	P3B	211	20	52 41.7	45 15.06	17	7	50	leaky bottles slightly less than 4L filtered
02/12/2017	P3B	211	20	52 41.7	45 15.06	18	6	40	leaky bottles slightly less than 4L filtered
02/12/2017	P3B	211	20	52 41.7	45 15.06	19	5	30	leaky bottles slightly less than 4L filtered
02/12/2017	P3B	211	20	52 41.7	45 15.06	20	4	20	leaky bottles slightly less than 4L filtered
02/12/2017	P3B	211	20	52 41.7	45 15.06	21	3	15	leaky bottles slightly less than 4L filtered
02/12/2017	P3B	211	20	52 41.7	45 15.06	22 or 23	2	10	leaky bottles slightly less than 4L filtered
02/12/2017	P3B	211	20	52 41.7	45 15.06	24	1	5	leaky bottles slightly less than 4L filtered
11/12/2017	P3C	318	30	52 45.36	40 24.71	1 or 2	15	1000	leaky bottles slightly less than 4L filtered
11/12/2017	P3C	318	30	52 45.36	40 24.71	1 or 2	14	1000	leaky bottles slightly less than 4L filtered
11/12/2017	P3C	318	30	52 45.36	40 24.71	1 or 2	13	1000	leaky bottles slightly less than 4L filtered
11/12/2017	P3C	318	30	52 45.36	40 24.71	1 or 2	12	1000	leaky bottles slightly less than 4L filtered
11/12/2017	P3C	318	30	52 45.36	40 24.71	1 or 2	11	1000	leaky bottles slightly less than 4L filtered
11/12/2017	P3C	318	30	52 45.36	40 24.71	4 or 5	10	500	leaky bottles slightly less than 4L filtered
11/12/2017	P3C	318	30	52 45.36	40 24.71	8 or 9	9	250	leaky bottles slightly less than 4L filtered
11/12/2017	P3C	318	30	52 45.36	40 24.71	11 or 12	8	150	leaky bottles slightly less than 4L filtered
11/12/2017	P3C	318	30	52 45.36	40 24.71	14	7	100	leaky bottles slightly less than 4L filtered
11/12/2017	P3C	318	30	52 45.36	40 24.71	15 or 16	6	75	leaky bottles slightly less than 4L filtered
11/12/2017	P3C	318	30	52 45.36	40 24.71	17 or 18	5	50	lost bottle during filtration
11/12/2017	P3C	318	30	52 45.36	40 24.71	19	4	30	leaky bottles slightly less than 4L filtered
11/12/2017	P3C	318	30	52 45.36	40 24.71	20 or 21	3	20	leaky bottles slightly less than 4L filtered
11/12/2017	P3C	318	30	52 45.36	40 24.71	22	2	10	leaky bottles slightly less than 4L filtered
11/12/2017	P3C	318	30	52 45.36	40 24.71	23 or 24	1	5	leaky bottles slightly less than 4L filtered

Table 2.52: Preliminary data for total (from CTD) and particulate (from SAPS) ^{234}Th measurements. The data has not been calibrated for precision nor corrected for blanks.

Date	Station	Event	Lat (S)	Lon (E)	Sample type	Sample ID	Depth (m)	Counting Start	Counting End	Total counts	cpm	± %
15/11/2017	P3A	14	52 42.5	40 06.3	CTD (Cast) 2	5m	5	17/11/17 10.30	19/11/17 08.50	3	0.46	2.8
15/11/2017	P3A	14	52 42.5	40 06.3	CTD (Cast) 2	10m	10	17/11/17 10.30	19/11/17 08.50	8	1.65	1.5
15/11/2017	P3A	14	52 42.5	40 06.3	CTD (Cast) 2	15m	15	17/11/17 10.30	19/11/17 08.50	14	1.92	1.4
15/11/2017	P3A	14	52 42.5	40 06.3	CTD (Cast) 2	20m	20	17/11/17 10.30	19/11/17 08.50	5	2.23	1.3
15/11/2017	P3A	14	52 42.5	40 06.3	CTD (Cast) 2	30m	30	17/11/17 10.30	19/11/17 08.50	11	2.27	1.3
15/11/2017	P3A	14	52 42.5	40 06.3	CTD (Cast) 2	40m	40	19/11/17 09.07	19/11/17 18.30	7	2.33	2.8
15/11/2017	P3A	14	52 42.5	40 06.3	CTD (Cast) 2	50m	50	19/11/17 09.07	19/11/17 18.30	11	2.03	3
15/11/2017	P3A	14	52 42.5	40 06.3	CTD (Cast) 2	75m	75	19/11/17 09.07	19/11/17 18.30	2	2.14	2.9
15/11/2017	P3A	14	52 42.5	40 06.3	CTD (Cast) 2	100m	100	19/11/17 09.07	19/11/17 18.30	12	2.65	2.6
15/11/2017	P3A	14	52 42.5	40 06.3	CTD (Cast) 2	150m	150	19/11/17 09.07	19/11/17 18.30	8	2.58	2.6
15/11/2017	P3A	14	52 42.5	40 06.3	CTD (Cast) 2	200m	200	20/11/17 09.00	20/11/17 15.40	14	3	2.9
15/11/2017	P3A	14	52 42.5	40 06.3	CTD (Cast) 2	250m	250	20/11/17 09.00	20/11/17 15.40	19	3.56	2.7
15/11/2017	P3A	14	52 42.5	40 06.3	CTD (Cast) 2	350m	350	20/11/17 09.00	20/11/17 15.40	23	3.69	2.8
15/11/2017	P3A	14	52 42.5	40 06.3	CTD (Cast) 2	500m	500	20/11/17 09.00	20/11/17 15.40	18	3.4	2.8
17/11/2017	P3A	58	52 42.0	40 06.4	SAPS	5m	5	21/11/17 11.05	21/11/17 21.00	2	3.08	1.5
17/11/2017	P3A	58	52 42.0	40 06.4	SAPS	30m	32	21/11/17 11.05	21/11/17 21.00	10	5.69	1.1
17/11/2017	P3A	58	52 42.0	40 06.4	SAPS	80m	85	21/11/17 11.05	21/11/17 21.00	2	2.92	1.5
17/11/2017	P3A	58	52 42.0	40 06.4	SAPS	180m	185	21/11/17 11.05	21/11/17 21.00	4	2.11	1.8
17/11/2017	P3A	58	52 42.0	40 06.4	SAPS	430m	435	21/11/17 11.05	21/11/17 21.00	0	1.03	2.6
20/11/2017	P3A	94	52 44.9	40 11.9	SAPS	25m	25	24/11/17 12.50	25/11/17 10.50	1	1.34	2.4
20/11/2017	P3A	94	52 44.9	40 11.9	SAPS	50m	49	24/11/17 12.50	25/11/17 10.50	1	2.5	1.8
20/11/2017	P3A	94	52 44.9	40 11.9	SAPS	150m	153	24/11/17 12.50	25/11/17 10.50	0	1.16	2.6
20/11/2017	P3A	94	52 44.9	40 11.9	SAPS	250m	255	24/11/17 12.50	25/11/17 10.50	0	1.15	2.6
20/11/2017	P3A	94	52 44.9	40 11.9	SAPS	440m	448	24/11/17 12.50	25/11/17 10.50	1	1.19	2.6

Table 2.52: continued

Date	Station	Event	Lat (S)	Lon (E)	Sample type	Sample ID	Depth (m)	Counting Start	Counting End	Total counts	cpm	± %
21/11/2017	P3A	108	52 42.09	40 08.39	CTD cast 10	5m	5	25/11/17 10.45	26/11/17 15.30	9	1.43	2
21/11/2017	P3A	108	52 42.09	40 08.39	CTD cast 10	10m	10	25/11/17 10.45	26/11/17 15.30	5	1.15	2.2
21/11/2017	P3A	108	52 42.09	40 08.39	CTD cast 10	15m	15	25/11/17 10.45	26/11/17 15.30	9	1.96	1.7
21/11/2017	P3A	108	52 42.09	40 08.39	CTD cast 10	20m	20	25/11/17 10.45	26/11/17 15.30	5	0.65	3
21/11/2017	P3A	108	52 42.09	40 08.39	CTD cast 10	30m	30	25/11/17 10.45	26/11/17 15.30	12	1.41	2
21/11/2017	P3A	108	52 42.09	40 08.39	CTD cast 10	40m	40	26/11/17 15.40	27/11/17 09.45	8	1.81	2.3
21/11/2017	P3A	108	52 42.09	40 08.39	CTD cast 10	50m	50	26/11/17 15.40	27/11/17 09.45	15	1.92	2.2
21/11/2017	P3A	108	52 42.09	40 08.39	CTD cast 10	75m	75	26/11/17 15.40	27/11/17 09.45	17	2.17	2.1
21/11/2017	P3A	108	52 42.09	40 08.39	CTD cast 10	100m	100	26/11/17 15.40	27/11/17 09.45	10	1.4	2.6
21/11/2017	P3A	108	52 42.09	40 08.39	CTD cast 10	125m	125	26/11/17 15.40	27/11/17 09.45	15	1.56	2.4
21/11/2017	P3A	108	52 42.09	40 08.39	CTD cast 10	150m	150	27/11/17 10.00	28/11/17 13.00	4	3.6	1.4
21/11/2017	P3A	108	52 42.09	40 08.39	CTD cast 10	200m	200	27/11/17 10.00	28/11/17 13.00	1	1.45	2.2
21/11/2017	P3A	108	52 42.09	40 08.39	CTD cast 10	250m	250	27/11/17 10.00	28/11/17 13.00	2	3.48	1.4
21/11/2017	P3A	108	52 42.09	40 08.39	CTD cast 10	350m	350	27/11/17 10.00	28/11/17 13.00	0	1.42	2.2
21/11/2017	P3A	108	52 42.09	40 08.39	CTD cast 10	500m	500	27/11/17 10.00	28/11/17 13.00	1	1.04	2.6
25/11/2017	P2A	144	56 38.0	40 55.0	CTD cast 13	5m	5	28/11/17 21.30	29/11/17 17.00	23	5.11	1.3
25/11/2017	P2A	144	56 38.0	40 55.0	CTD cast 13	10m	10	28/11/17 21.30	29/11/17 17.00	15	2.61	1.8
25/11/2017	P2A	144	56 38.0	40 55.0	CTD cast 13	15m	15	28/11/17 21.30	29/11/17 17.00	16	2.58	1.8
25/11/2017	P2A	144	56 38.0	40 55.0	CTD cast 13	20m	20	28/11/17 21.30	29/11/17 17.00	1	0.97	3
25/11/2017	P2A	144	56 38.0	40 55.0	CTD cast 13	30m	30	28/11/17 21.30	29/11/17 17.00	20	2.01	2.1
25/11/2017	P2A	144	56 38.0	40 55.0	CTD cast 13	40m	40	29/11/17 17.05	30/11/17 10.30	7	2.72	1.9
25/11/2017	P2A	144	56 38.0	40 55.0	CTD cast 13	50m	50	29/11/17 17.05	30/11/17 10.30	3	1.22	2.8
25/11/2017	P2A	144	56 38.0	40 55.0	CTD cast 13	75m	75	29/11/17 17.05	30/11/17 10.30	4	2.34	2
25/11/2017	P2A	144	56 38.0	40 55.0	CTD cast 13	100m	100	29/11/17 17.05	30/11/17 10.30	10	2.89	1.8
25/11/2017	P2A	144	56 38.0	40 55.0	CTD cast 13	125m	125	29/11/17 17.05	30/11/17 10.30	6	3.19	1.7

Table 2.52: continued

Date	Station	Event	Lat (S)	Lon (E)	Sample type	Sample ID	Depth (m)	Counting Start	Counting End	Total counts	cpm	± %
25/11/2017	P2A	144	56 38.0	40 55.0	CTD cast 13	150m	150	30/11/17 10.45	30/11/17 17.00	15	3.65	2.7
25/11/2017	P2A	144	56 38.0	40 55.0	CTD cast 13	200m	200	30/11/17 10.45	30/11/17 17.00	10	3.78	2.7
25/11/2017	P2A	144	56 38.0	40 55.0	CTD cast 13	250m	250	30/11/17 10.45	30/11/17 17.00	12	3.47	2.8
25/11/2017	P2A	144	56 38.0	40 55.0	CTD cast 13	350m	350	30/11/17 10.45	30/11/17 17.00	9	3.98	2.6
25/11/2017	P2A	144	56 38.0	40 55.0	CTD cast 13	500m	500	30/11/17 10.45	30/11/17 17.00	8	3.7	2.7
01/12/2017	P3B	183	52 42.3	40 06.2	SAPS	25m	25	02/12/17 19.10	04/12/17 14.30	6	0.42	3
01/12/2017	P3B	183	52 42.3	40 06.2	SAPS	50m	51	02/12/17 19.10	04/12/17 14.30	27	2.8	1.2
01/12/2017	P3B	183	52 42.3	40 06.2	SAPS	150m	155	02/12/17 19.10	04/12/17 14.30	14	2.23	1.3
01/12/2017	P3B	183	52 42.3	40 06.2	SAPS	250m	258	02/12/17 19.10	04/12/17 14.30	8	1.18	1.8
01/12/2017	P3B	183	52 42.3	40 06.2	SAPS	440m	460	02/12/17 19.10	04/12/17 14.30	3	0.83	2.2
02/12/2017	P3B	211	52 41.7	40 15.06	CTD cast 20	5m	5	06/12/17 12.30	08/12/17 12.30	5	2.07	1.3
02/12/2017	P3B	211	52 41.7	41 15.06	CTD cast 20	10m	10	06/12/17 12.30	08/12/17 12.30	3	1.04	1.8
02/12/2017	P3B	211	52 41.7	42 15.06	CTD cast 20	15m	15	06/12/17 12.30	08/12/17 12.30	4	1.95	1.3
02/12/2017	P3B	211	52 41.7	43 15.06	CTD cast 20	20m	20	06/12/17 12.30	08/12/17 12.30	1	0.4	2.9
02/12/2017	P3B	211	52 41.7	44 15.06	CTD cast 20	30m	30	06/12/17 12.30	08/12/17 12.30	5	1.2	1.8
02/12/2017	P3B	211	52 41.7	45 15.06	CTD cast 20	40m	40	08/12/17 13.00	10/12/17 13.00	1	1.18	1.3
02/12/2017	P3B	211	52 41.7	45 15.06	CTD cast 20	50m	50	08/12/17 13.00	10/12/17 13.00	4	1.7	1.4
02/12/2017	P3B	211	52 41.7	45 15.06	CTD cast 20	75m	75	08/12/17 13.00	10/12/17 13.00	1	0.5	2.6
02/12/2017	P3B	211	52 41.7	45 15.06	CTD cast 20	100m	100	08/12/17 13.00	10/12/17 13.00	2	1.7	1.4
02/12/2017	P3B	211	52 41.7	45 15.06	CTD cast 20	125m	125	08/12/17 13.00	10/12/17 13.00	3	2.12	1.3
02/12/2017	P3B	211	52 41.7	45 15.06	CTD cast 20	150m	150	10/12/17 13.15	11/12/17 00.00	8	3.28	2.3
02/12/2017	P3B	211	52 41.7	45 15.06	CTD cast 20	200m	200	10/12/17 13.15	11/12/17 00.00	9	2.42	2.6
02/12/2017	P3B	211	52 41.7	45 15.06	CTD cast 20	250m	250	10/12/17 13.15	11/12/17 00.00	11	3.19	2.3
02/12/2017	P3B	211	52 41.7	45 15.06	CTD cast 20	350m	350	10/12/17 13.15	11/12/17 00.00	7	1.9	2.9
02/12/2017	P3B	211	52 41.7	45 15.06	CTD cast 20	500m	500	10/12/17 13.15	11/12/17 00.00	13	3.63	2.1

Table 2.52: continued

Date	Station	Event	Lat (S)	Lon (E)	Sample type	Sample ID	Depth (m)	Counting Start	Counting End	Total counts	cpm	± %
05/12/2017	P3B	253	52 43.3	40 19.6	SAPS	25m	30	11/12/17 00.30	11/12/17 14.30	1	0.62	2.7
05/12/2017	P3B	253	52 43.3	40 19.6	SAPS	50m	53	11/12/17 00.30	11/12/17 14.30	3	1.75	1.6
05/12/2017	P3B	253	52 43.3	40 19.6	SAPS	150m	158	11/12/17 00.30	11/12/17 14.30	1	0.92	2.2
05/12/2017	P3B	253	52 43.3	40 19.6	SAPS	250m	259	11/12/17 00.30	11/12/17 14.30	3	1.16	1.9
05/12/2017	P3B	253	52 43.3	40 19.6	SAPS	440m	462	11/12/17 00.30	11/12/17 14.30	3	0.84	2.3
10/12/2017	P3C	288	52 41.7	40 19.4	SAPS	66m	66	11/12/17 15.00	14/12/17 10.20	7	1.14	1.8
10/12/2017	P3C	288	52 41.7	40 19.4	SAPS	170m	170	11/12/17 15.00	14/12/17 10.20	9	1.31	1.7
10/12/2017	P3C	288	52 41.7	40 19.4	SAPS	268m	268	11/12/17 15.00	14/12/17 10.20	2	0.46	2.9
10/12/2017	P3C	288	52 41.7	40 19.4	SAPS	460m	460	11/12/17 15.00	14/12/17 10.20	4	1.16	1.8
02/12/2017	P3C	318	52 45.36	40 24.71	CTD cast 30	5m	5	06/12/17 12.30	08/12/17 12.30	12	1.61	2.3
02/12/2017	P3C	318	52 45.36	40 24.71	CTD cast 30	10m	10	06/12/17 12.30	08/12/17 12.30	10	1.42	2.5
02/12/2017	P3C	318	52 45.36	40 24.71	CTD cast 30	20m	20	06/12/17 12.30	08/12/17 12.30	11	2.36	1.9
02/12/2017	P3C	318	52 45.36	40 24.71	CTD cast 30	30m	30	06/12/17 12.30	08/12/17 12.30	5	1.1	2.8
02/12/2017	P3C	318	52 45.36	40 24.71	CTD cast 30	50m	50	06/12/17 12.30	08/12/17 12.30	14	2.91	1.7
02/12/2017	P3C	318	52 45.36	40 24.71	CTD cast 30	100m	100	08/12/17 13.00	10/12/17 13.00	19	2.3	2.2
02/12/2017	P3C	318	52 45.36	40 24.71	CTD cast 30	150m	150	08/12/17 13.00	10/12/17 13.00	16	3.61	2.1
02/12/2017	P3C	318	52 45.36	40 24.71	CTD cast 30	250m	250	08/12/17 13.00	10/12/17 13.00	4	1.86	2.9
02/12/2017	P3C	318	52 45.36	40 24.71	CTD cast 30	500m	500	08/12/17 13.00	10/12/17 13.00	20	3.28	2.2
02/12/2017	P3C	318	52 45.36	40 24.71	CTD cast 30	1000m	1000	10/12/17 13.15	11/12/17 00.00	10	4.05	1.5
02/12/2017	P3C	318	52 45.36	40 24.71	CTD cast 30	1000m	1000	10/12/17 13.15	11/12/17 00.00	26	3.68	1.6
02/12/2017	P3C	318	52 45.36	40 24.71	CTD cast 30	1000m	1000	10/12/17 13.15	11/12/17 00.00	20	3.45	1.6
02/12/2017	P3C	318	52 45.36	40 24.71	CTD cast 30	1000m	1000	10/12/17 13.15	11/12/17 00.00	13	3.28	1.7
02/12/2017	P3C	318	52 45.36	40 24.71	CTD cast 30	1000m	1000	10/12/17 13.15	11/12/17 00.00	21	3.38	1.2

2.31 ^{210}**Po-**^{210}**Pb profiles**

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2.31.1   **Objectives**

^{210}Pb ($T_{1/2}$ = 22.3 years) and its daughter ^{210}Po ($T_{1/2}$ = 138.4 days) are natural particle reactive radioisotopes that can be used as tracers of particle cycling in the upper ocean. Both radioisotopes have a strong affinity for particles, but whereas ^{210}Pb is only adsorbed on particle surfaces, ^{210}Po is also incorporated into the cytoplasm of some phytoplankton and bacteria. Its partitioning is similar to that of protein and sulphur within the cell. These differences result in ^{210}Po being more efficiently removed from surface waters than ^{210}Pb via sinking particles. Hence, disequilibrium between the two radionuclides occurs when biological activity is high. The degree of disequilibrium between ^{210}Pb and ^{210}Po and the dynamics of association to particles can be used to asses scavenging rates, export fluxes and remineralisation rates. POC contents measured in sinking particles will be used to convert ^{210}Po fluxes into POC fluxes. Those results are complementary to the export fluxes that are obtained from the disequilibrium between ^{234}Th and ^{238}U.

^{210}Pb-^{210}Po disequilibrium has different characteristics than that of the pair ^{234}Th-^{238}U. ^{234}Th is attached to the surface of the particles, whereas ^{210}Po it is incorporated into organic matter. Thus, it is expected that ^{210}Po-^{210}Pb disequilibrium allows us to more accurately estimate POC fluxes (albeit over a longer time scale). Furthermore, the different half-lives of ^{234}Th (24 days) and ^{210}Po (138.4 days) allows us to compare timescales ranging from several days to several months. Recent modelling efforts further suggest that ^{210}Po-^{210}Pb disequilibria can be used to estimate bulk sinking velocities of sinking particles.

2.31.2   **Sampling methodology and sampling treatment on board**

Samples for ^{210}Po and ^{210}Pb analysis were collected from 20-L Niskin bottles mounted on a stainless steel CTD rosette. 5L water samples were collected from 10 depths between 5-1000 m: 5, 10, 50, 75, 100, 150, 250, 350, 500 and 1000 m. On two occasions (CTD002 and CTD013), we were not able to sample from 5 m depth; we used water from the underway sampling system instead. Uncertainties on the measurements were estimated by taking triplicate samples from 250 and 500 m. Four blanks were prepared by treating 1000 mL MilliQ the same as a sample (note that final pH was >8.5).

Samples were immediately acidified (10 mL HNO$_3$) and vigorously shaken. The spikes of 200 μL ^{209}Po and 200 μL Pb^{2+} as yield tracers, and 4 mL Fe^{3+} as carrier were added, and the samples were, again, vigorously shaken. 11.5-14 mL of NH$_4$OH was added to neutralize the solution (to a final pH of 8.5). The solution was mixed and the pH checked. Samples were allowed to precipitate and settle for at least 24 h.

After settling, as much supernatant as possible was removed by carefully siphoning. The precipitate was transferred into 1 L HDPE bottles and left to settle for another 24 h. Again, the supernatant was carefully siphoned off, and the precipitate transferred into 250 mL HDPE bottles. Carboys/bottles were rinsed with pH adjusted MilliQ water (180 μL 25% NH$_4$OH in 1 L MilliQ water).

The radiochemical analysis of these samples will be carried out at the Universidad de Sevilla.

Table 2.53: Details of ^{210}Po-^{210}Pb sampling

Date	Station	Cast	Lat	Long	GMT
15/11/2017	P3A	CTD002	52 42.533 S	40 05.313 W	17:35
21/11/2017	P3A	CTD010			
25/11/2017	P2	CTD013	56 38.00 S	40 54.94 W	13:51
02/12/2017	P3B	CTD020	52 41.738 S	40 15.146 W	21:45
12/12/2017	P3C	CTD030	52 45.36 S	40 24.70 W	
15/12/2017*	P3C	CTD033	52 42.108 S	39 56.981 W	08:35

*Triplicates for blanks from 250 and 500 m depth, only.

2.32   Zooplankton and micronekton

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2.32.1   Overview

A series of depth discrete net sampling operations were carried out in order to address the objectives of COMICS to derive a mechanistic understanding of the key processes in, and overall function of, the mesopelagic community. Towards this aim, we obtained samples to allow us to describe vertical profiles in the taxonomic composition, biomass and abundance of the pelagic community through epipelagic and mesopelagic depth layers. To define the respective roles of these organisms, and the structure of the pelagic community, a subset of specimens were rapidly frozen in order to determine the metabolic performance and trophic interactions through measurement of Electron Transport System (ETS) activity, Elemental (CHN) analysis, Stable Isotope analysis and Biomarker analysis. Furthermore, live specimens were incubated to establish rates and selectivities of feeding and their utilisation of storage reserves. This work compliments accompanying acoustic surveys that provide a mesoscale perspective on the distribution of pelagic biomass, as well as its diel vertical migration behaviour (see Section 2.9).

Net sampling device overview

Our overall strategy was to sample a range of size classes of the pelagic community with different sampling devices, which comprised a Bongo net (100 μm mesh, 53 cm diameter rings), Hydrobios Mammoth Net (300 μm mesh, 1 m^2 square opening), a Multiple Open-Closing Net and Environmental Sampling System (MOCNESS) net (330 μm mesh, 1 m^2 rectangular opening) and an RMT 25 midwater trawl (minimum of 4 mm mesh, 25 m^2 rectangular opening). The Bongo net was deployed vertically and was effective at capturing mesozooplankton, including microcopepods such as *Oithona* and *Ctenocalanus*. The Mammoth net was also a vertical deployment that mainly captured mesozooplankton, especially calanoid copepods. The MOCNESS was deployed obliquely and has a greater capability of capturing fasting moving mesozooplakton and macrozooplankton species, such as euphausiids, fish larvae and chaetognaths. The RMT25 was most effective at capturing macrozooplankton and micronekton, particularly euphausiids (including Antarctic krill), salps, chaetognaths, and mesopelagic fish, particularly myctophids and *Bathylagus* spp. Notes on the deployment protocols of each of these devices is provided in later sections.

Sampling strategy overview

The main aims in deploying these devices were to obtain a depth discrete view of how the pelagic community was distributed through the epipelagic and mesopelagic layers, and to establish how these vertical distributions changed between day and night. All deployments were carried out within the top 500 m of the water column, consistent with the maximum depth of the majority of particle trap deployments carried out as part of COMICS I.

   Each of the devices had different capabilities in depth resolution. The Bongo net was capable of opening and closing its two cod ends between 2 respective set depths. Although there were some variations, the most common pattern was to carry out two sequential deployments, with one opening at 150 m and closing at 5m, and the other opening at 500 m and closing at 150 m. The Mammoth net has 9 nets that open and close sequentially. These opening/closing preset depths were consistent across all deployments and divided the sampled water column into intervals of 62.5 m, except the surfacemost 2 nets, which were in app. 30 m intervals. The MOCNESS net also has 9 nets, but must be deployed with the first net open, so providing a depth integrated haul between the

surface and the maximum depth. The remaining nets were opened in sequence as the net is hauled in, dividing the water column in 62.5 m intervals. The RMT25 has 2 nets which can be opened and closed independently of each other. Throughout COMICS I, the first net was opened at 500 m and closed at 250 m and the second net opened at 250 m and closed at app. 5 m.

All of the nets were deployed both day and night. It is to be noted however that the duration between day and night deployments was not always consistent, with intervals ranging between 4 and 12 hrs.

Overview of performance of devices

The performance of each of the devices is recorded in the subsequent tables. To summarise:

RMT25 – all deployments were mechanically successful, although the capture large jellyfish to potentially reduce the sampling efficiency of certain catches.

MOCNESS – earlier catches suffered from mechanical issues, meaning that that the first visit to P3 (P3a) did not obtain a full set of depth discrete samples either day or night. These issues had been resolved in subsequent visits and full depth discrete sets were obtained day and night for P3b and P3c

Mammoth – apart from the first deployment which did not fire, all subsequent deployments were mechanically successful and day and night sample sets were obtained for P3a, P3b and P3c. However, an issue with twisting of nets may have limited overall sampling efficiency and the condition of specimens (see Section 9).

Bongo – although the majority of deployments performed as expected, a number did suffer from incomplete or inaccurate rotation of the cod-end opening and closing devices. These failures have been noted in subsequent tables

Fate of the catch overview

RMT 25 catches were analysed immediately to determine taxonomic composition, abundance and wet weights. The catches from all other devices were preserved for subsequent analysis in the home laboratory.

Preservation - 4% Formaldehyde, buffered with sodium tetraborate (Borax) was used to preserve

1. the entire contents of one of the two Bongo cod-ends.
2. 1/2 of the contents of each of the Mammoth nets.
3. 1/2 of the contents of each of the MOCNESS nets. The 1/2 split of the Mammoth net catches was carried out using a Folsom splitter. For the MOCNESS net catches, the 1/2 split was achieved by dividing the contents of a graduated bucket, thoroughly mixing the contents before division.

Freezing - Sub-samples of specimens from all devices were frozen for a number of further biochemical analyses from all of the 4 sampling devices.

1. ETS activity:
   - Large mesozooplankton, macrozoopankton and nekton specimens were rapidly frozen in liquid N_2 from RMT25 and MOCNESS catches.
   - Mammoth catches were split with the Folsom splitter to a suitable amount of material and filtered onto a GFF filter before subsequent freezing at -80°C
   - Bongo catches were size fractionated and then filtered onto a GFF filter before subsequent freezing at -80°C.
2. Elemental and Stable Isotope Analysis:
   - Macrozoopankton and nekton specimens were extracted from RMT25 and MOCNESS catches and frozen at -80°C.
   - Calanoid copepods (mainly Rhicalanus gigas, Calanoides acutus, Metridia spp) were extracted from Mammoth and MOCNESS catches and placed onto petri dishes for subsequent freezing at -80°C

3. Biomarker analysis:
   - Macrozoopankton and nekton specimens were extracted from RMT25 and MOC-NESS catches and frozen at -80°C.
   - Calanoid and harpacticoid copepods and other mesozooplankton were extracted from MOCNESS, Mammoth and Bongo catches and placed in glass vials for freezing at -80°C.

Detailed reports on each of the sampling activities and process work now follow.

2.32.2   Bongo protocols and deployments

The Bongo net was deployed from the aft starboard using the NMF winch (850 m max wire) and starboard aft crane, which held the block. The BONGO was stored in a horizontal position and was moved gradually to the vertical during hauling in by the winch, taking in the entire length of tensioned compensation wire during the process. Once upright and clear of the deck, the net was moved outboard by the crane and the wire paid out to start the deployment (see Section 2.32.9 for a more detailed description of deployment protocols).

The net was equipped with pre-programmable open/closing cod ends. These were connected to a laptop running Oceanlab software with a RS232 cable. The cable was connected between every deployment in order to upload new instructions regarding open closing depths for the subsequent deployment. Tables 2.54 and 2.55 give a full list of deployments and the fate of the samples, respectively.

Table 2.54: Bongo net deployments during DY086

Event	Station	Deployment	Date	Time	Lat	Lon	Depth sampled
27	P3A	Bongo001	16/11/2017	06:35:00	-52.69	-40.125	*
28	P3A	Bongo002	16/11/2017	07:12:00	-52.69	-40.125	(1) 147 to 9
64	x	Bongo003	18/11/2017	06:16:00	-52.6983	-40.17	(1) 347 to 148 & (2) 148 to surface
65	P3A	Bongo004	18/11/2017	08:09:00	-52.6983	-40.17	(1) 147 to 9
89	P3A	Bongo005	20/11/2017	12:52:00	-52.7492	-40.1993	(1) 149 to 9
135	P2A	Bongo006	25/11/2017	09:21:00	-56.6333	-40.9167	*
136	P2A	Bongo007	25/11/2017	10:02:00	-56.6333	-40.9167	(1) 147 to 3
147	P2A	Bongo008	25/11/2017	19:20:00	-56.6333	-40.9167	(1) 498 to 148 & (2) 148 to surface
148	P2A	Bongo009	25/11/2017	20:29:00	-56.6333	-40.9167	(1) 148 to 5
174	P3B	Bongo010	30/11/2017	17:38:00	-52.705	-40.1017	No file recorded
189	P3B	Bongo011	01/12/2017	15:05:00	-52.705	-40.1017	(1) 148 to 3
190	P3B	Bongo012	01/12/2017	15:35:00	-52.705	-40.1017	(1) 498 to 148 & (2) 148 to surface
191	P3B	Bongo013	01/12/2017	16:32:00	-52.705	-40.1017	(1) 147 to 3
201	P3B	Bongo014	02/12/2017	03:03:00	-52.5933	-40.2983	(1) 148 to 3
202	P3B	Bongo015	02/12/2017	03:55:00	-52.5933	-40.2983	(1) 499 to 149 & (2) 149 to surface
219	P3B	Bongo016	03/12/2017	07:20:00	-52.7717	-40.0517	(1) 148 to 3
220	P3B	Bongo017	03/12/2017	07:41:00	-52.7717	-40.0517	(1) 498 to 149 & (2) 149 to surface
249	P3B	Bongo018	05/12/2017	02:20:00	-52.7207	-40.3262	(1) 147 to 4
250	P3B	Bongo019	05/12/2017	02:47:00	-52.7207	-40.3262	(1) 148 to 4
251	P3B	Bongo020	05/12/2017	03:15:00	-52.7217	-40.3267	(1) 497 to 148 & (2) 148 to surface
271	P3C	Bongo021	09/12/2017	12:05:00	-52.72	-40.3283	(1) 149 to 4
272	P3C	Bongo022	09/12/2017	12:40:00	-52.72	-40.3283	(1) 148 to 3
273	P3C	Bongo023	09/12/2017	13:35:00	-52.72	-40.3283	No file
276	P3C	Bongo024	09/12/2017	17:35:00	-52.7217	-40.3283	(1) 75 to 4
277	P3C	Bongo025	09/12/2017	18:05:00	-52.7217	-40.3283	(1) 149 to 74
278	P3C	Bongo026	09/12/2017	18:40:00	-52.7217	-40.3283	(1) 149 to 75
279	P3C	Bongo027	09/12/2017	19:16:00	-52.7217	-40.3283	(1) 249 to149
280	P3C	Bongo028	09/12/2017	20:05:00	-52.7217	-40.3283	(1) 498 to 249
321	P3C	Bongo029	12/12/2017	16:49:00	-52.6433	-40.2117	(1) 149 to 3
322	P3C	Bongo030	12/12/2017	17:12:00	-52.6433	-40.2117	(1) 498 to 148
323	P3C	Bongo031	12/12/2017	18:04:00	-52.6433	-40.2117	(1) 490 to 3

* Looks like it didn't fire according to log file

Table 2.55: Fate of Bongo Samples during Cruise DY086. Buckets A and B refer to respectively to the 2 buckets containing collected material in each catch. A and B may be interchanged between deployments

Event	Depth (m)	A	B	Box	Comment
27	400-150	Formaldehyde	Dispose		didn't open properly. Ignore
28	150-10	Formaldehyde	Experiments		
64	350-150	Formaldehyde	ETS (size-frac.; 47-mm GF/F)	3	Size fraction mesh: 2000, 1000, 500, 200, 100
65	150-5	Formaldehyde	Experiments		Net A went through 200 μm mesh; Net B was put into formaldehyde after picking experimental animals
89	150-5	Experiments	Experiments		
135	500-0	Formaldehyde	Experiments		Net didn't close properly so sample is from 500 m to surface
136	150-5	Formaldehyde	Experiments		
147	500-150	Formaldehyde	Experiments		Experimental side didn't close properly = 500-0 m (preserved as this); Other side preserved as 150-0
148	150-5	Formaldehyde	Experiments		Formaldehyde side = 200-0 m
174	150-5	Experiments	Experiments		
189	150-5	Formaldehyde	ETS (size-frac.; 47-mm GF/F)	3	Size fraction mesh: 2000, 1000, 500, 200, 100
190	500-150	Formaldehyde	ETS (size-frac.; 47-mm GF/F)	3	Size fraction mesh: 2000, 1000, 500, 200, 100
191	150-5	Experiments	Experiments		
201	150-5	Formaldehyde	ETS (size-frac.; 47-mm GF/F)	3	Size fraction mesh: 2000, 1000, 500, 200, 100
202	500-150	Formaldehyde	ETS (size-frac.; 47-mm GF/F)	3	Size fraction mesh: 2000, 1000, 500, 200, 100; *Bathylargus* frozen; box 6
219	150-5	Formaldehyde	ETS (size-frac.; 47-mm GF/F)	4	Size fraction mesh: 2000, 1000, 500, 200, 100
220	500-150	Formaldehyde	ETS (size-frac.; 47-mm GF/F)	4	Size fraction mesh: 2000, 1000, 500, 200, 100
249	150-5	Formaldehyde	ETS (size-frac.; 47-mm GF/F)	3	Size fraction mesh: 2000, 1000, 500, 200, 100
250	150-5	Experiments	Experiments		faecal pellets picked onto GF/F - box 6
251	500-150	Formaldehyde	ETS (size-frac.; 47-mm GF/F)	3	Size fraction mesh: 2000, 1000, 500, 200, 100; 100 μm sieve was dropped briefly half way through size fractionating
271	150-5	Experiments	Experiments		
272	150-5	Formaldehyde	Experiments		
273	?	?	?		This net never went over the side
276	75-5	Formaldehyde	ETS (not size fractionated)	3	
277	150-75	Experiments	Experiments		Nets didn't close properly so sample is from 150 m to surface
278	150-75	Formaldehyde	ETS (not size fractionated)	3	Preservation label reads EV277
279	250-150	Formaldehyde	ETS (not size fractionated)	3	
280	500-250	Formaldehyde	ETS (not size fractionated)	3	
321	150-5	Formaldehyde	ETS (size-frac.; 47-mm GF/F)	4	Size fraction mesh: 2000, 1000, 500, 200, 100
322	500-150	Formaldehyde	ETS (size-frac.; 47-mm GF/F)	4	Size fraction mesh: 2000, 1000, 500, 200, 100
323	50-5	Experiments	Experiments		

Table 2.56: Nominal opening/closing depths of Mammoth net

Net	Depth (m)
Wake	520
1	500-438
2	438-375
3	375-313
4	313-250
5	250-188
6	188-125
7	125-63
8	63-33
9	33-5

2.32.3 MAMMOTH protocols and deployments

The MAMMOTH was deployed from the mid-ships P-frame. The trawl warp was fed through the main winch, and two Rexwroth winches were used on the side wires. The trawl warp was inboard of the anti-pendulum roller attached to a swivel on the main net, whilst the two side wires for the cod-ends are out-board. The anti-pendulum roller is bent inwards to create a gap between the cod-ends and the main net body. Steady lines are used on both the cod-ends and the net frame to control the system going outboard. Once over the side, a third line is used to turn the net around so the safety bar can be disengaged prior to deployment.

Retrieval is the reverse. Care needs to be taken to stop the wires connecting the net frame to the cod-ends from becoming trapped in the door holes on the bulwark. The net was deployed to a depth of 600 m w/o, at a rate up to 0.3 m s^1 dependent on the swell. Initial speeds were 0.1 m s^1. In each case the wire out was slow such that the tension on the line remained above 0.2 tonnes at all times. The haul rate on retrieval was 0.2 m s^1.

The MAMMOTH was run in self-logging mode. The trigger depth for the instrument to turn on was 520m, and pre-programmed net depths are listed in Table 2.56.

Net Performance

The MAMMOTH net was deployed 7 times. On the very first occasion it was found not to have fired. Closer inspection identified that it had not switched on. The cause of this was chased down to the system requiring a dummy plug (rather than a blanked off cable to the main towing warp).

Requiring attention

1. New dummy plugs required, so at least one spare as they are required for both the MAM-MOTH and the opening/closing bongo.
2. The canvas holding the nets to the frame are looking frayed in places. They either need some TLC or replacing (also see Section 2.32.9).

2.32.4 The MOCNESS protocols and deployments

The MOCNESS (Multiple Opening and Closing Net and Environmental Sampling System) comprises of a suite of 9 nets, towed horizontally from the aft gantry. Deployment is on the fibre optic deep tow cable, with real-time communications controlling the opening and closing mechanism. This is the first trial of the fibre optic DWNM system. The FO termination, housed in an old battery housing, was placed with due care on the MOCNESS frame to ensure that the cable didn't twist too much. After each haul, the mechanical termination was re-seated if required to prevent undue stress on the termination (photo).

Table 2.57: Deployments of Mammoth net

Event	Site	Date	Time	Lat	Lon	Depth	Nets	Comment
110	P3A	21/11/2017	19:30:00	-52.7525	-40.2033	600 m	9	Net failed to trigger, identified that lack of blanking plug prevented firing
111	P3A	21/11/2017	23:15:00	-52.7525	-40.2033	600 m	9	Successful deployment
117	P3A	22/11/2017	15:54:00	-52.7517	-40.2033	600 m	9	Successful deployment
175	P3B	30/11/2017	18:34:00	-52.705	-40.1017	600 m	9	Successful deployment
181	P3B	30/11/2017	23:35:00	-52.705	-40.1033	600 m	9	Successful deployment
306	P3C	11/12/2017	03:18:00	-52.61	-40.1267	600 m	9	Successful deployment
316	P3C	11/12/2017	19:24:00	-52.7167	-40.2417	600 m	9	Successful deployment

MOCNESS deployment

- Ship speed to 2 knots.
- Trail cod-ends over the back end of the vessel.
- Steadying lines through the black stand brackets.
- Pick up frame by hauling on towing warp and/or moving gantry out.
- Lower MOCNESS into water with gantry at full(ish) extent.
- Deploy at 0.1 m s^1 until tension is consistently above 0.3 tonnes. Increase veering speed up to 0.3 m s^1 when possible.
- Recover at 0.2 m s^1 hauling speed.
- Slow ship to 1.5 knots
- Use hooks on poles/ropes to get MOCNESS under control when coming in.
- Place weight bar on stand and use steadying lines to bring MOCNESS towing end down onto deck.

Performance

The first two MOCNESS hauls were retrieved with nets still open (the 8th and 6th net, respectively), and it was not possible to recreate where the nets had opened and closed. Several trials indicated that the cable controlling the motor was working appropriately on deck. Looking through the DWNM file, the voltage was dropping each time the motor was fired, suggesting that the command to turn was received by the motor, it just wasn't necessarily undertaking it. DA took the motor apart to see whether the shaft was slipping, there was no evidence on the shaft that this was occurring (scoring from loose grub screws), although the grub screws were replaced to enable tightening more easily. Likewise, inside the motor housing there was no obvious loosening of parts. Once everything was put together, the shaft did not turn easily on triggering (this has been noticed prior to it being taken apart). A replacement disc covering the o-rings over the shaft could be the culprit, either rubbing on the shaft when incorrectly aligned, or shrinking due to temperature and/or pressure at depth. The motor was put together without over-tightening to give some looseness, and a test haul to 150 m (the temperature minimum layer) proved successful. A subsequent haul failed, but after that ? hauls were successful.

Table 2.58: Deployments of MOCNESS nets during DY086

Event	Start Date/time	End Date/time	Start Lat	Start Lon	End Lat	End Lon	Comments
25	16/11/2017 01:26	16/11/2017 03:28	-52.71	-40.1135	-52.7776	-40.1135	
95	20/11/2017 19:47	20/11/2017 22:11	-52.75	-40.2068	-52.774	-40.3418	
192	01/12/2017 17:53	01/12/2017 19:06	-52.7145	-40.0102	-52.762	-40.012	Test net
210	02/12/2017 17:06	02/12/2017 19:43	-52.6945	-40.2577	-52.6598	-40.3855	Net failed
217	03/12/2017 00:36	03/12/2017 03:10	-52.6906	-40.2688	-52.6536	-40.3977	
234	04/12/2017 12:51	04/12/2017 15:55	-52.6916	-40.3524	-52.7516	-40.4763	
305	10/12/2017 23:04	11/12/2017 01:51	-52.6616	-40.2499	-52.6126	-40.125	
315	11/12/2017 15:41	11/12/2017 18:25	-52.7193	-40.2485	-52.7462	-40.3963	

Table 2.59: Depth discrete details of MOCNESS deployments during DY086

Event	Net	Depth min (m)	Depth mean (m)	Depth max (m)	Temp min (°C)	Temp mean (°C)	Temp max (°C)	Flow (m² per haul)	Start Lat (°)	Start Lon (°)	End Lat (°)	End Lon (°)	Start date (GMT)	End date (GMT)
25	1	1.4	185.9786	505.5	0.83	1.7811	2.4	1947.5	-52.71	-40.1135	-52.748	-40.0909	16-Nov-2017 01:26:31	16-Nov-2017 02:34:47
25	2	400.7	456.4893	504.7	1.98	2.0142	2.05	327.2	-52.748	-40.0909	-52.7541	-40.0873	16-Nov-2017 02:34:47	16-Nov-2017 02:45:49
25	3	299.2	351.8136	400.9	1.91	1.9669	2.02	310.9	-52.7541	-40.0873	-52.7596	-40.084	16-Nov-2017 02:45:49	16-Nov-2017 02:56:15
25	4	250.9	275.2667	300	1.82	1.904	1.96	158.9	-52.7596	-40.084	-52.7623	-40.0824	16-Nov-2017 02:56:15	16-Nov-2017 03:01:20
25	5	200.7	225.286	251.5	1.42	1.6685	1.84	177.7	-52.7623	-40.0824	-52.7656	-40.0804	16-Nov-2017 03:01:20	16-Nov-2017 03:07:03
25	6	150.2	175.5531	201	0.77	1.0722	1.43	150.7	-52.7656	-40.0804	-52.7683	-40.0788	16-Nov-2017 03:07:03	16-Nov-2017 03:11:56
25	7	100.5	125.1425	150.2	0.78	0.9155	1.04	149.5	-52.7683	-40.0788	-52.771	-40.0772	16-Nov-2017 03:11:56	16-Nov-2017 03:16:35
25	8	50.8	75.3012	100.5	1.04	1.8596	2.43	218.6	-52.771	-40.0772	-52.7749	-40.0749	16-Nov-2017 03:16:35	16-Nov-2017 03:23:43
25	9	13.7	32.8793	51.1	2.39	2.3943	2.41	130.1	-52.7749	-40.0749	-52.7771	-40.0736	16-Nov-2017 03:23:43	16-Nov-2017 03:27:58
95	1	1.9	190.7973	501.8	0.79	1.8595	2.52	2267.8	-52.75	-40.2068	-52.7617	-40.2783	20-Nov-2017 19:47:23	20-Nov-2017 20:58:29
95	2	436.9	474.7792	501.8	1.79	1.8152	1.96	340	-52.7617	-40.2783	-52.7634	-40.287	20-Nov-2017 20:58:29	20-Nov-2017 21:08:23
95	3	374.7	405.6741	438	1.94	2.0483	2.09	276.2	-52.7634	-40.287	-52.7648	-40.2943	20-Nov-2017 21:08:23	20-Nov-2017 21:16:16
95	4	312.1	342.7523	375.5	1.99	2.0287	2.07	310.4	-52.7648	-40.2943	-52.7664	-40.3025	20-Nov-2017 21:16:16	20-Nov-2017 21:24:51
95	5	250.7	281.7362	312.7	1.79	1.8921	2.01	320.3	-52.7664	-40.3025	-52.7678	-40.3099	20-Nov-2017 21:24:51	20-Nov-2017 21:33:24
95	6	187.6	219.8474	250.9	0.98	1.5314	1.79	352.2	-52.7678	-40.3099	-52.7696	-40.319	20-Nov-2017 21:33:24	20-Nov-2017 21:42:44
95	7	124.7	162.7874	187.6	0.8	0.8985	1.05	365.9	-52.7696	-40.319	-52.7712	-40.3273	20-Nov-2017 21:42:44	20-Nov-2017 21:53:03
95	8	61.8	94.9952	125	0.92	1.3682	2.13	309.7	-52.7712	-40.3273	-52.7726	-40.3347	20-Nov-2017 21:53:03	20-Nov-2017 22:01:43
95	9	12.1	38.1015	62.4	2.08	2.4008	2.58	321.1	-52.7726	-40.3347	-52.774	-40.3418	20-Nov-2017 22:01:43	20-Nov-2017 22:10:38
192	1	1.4	81.5954	150.2	0.77	1.7556	3.33	1214.1	-52.7145	-40.0102	-52.7389	-40.0142	01-Dec-2017 17:53:02	01-Dec-2017 18:31:30
192	2	148.9	149.572	150.2	0.83	0.844	0.88	50.3	-52.7389	-40.0142	-52.7401	-40.0144	01-Dec-2017 18:31:30	01-Dec-2017 18:33:02
192	3	148.1	149.1484	150.2	0.83	0.8761	0.92	48.9	-52.7401	-40.0144	-52.7407	-40.0145	01-Dec-2017 18:33:02	01-Dec-2017 18:34:34
192	4	145.1	147.6927	150	0.83	0.8491	0.87	53.5	-52.7407	-40.0145	-52.742	-40.0146	01-Dec-2017 18:34:34	01-Dec-2017 18:36:09
192	5	142.7	143.7885	145.7	0.82	0.8469	0.88	58.2	-52.742	-40.0146	-52.7433	-40.0146	01-Dec-2017 18:36:09	01-Dec-2017 18:37:52
192	6	140.3	142.3711	143.5	0.85	0.8641	0.89	54.8	-52.7433	-40.0146	-52.744	-40.0146	01-Dec-2017 18:37:52	01-Dec-2017 18:39:28
192	7	134.4	137.733	141.4	0.78	0.8337	0.86	55.7	-52.744	-40.0146	-52.7454	-40.0145	01-Dec-2017 18:39:28	01-Dec-2017 18:41:07

Table 2.59: continued

Event	Net	Depth min (m)	Depth mean (m)	Depth max (m)	Temp min (°C)	Temp mean (°C)	Temp max (°C)	Flow (m² per haul)	Start Lat (°)	Start Lon (°)	End Lat (°)	End Lon (°)	Start date (GMT)	End date (GMT)
192	8	130.9	133.112	134.9	0.78	0.7874	0.79	63.4	-52.7454	-40.0145	-52.7461	-40.0144	01-Dec-2017 18:41:07	01-Dec-2017 18:42:54
192	9	130.6	131.2938	132.2	0.78	0.7911	0.81	57.8	-52.7461	-40.0144	-52.7481	-40.0142	01-Dec-2017 18:42:54	01-Dec-2017 18:44:30
210	1	2.2	210.9587	504.2	0.82	1.7263	3.46	2662.4	-52.6945	-40.2577	-52.6716	-40.3327	02-Dec-2017 17:06:16	02-Dec-2017 18:32:57
210	2	437.7	471.4049	502.3	1.92	1.9983	2.06	227.5	-52.6716	-40.3327	-52.6691	-40.3387	02-Dec-2017 18:32:57	02-Dec-2017 18:40:25
210	3	374.9	403.3089	438.5	1.85	1.9571	2.05	290.7	-52.6691	-40.3387	-52.6656	-40.3448	02-Dec-2017 18:40:25	02-Dec-2017 18:49:32
210	4	312.1	342.9393	374.9	1.7	1.79	1.87	229.5	-52.6656	-40.3448	-52.664	-40.3501	02-Dec-2017 18:49:32	02-Dec-2017 18:56:44
210	5	249.8	278.267	312.1	1.56	1.8069	1.92	487.7	-52.664	-40.3501	-52.6622	-40.3632	02-Dec-2017 18:56:44	02-Dec-2017 19:12:03
210	6	187.6	213.5874	250.4	0.93	1.3537	1.76	260.2	-52.6622	-40.3632	-52.6617	-40.37	02-Dec-2017 19:12:03	02-Dec-2017 19:20:38
210	7	125	160.6168	188.1	0.71	0.8036	0.93	248.6	-52.6617	-40.37	-52.6613	-40.3754	02-Dec-2017 19:20:38	02-Dec-2017 19:29:15
210	8	62.6	89.9244	125.2	0.84	1.6204	2.59	219.8	-52.6613	-40.3754	-52.6607	-40.3807	02-Dec-2017 19:29:15	02-Dec-2017 19:36:40
210	9	13.5	38.2577	62.9	2.55	2.9873	3.3	175.7	-52.6607	-40.3807	-52.6598	-40.3855	02-Dec-2017 19:36:40	02-Dec-2017 19:42:45
217	1	1.6	188.8098	502.1	0.79	1.8148	3.4	2542	-52.6906	-40.2688	-52.6706	-40.3397	03-Dec-2017 00:36:11	03-Dec-2017 02:01:37
217	2	436.9	472.1881	501.3	1.98	2.0311	2.07	229.4	-52.6706	-40.3397	-52.6687	-40.3465	03-Dec-2017 02:01:37	03-Dec-2017 02:09:00
217	3	375.5	404.1093	436.9	1.88	1.9652	2.02	280	-52.6687	-40.3465	-52.6668	-40.3531	03-Dec-2017 02:09:00	03-Dec-2017 02:17:25
217	4	312.1	344.1348	375.7	1.65	1.771	1.93	312.6	-52.6668	-40.3531	-52.6647	-40.3606	03-Dec-2017 02:17:25	03-Dec-2017 02:26:41
217	5	250.9	282.7444	312.9	1.55	1.7165	1.86	334.2	-52.6647	-40.3606	-52.6621	-40.3697	03-Dec-2017 02:26:41	03-Dec-2017 02:36:46
217	6	187.8	219.2783	251.5	0.95	1.2359	1.64	297.3	-52.6621	-40.3697	-52.66	-40.3771	03-Dec-2017 02:36:46	03-Dec-2017 02:45:54
217	7	124.7	156.7188	188.6	0.77	0.839	0.99	270.8	-52.66	-40.3771	-52.658	-40.3836	03-Dec-2017 02:45:54	03-Dec-2017 02:54:29
217	8	61.6	92.1421	125	0.79	1.4133	2.53	299	-52.658	-40.3836	-52.6557	-40.391	03-Dec-2017 02:54:29	03-Dec-2017 03:03:42
217	9	12.6	35.8204	61.8	2.53	2.8766	3.28	215	-52.6557	-40.391	-52.6539	-40.3968	03-Dec-2017 03:03:42	03-Dec-2017 03:10:14
234	1	0.8	212.5028	501.8	0.77	1.8622	3.38	3014.2	-52.6916	-40.3524	-52.7273	-40.4247	04-Dec-2017 12:51:22	04-Dec-2017 14:44:03
234	2	437.2	473.2979	501	2.04	2.0684	2.15	184	-52.7273	-40.4247	-52.7293	-40.4288	04-Dec-2017 14:44:03	04-Dec-2017 14:51:05
234	3	374.9	405.1855	438.2	2.08	2.1136	2.14	228.8	-52.7293	-40.4288	-52.7319	-40.4343	04-Dec-2017 14:51:05	04-Dec-2017 14:58:46
234	4	312.4	344.7518	376	1.93	2.02	2.12	248.7	-52.7319	-40.4343	-52.7342	-40.4392	04-Dec-2017 14:58:46	04-Dec-2017 15:06:53
234	5	249.8	280.9694	312.4	1.83	1.9022	1.95	249.9	-52.7342	-40.4392	-52.7376	-40.4464	04-Dec-2017 15:06:53	04-Dec-2017 15:15:19

Table 2.59: continued

Event	Net	Depth min (m)	Depth mean (m)	Depth max (m)	Temp min (°C)	Temp mean (°C)	Temp max (°C)	Flow (m² per haul)	Start Lat (°)	Start Lon (°)	End Lat (°)	End Lon (°)	Start date (GMT)	End date (GMT)
234	6	187	216.1842	249.8	1.38	1.5573	1.84	268.7	-52.7376	-40.4464	-52.7404	-40.4525	04-Dec-2017 15:15:19	04-Dec-2017 15:23:44
234	7	125.2	155.8976	188.1	0.81	1.0345	1.42	286.7	-52.7404	-40.4525	-52.7436	-40.4593	04-Dec-2017 15:23:44	04-Dec-2017 15:32:42
234	8	61.8	92.239	125.2	0.8	1.1176	1.91	328.2	-52.7436	-40.4593	-52.7468	-40.4662	04-Dec-2017 15:32:42	04-Dec-2017 15:42:46
234	9	13.7	38.6916	64.5	1.58	2.735	3.33	317.3	-52.7468	-40.4662	-52.7505	-40.4741	04-Dec-2017 15:42:46	04-Dec-2017 15:52:52
305	1	0.3	182.5051	501.8	0.82	2.0216	3.83	3025.4	-52.6616	-40.2499	-52.6345	-40.1867	10-Dec-2017 23:04:59	11-Dec-2017 00:38:21
305	2	436.9	471.1549	499.9	2.04	2.0783	2.12	273.1	-52.6345	-40.1867	-52.6325	-40.182	11-Dec-2017 00:38:21	11-Dec-2017 00:45:43
305	3	375.2	405.6255	437.7	2.01	2.0971	2.15	344.7	-52.6325	-40.182	-52.6299	-40.1759	11-Dec-2017 00:45:43	11-Dec-2017 00:54:12
305	4	299	336.9444	375.2	1.9	1.9913	2.05	424.9	-52.6299	-40.1759	-52.6267	-40.1682	11-Dec-2017 00:54:12	11-Dec-2017 01:04:35
305	5	249.8	274.3657	299	1.77	1.8803	1.93	281.5	-52.6267	-40.1682	-52.6245	-40.1633	11-Dec-2017 01:04:35	11-Dec-2017 01:11:19
305	6	187.6	218.7652	249.8	1.33	1.5375	1.77	376.1	-52.6245	-40.1633	-52.6218	-40.1569	11-Dec-2017 01:11:19	11-Dec-2017 01:20:16
305	7	125.2	155.381	187.6	0.8	0.9445	1.34	403.9	-52.6218	-40.1569	-52.6191	-40.1505	11-Dec-2017 01:20:16	11-Dec-2017 01:30:00
305	8	61.8	94.6886	125.2	0.81	1.5394	3.11	367.2	-52.6191	-40.1505	-52.6164	-40.1441	11-Dec-2017 01:30:00	11-Dec-2017 01:38:56
305	9	8.6	36.2131	61.8	3.11	3.411	3.79	437.6	-52.6164	-40.1441	-52.6134	-40.1369	11-Dec-2017 01:38:56	11-Dec-2017 01:49:28
315	1	0	190.1149	502.1	0.81	1.8823	3.68	3143.2	-52.7193	-40.2485	-52.738	-40.3314	11-Dec-2017 15:41:37	11-Dec-2017 17:10:24
315	2	436.6	467.1686	502.3	2.01	2.0265	2.07	475.9	-52.738	-40.3314	-52.7394	-40.3414	11-Dec-2017 17:10:24	11-Dec-2017 17:22:27
315	3	374.9	409.9951	438.5	2.02	2.0388	2.09	345.3	-52.7394	-40.3414	-52.7404	-40.3483	11-Dec-2017 17:22:27	11-Dec-2017 17:31:17
315	4	312.7	341.5953	374.9	1.96	2.0037	2.1	313.1	-52.7404	-40.3483	-52.7416	-40.3554	11-Dec-2017 17:31:17	11-Dec-2017 17:39:02
315	5	250.7	279.9046	313.7	1.84	1.9315	2	406.9	-52.7416	-40.3554	-52.743	-40.3642	11-Dec-2017 17:39:02	11-Dec-2017 17:48:48
315	6	187.3	218.5411	251.5	1.53	1.7591	1.9	328.7	-52.743	-40.3642	-52.7441	-40.3715	11-Dec-2017 17:48:48	11-Dec-2017 17:56:44
315	7	125	159.5327	187.6	0.79	1.1312	1.55	464.6	-52.7441	-40.3715	-52.7453	-40.3813	11-Dec-2017 17:56:44	11-Dec-2017 18:08:38
315	8	58.3	87.6853	125.2	0.79	1.3303	2.83	346.4	-52.7453	-40.3813	-52.7458	-40.3888	11-Dec-2017 18:08:38	11-Dec-2017 18:16:39
315	9	9.7	33.9125	58.3	2.82	3.2754	3.68	344.6	-52.7458	-40.3888	-52.7462	-40.3955	11-Dec-2017 18:16:39	11-Dec-2017 18:24:05

2.32.5 Rectangular Midwater Trawl 25 (RMT25) protocols and deployments

The RMT25 comprises of 2 nets, towed horizontally from the aft gantry. Deployment is on the fibre optic deep tow cable, with real-time communications controlling the opening and closing mechanism using the BAS Down Wire Net Monitor (DWNM). This is the first trial of the fibre optic DWNM system. The FO termination, housed in an old battery housing, was placed with due care on the RMT25 frame (photo) to ensure that the cable didn't twist too much.

Deployment on the Discovery was developed during a trial cruise in May 2017 (RMT on Discovery.pdf appendix), and this procedure was adopted during cruise DY086. Harnesses were used fixed to a 3m strop attached to eye bolts in the deck (1 eye bolt in from the side of the red square). An additional safety feature was that on retrieval of the net, a ratchet strap was used to secure the RMT25 from accidental re-deployment whilst the cod-ends were being retrieved.

RMT25 deployment

- Ship speed to 2 knots.
- Trail cod-ends over the back end of the vessel.
- Side wires hauled up to maximum extent without g-links going on to winches
- Pick up net by moving gantry out.
- With gantry out so the nets are vertical, lower side wires together (note Discovery gantry and side wires do not work at the same time!)
- Bring gantry in to switch over side wires to main towing warp
- Attach side wires to G-links on ropes in square
- Deploy at 0.1 m s^1 initially. Increase up to 0.3 m s^1 as required and possible to sink net

RMT25 recovery

- Ship speed to 1.5 knots
- Pull gantry with top towing bar is just above deck level (and rest of net below)
- Shackle over to side wires
- Put gantry out so net vertical, then haul in on both side wires at same time to raise net.
- Pull side wires up to maximum extent, put gantry in. Lower side wires if additional control need
- Ratchet strap stop the RMT nets (round the release straps) to prevent accidental redeployment
- Pull nets in using auxiliary deck winch and haul lines

Fibre optic termination

To test the DWNM with the test cable, use an attenuator with the fibre optic box. Also consider pulling the cables out slightly. The light is too bright, the system is optimised for the signal length of the towed cable (9000 m).

Table 2.60: RMT 25 deployment details during DY086

Event	Net	Depth min (m)	Depth mean (m)	Depth max (m)	Temp min (°C)	Temp mean (°C)	Temp max (°C)	Flow (m/haul)	Start lat	Start lon	End lat	End lon	Start date GMT	End date GMT
40	In water	0	0	0	0	0	0	0	-52.7279	-40.2282	-52.7279	-40.2282	16-Nov-2017 23:11:44	16-Nov-2017 23:11:44
40	1	40.6	45.7187	50	2.24	2.2477	2.26	59.9	-52.7297	-40.2365	-52.73	-40.2374	16-Nov-2017 23:20:49	16-Nov-2017 23:22:03
40	2	39	42.6137	46	2.25	2.2589	2.26	61.8	-52.7304	-40.2393	-52.7306	-40.2403	16-Nov-2017 23:24:12	16-Nov-2017 23:25:24
40	Out water	0	0	0	0	0	0	0	-52.7331	-40.2516	-52.7331	-40.2516	16-Nov-2017 23:36:31	16-Nov-2017 23:36:31
41	In water	0	0	0	0	0	0	0	-52.7381	-40.277	-52.7381	-40.277	17-Nov-2017 00:33:54	17-Nov-2017 00:33:54
41	1	249	372.9756	500.2	1.61	1.9672	2.08	2183.1	-52.7447	-40.3134	-52.755	-40.3533	17-Nov-2017 01:12:47	17-Nov-2017 01:55:34
41	2	16.7	137.9068	257.4	0.82	1.4949	2.38	2375.8	-52.755	-40.3533	-52.7652	-40.3898	17-Nov-2017 01:56:15	17-Nov-2017 02:36:25
41	Out water	0	0	0	0	0	0	0	-52.7657	-40.3915	-52.7657	-40.3915	17-Nov-2017 02:37:50	17-Nov-2017 02:37:50
57	In water	0	0	0	0	0	0	0	-52.6957	-40.1405	-52.6957	-40.1405	17-Nov-2017 17:27:01	17-Nov-2017 17:27:01
57	1	248	369.6347	501.5	1.55	1.9543	2.06	2158.2	-52.7138	-40.1703	-52.7321	-40.2009	17-Nov-2017 18:10:11	17-Nov-2017 18:52:12
57	2	18.3	126.3214	256	0.78	1.3882	2.48	3000.5	-52.7326	-40.2017	-52.7552	-40.2392	17-Nov-2017 18:53:03	17-Nov-2017 19:41:56
57	Out water	0	0	0	0	0	0	0	-52.7556	-40.2399	-52.7556	-40.2399	17-Nov-2017 19:43:14	17-Nov-2017 19:43:14
153	In water	0	0	0	0	0	0	0	-52.6872	-40.1429	-52.6872	-40.1429	29-Nov-2017 18:45:03	29-Nov-2017 18:45:03
153	1	250.1	380.9846	504.2	1.25	1.8694	2.06	1974.9	-52.676	-40.1843	-52.6676	-40.2156	29-Nov-2017 19:32:47	29-Nov-2017 20:12:26
153	2	18.3	128.2659	260.9	0.65	1.7457	2.9	2362.8	-52.6676	-40.2156	-52.658	-40.2511	29-Nov-2017 20:12:58	29-Nov-2017 20:57:12
153	Out water	0	0	0	0	0	0	0	-52.6576	-40.2526	-52.6576	-40.2526	29-Nov-2017 20:58:03	29-Nov-2017 20:58:03
162	In water	0	0	0	0	0	0	0	-52.6894	-40.1339	-52.6894	-40.1339	30-Nov-2017 01:41:16	30-Nov-2017 01:41:16
162	1	250.4	371.1747	501.3	1.27	1.8039	2.06	2286.7	-52.674	-40.1898	-52.6632	-40.228	30-Nov-2017 02:39:35	30-Nov-2017 03:20:05

Table 2.60: continued

Event	Net	Depth min (m)	Depth mean (m)	Depth max (m)	Temp min (°C)	Temp mean (°C)	Temp max (°C)	Flow (m/haul)	Start lat	Start lon	End lat	End lon	Start date GMT	End date GMT
162	2	19.4	149.5086	262.2	0.76	1.5014	3.02	2502.2	-52.6632	-40.228	-52.6518	-40.2647	30-Nov-2017 03:20:38	30-Nov-2017 04:02:51
162	Out water	0	0	0	0	0	0	0	-52.651	-40.2663	-52.651	-40.2663	30-Nov-2017 04:03:35	30-Nov-2017 04:03:35
286	In water	0	0	0	0	0	0	0	-52.7466	-40.4726	-52.7466	-40.4726	10-Dec-2017 01:15:52	10-Dec-2017 01:15:52
286	1	249.8	370.0784	503.9	1.84	2.0042	2.09	2742.7	-52.7284	-40.4185	-52.7152	-40.3799	10-Dec-2017 02:14:03	10-Dec-2017 02:56:48
286	2	14.8	141.3632	259.8	0.84	1.7978	3.48	2751.1	-52.7152	-40.3799	-52.7019	-40.3415	10-Dec-2017 02:57:20	10-Dec-2017 03:40:09
286	Out water	0	0	0	0	0	0	0	-52.7016	-40.3406	-52.7016	-40.3406	10-Dec-2017 03:41:40	10-Dec-2017 03:41:40
295	In water	0	0	0	0	0	0	0	-52.6895	-40.3103	-52.6895	-40.3103	10-Dec-2017 15:31:44	10-Dec-2017 15:31:44
295	1	248.8	368.064	501.5	1.85	2.0012	2.1	2262.6	-52.6629	-40.2619	-52.6468	-40.2322	10-Dec-2017 16:30:21	10-Dec-2017 17:09:05
295	2	12.9	137.1752	259.8	0.81	1.8	3.66	2570.5	-52.6459	-40.2306	-52.6292	-40.2032	10-Dec-2017 17:10:22	10-Dec-2017 17:51:21
295	Out water	0	0	0	0	0	0	0	-52.6281	-40.202	-52.6281	-40.202	10-Dec-2017 17:52:32	10-Dec-2017 17:52:32

2.32.6   Samples catches of macro- and mesozooplankton communities and sub-sampling for stable isotopes and ETS

(G. Stowasser, A. Belcher, D. Mayor)

Gear

An RMT25 net was used to sample the mesopelagic fish, squid and macrozooplankton community during the survey. Depth-discrete samples were collected across three time stations (P3 A, B, C) between 0-500 m at intervals of 500-250 and 250-10 m. At each time station one RMT25 haul was deployed in the hours of darkness and one in daylight, with 6 deployments being undertaken overall. The RMT25 was operated via a downwire net monitor and was equipped with a flow meter, and temperature and salinity sensors. Each depth strata was sampled for approximately 40 mins.

The mesozooplankton community was sampled using a MOCNESS net that was equipped with nine 330 μm mesh nets. This net was deployed to 500 m and sampled the water column at 8 depth-discrete intervals of 62.5 m, with net 1 remaining open throughout deployment. The MOCNESS was deployed during daylight and night-time hours, with each depth strata being sampled for around 10-12 minutes.

The copepod community was sampled deploying a MAMMOTH net equipped with nine 300 μm mesh nets. This net was deployed to 500 m (daylight and hours of darkness) and sampled the water column at 9 depth discrete intervals of 62.5 m (nets 1-7), with the top 62.5 m being split into two further depth horizons (nets 8-9: 62.5-32 m and 32–10 m).

Sample processing

The total weight of each RMT25 net haul was recorded. All fish, squid and macrozooplankton specimens were first identified to species level, where possible, and the composite weight and numbers per species recorded. Specimens were then either frozen for stable isotope and lipid analysis at -80°C or flash-frozen in liquid nitrogen for ETS. Numbers sampled from RMT25 catches for each type of biochemical analysis are listed in Table.

Of the MOCNESS catches one half aliquot of each net was retained in formalin for future biomass analysis. For stable isotope and lipid analysis samples were taken from the remaining aliquot from every 2nd net (depth strata: Net 3: 437.5-375 m; Net 5: 312.5-250 m; Net 7: 187.5-125 m; Net 9: 62.5-10 m) overlapping with depth strata sampled from the RMT25. The remainder of nets were sampled for ETS (Table).

MAMMOTH catches were split into two aliquots for each net, with one half being retained in formalin and the other half being either processed for ETS or stable isotope and lipid analysis (Table).

Macrozooplankton and fish catches

A total of 6 RMT25 hauls were obtained at the 3 time stations sampled. In total 777 fish were caught belonging to at least 23 species (Table), with catches dominated by the myctophids *Krefftichthys anderssoni*, *Gymnoscopelus braueri*, *Electrona antarctica* and *Protomyctophum tenesoni*. The water column below 250 m was dominated by *Bathylagus spp*. Predominantly temperate myctophid species, such as *Protomyctophum parallelum* and *Protomyctophum andreyeshevi* were also caught in small numbers.

In deeper waters (250-500 m) the macrozooplankton component of the RMT25 net catches was mostly dominated by jellyfish of the genera *Atolla* and *Periphylla*. The tunicate *Salpa thompsoni* and the euphausiids *Euphausia triacantha* and *Thysanoessa spp.* were also relatively abundant. Jellyfish still dominated catches in shallower waters (250-10 m), closely followed by euphausiids and *Salpa thompsoni*. Chaetognaths were also abundant in this layer. *Themisto gaudichaudii* and *Parandania boecki* were the most numerous amphipod species caught. While amphipods showed a similar distribution in deep and shallow waters, decapods were only caught in deeper waters.

Stable isotope analysis

The use of stable isotopes as dietary tracers is based on the principle that isotopic concentrations of consumer diets can be related to those of consumer tissues in a predictable fashion. It has been extensively applied in the investigation of trophic relationships in various marine ecosystems and has been used to determine feeding migrations in numerous species. The stepwise enrichment of both carbon and nitrogen in a predator relative to its prey suggests that the predator will reflect the isotopic composition in the prey and isotope values can be used to identify the trophic position of species in the food web investigated. Additionally $\delta 13C$ values can successfully be used to identify carbon pathways and sources of primary productivity.

The objective in this study is to identify the trophic position of the dominant species in the mesopelagic layer and improve our understanding of the energy transfer between specific depth horizons. To this purpose we sampled both fish and zooplankton from discrete depth horizons. In order to establish an isotopic baseline for the depth horizons where zooplankton and fish samples originated from corresponding particulate organic matter (POM) was collected. POM samples were obtained through filtering waters collected by Niskin bottles deployed via a CTD rosette. Water was taken from various depths at each station (Table). All water samples collected from Niskin bottles were processed on-board. Depending on the density of particles varying volumes of seawater per depth were filtered onto 47mm GF/F filters and the filters stored frozen at -80°C. Also opportunistic samples of concentrated POM were collected from PELAGRA traps on two deployments.

Table 2.61: Macrozooplankton species sampled and preserved for stable isotope analysis from RMT25 hauls during cruise DY086

Species	Event	Net	Numbers sampled	Depth	Time
Atolla spp.	41	1	10	500-250m	night
	41	2	10	250-10m	night
	57	1	10	500-250m	day
	286	1	9	500-250m	night
Calycopsis borchgrevinki	41	2	10	250-10m	night
	57	2	10	250-10m	day
	286	2	6	250-10m	night
	295	1	7	500-250m	day
	295	2	5	250-10m	day
Cephalopoda paralarvae	295	1	10	500-250m	day
	295	1	3	500-250m	day
Cephalopoda spp.	153	1	1	500m-250m	day
	286	1	3	500-250m	night
Chaetognatha spp.	295	2	10	250-10m	day
	41	2	10	250-10m	night
	57	1	10	500-250m	day
	57	2	10	250-10m	day
	153	1	3	500m-250m	day
	41	1	10	500-250m	night
Clio pyramidata	41	2	10	250-10m	night
Coronatae spp.	295	1	3	500-250m	day
Cyphocaris richardii	41	1	10	500-250m	night
	41	2	10	250-10m	night
	57	1	10	500-250m	day
	286	1	20	500-250m	night

Table 2.61: continued

Species	Event	Net	Numbers sampled	Depth	Time
Diphyes spp.	41	2	10	250-10m	night
Euphausia frigida	41	2	10	250-10m	night
	57	1	10	500-250m	day
	57	2	10	250-10m	day
	286	1	10	500-250m	night
	286	2	10	250-10m	night
Euphausia superba	41	1	8	500-250m	night
	41	2	10	250-10m	night
	57	2	10	250-10m	day
	286	1	3	500-250m	night
Euphausia triacantha	41	1	10	500-250m	night
	41	2	10	250-10m	night
	57	1	10	500-250m	day
	57	2	10	250-10m	day
	286	1	20	500-250m	night
	286	2	10	250-10m	night
	295	1	10	500-250m	day
	295	2	30	250-10m	day
Euphausia vallentini	57	2	10	250-10m	day
	286	2	5	250-10m	night
	295	1	10	500-250m	day
Galiteuthis glacialis	41	2	10	250-10m	night
	57	1	2	500-250m	day
	57	2	1	250-10m	day
	153	1	1	500m-250m	day
	153	2	1	250-10m	day
	162	1	2	500-250m	night
Gigantocypris muelleri	41	1	10	500-250m	night
	57	1	10	500-250m	day
	286	1	4	500-250m	night
Histioteuthis spp.	41	1	1	500-250m	night
Parandania boecki	41	2	10	250-10m	night
	57	1	10	500-250m	day
	286	1	5	500-250m	night
	286	2	5	250-10m	night
	295	1	4	500-250m	day
Pasiphaea spp.	41	1	7	500-250m	night
Periphylla periphylla	41	1	6	500-250m	night
	41	2	10	250-10m	night
	286	1	4	500-250m	night
	286	2	2	250-10m	night
Peryphilidae spp.	295	1	3	500-250m	day
Salpa thompsoni	41	1	20	500-250m	night
	41	2	10	250-10m	night
	57	1	20	500-250m	day
	57	2	20	250-10m	day

Table 2.61: continued

Species	Event	Net	Numbers sampled	Depth	Time
	153	1	20	500m-250m	day
	162	1	10	500-250m	night
	286	2	10	250-10m	night
	295	1	10	500-250m	day
	295	2	8	250-10m	day
Salpa thompsoni aggregate	153	2	20	250-10m	day
Sergia sp.	57	1	10	500-250m	day
Siphonophores	295	1	10	500-250m	day
	41	1	1	500-250m	night
	41	2	10	250-10m	night
	57	1	1	500-250m	day
	57	2	3	250-10m	day
Slosarczykovia circumantarctica	162	2	2	250-10m	night
	286	2	2	250-10m	night
	295	1	1	500-250m	day
	286	2	15	250-10m	night
	162	1	2	500-250m	night
	41	2	10	250-10m	night
	57	2	10	250-10m	day
Themisto gaudichaudii	286	1	20	500-250m	night
	286	2	10	250-10m	night
	295	1	13	500-250m	day
	295	2	10	250-10m	day
	41	2	10	250-10m	night
	57	1	10	500-250m	day
	57	2	10	250-10m	day
Thysanoessa spp.	153	2	10	250-10m	day
	286	1	20	500-250m	night
	286	2	10	250-10m	night
	295	1	10	500-250m	day
	295	2	40	250-10m	day
	41	2	10	250-10m	night
	57	2	10	250-10m	day
Tomopteris spp.	286	2	7	250-10m	night
	295	1	10	500-250m	day
	295	2	3	250-10m	day

Table 2.62: Macrozooplankton and fish species sampled and preserved for ETS and lipid analysis from RMT25 hauls during cruise DY086. # lists the number of individuals samples for the respective sample.

Species	Event	Net	# ETS	# Lipids	Depth	Time
Acanthephyra spp.	57	1		4	500-250m	Day
	57	1		10	500-250m	day
Atolla spp.	153	1	4		500m-250m	day
	162	1	8		500-250m	night

Table 2.62: continued

Species	Event	Net	# ETS	# Lipids	Depth	Time
Bathylagus spp.	153	1	10		500m-250m	day
	153	2	1		250-10m	day
	162	1	10		500-250m	night
	162	2	5		250-10m	night
	286	1	5		500-250m	night
	286	2	5		250-10m	night
Calycopsis borchgrevinki	57	1		2	500-250m	day
	57	2		10	250-10m	day
cf *Eurythenes* spp.	286	1		3	500-250m	night
	295	2		1	250-10m	day
	286	2		1	250-10m	night
Chaetognatha spp.	153	1	9		500m-250m	day
	153	2	20	10	250-10m	day
	162	1	10	10	500-250m	night
	295	2		10	250-10m	day
Coronatae spp.	162	1	9		500-250m	night
Cyphocaris richardii	57	1		10	500-250m	day
	153	1	10	10	500m-250m	Day
	163	1	10	10	500-250m	Night
	162	2	17		250-10m	Night
	286	1	10	4	500-250m	Night
	286	2		1	250-10m	Night
	295	1	5		500-250m	Day
Electrona antarctica	153	1	11		500m-250m	day
	153	2	4		250-10m	day
	162	1	5		500-250m	night
	162	2	10		250-10m	night
	286	1	5		500-250m	night
	286	2	5		250-10m	night
	295	1	2		500-250m	day
Electrona carlsbergi	153	2	3		250-10m	day
	162	2	2		250-10m	night
Electrona spp.	295	1	4		500-250m	day
Euphausia frigida	57	1		10	500-250m	day
	57	2		10	250-10m	day
	153	1		10	500m-250m	day
	286	1	10	10	500-250m	night
	286	2		10	250-10m	night
Euphausia superba	57	2		10	250-10m	day
	153	1	9		500m-250m	day
	153	2	14	5	250-10m	day
	162	1	10		500-250m	night
	162	2	15		250-10m	night
	286	1	5		500-250m	night
	286	2	5		250-10m	night
	295	2		5	250-10m	day

Table 2.62: continued

Species	Event	Net	# ETS	# Lipids	Depth	Time
Euphausia triacantha	57	1		10	500-250m	day
	57	2		10	250-10m	day
	153	1	10	10	500m-250m	day
	153	2	30	10	250-10m	day
	162	1	10	10	500-250m	night
	162	2	30		250-10m	night
	286	1	20		500-250m	night
	286	2	30	10	250-10m	night
	295	1	30	10	500-250m	day
	295	2	30	10	250-10m	day
Euphausia vallentini	57	2		10	250-10m	day
	286	2		5	250-10m	night
	295	1	10		500-250m	day
Gigantocypris muelleri	57	1		10	500-250m	day
	153	1	10		500m-250m	day
	286	1		4	500-250m	night
	295	1	10		500-250m	day
	295	2		1	250-10m	day
Gymnoscopelus braueri	153	1	8		500m-250m	day
	162	1	6		500-250m	night
	162	2	3		250-10m	night
	286	1	5		500-250m	night
	286	2	10		250-10m	night
	295	1	1		500-250m	day
Gymnoscopelus fraseri	153	1	2		500m-250m	day
	153	2	3		250-10m	Day
	162	2	5		250-10m	Night
	286	2	5		250-10m	Night
	295	1	3		500-250m	Day
Gymnoscopelus nicholsi	286	2	1		250-10m	Night
Gymnoscopelus spp.	295	1	1		500-250m	Day
Hyperia macrocephala	153	2		2	250-10m	Day
Hyperia spp.	153	1		1	500m-250m	day
	162	1		2	500-250m	night
	286	1		3	500-250m	night
	295	2		4	250-10m	day
Krefftichthys anderssoni	153	1	15		500m-250m	day
	162	1	1		500-250m	night
	162	2	6		250-10m	night
	286	1	10		500-250m	night
	286	2	2		250-10m	night
	295	1	10		500-250m	day
Parandania boecki	57	1		10	500-250m	day
	153	1	10	10	500m-250m	day
	162	1	7		500-250m	night
	162	2	20		250-10m	night

Table 2.62: continued

Species	Event	Net	# ETS	# Lipids	Depth	Time
	286	1	10		500-250m	night
	286	2	10	5	250-10m	night
	295	1	10		500-250m	day
	295	2		1	250-10m	day
Pasiphaea spp.	286	1		6	500-250m	night
Pegohyperia spp.	162	1		1	500-250m	night
	153	1		1	500m-250m	day
Periphylidae spp.	153	1	5		500m-250m	day
Periphylla periphylla	153	1	6		500m-250m	day
	162	1	10		500-250m	night
Primno macropa	153	1		2	500m-250m	day
	162	1		1	500-250m	night
	286	1		1	500-250m	night
	295	1		3	500-250m	day
	295	2		1	250-10m	day
Protomyctophum andreyeshevi	295	2	2		250-10m	day
Protomyctophum bolini	153	1	1		500m-250m	day
	153	2	1		250-10m	day
	162	1	12		500-250m	night
	162	2	4		250-10m	night
	286	1	1		500-250m	night
	295	2	2		250-10m	day
Protomyctophum choriodon	153	1	3		500m-250m	day
	162	2	2		250-10m	night
	286	1	2		500-250m	night
	286	2	2		250-10m	night
Protomyctophum gemmatum	286	2	2		250-10m	night
Protomyctophum spp.	153	1	1		500m-250m	day
	153	2	4		250-10m	day
	162	1	7		500-250m	night
	162	2	2		250-10m	Night
Protomyctophum tenisoni	153	2	2		250-10m	day
	162	1	4		500-250m	night
	162	2	6		250-10m	night
	295	2	2		250-10m	day
Sagitta maxima	57	1		6	500-250m	day
	57	2		10	250-10m	day
	295	1	10		500-250m	day
Salpa thompsoni	57	1		10	500-250m	day
	57	2		10	250-10m	day
	153	1	20		500m-250m	day
	153	2	30		250-10m	day
	153	2	2		250-10m	day
	162	1	10		500-250m	night
	162	2	30		250-10m	night
	286	2	10	10	250-10m	night

Table 2.62: continued

Species	Event	Net	# ETS	# Lipids	Depth	Time
	295	1	10		500-250m	day
	295	2	10		250-10m	day
Sergia spp.	153	1	7		500m-250m	day
	286	2		1	250-10m	night
Siphonophores yellow	295	1		10	500-250m	day
Themisto gaudichaudii	57	2		10	250-10m	day
	153	1	10	10	500m-250m	day
	153	2	10		250-10m	day
	162	1	10		500-250m	night
	162	2	30		250-10m	night
	286	1	30	20	500-250m	night
	286	2	10	10	250-10m	night
	295	1	10	13	500-250m	day
	295	2	10	4	250-10m	day
Thysanoessa spp.	57	1		10	500-250m	day
	57	2		10	250-10m	day
	153	1	10	11	500m-250m	day
	153	2	30		250-10m	day
	162	1	10		500-250m	night
	162	2	30		250-10m	night
	286	1	20	20	500-250m	night
	286	2	10	10	250-10m	night
	295	1	30	10	500-250m	day
	295	2	30	20	250-10m	day
Tomopteris spp.	57	2		5	250-10m	day
	295	1	10	10	500-250m	day
	295	2		2	250-10m	day

Table 2.63: Macrozooplankton species sampled and preserved for ETS and stable isotope analysis from MOCNESS hauls during cruise DY086.

Species	Event	Net (Depth range in m and planned analysis)							
		2	3	4	5	6	7	8	9
		500 -437.5	437.5 -375	375 -312.5	312.5 -250	250 -187.5	187.5 -125	125 -62.5	62.5 62.5-10
		ETS	SI	ETS	SI	ETS	SI	ETS	SI
Aetidae	217	10							
Chaetognatha spp.	217		15		15				
Clio pyramidata	217								1
Euphausia frigida	217								20
Euphausia superba	217								2
Euphausia triacantha	217		1	3	2	1	10	6	3
Fish larvae	217								6
Limacina spp.	217								5
Parandania boecki	217					2			
Paraeuchaeta spp.	217	5	6	3			6	8	

Table 2.63: continued

Species	Event	Net							
		2	3	4	5	6	7	8	9
Rhincalanus gigas	217	15		15	20	15	20	15	17
Sagitta maxima	217				2				
Themisto gaudichaudii	217				4		6	15	
Thysanoessa spp.	217		3	1	11	17	20	17	20
Chaetognatha spp.	234		15	14	15	15	14	13	11
Cyllopus Lucasi	234			4		1		1	
Euphausia triacantha	234		2	6	6	6	1		
Fish larvae	234						1		28
Limacina spp.	234						4		
Parandania boecki	234	1		1					
Paraeuchaeta spp.	234	3		7		2		2	
Primno macropa	234	2		4					
Rhincalanus gigas	234	18	20	20	20	20	20	20	20
Salpa thompsoni	234	1	2			5			
Spongiobranchia spp.	234		3						
Themisto gaudichaudii	234	1				1		15	20
Thysanoessa spp.	234		3	2	2	2			6
Thysanoessa furcilla	234							20	
Calanoides acutus	305		30		30		30		30
Chaetognatha spp.	305	15	10	15	10	15	10	15	
Clione spp.	305								2
Cyllopus spp.	305				4				2
Cyphocaris richardii	305				1				
Euphausia frigida	305								10
Euphausia triacantha	305				1	9	5	4	1
Fish larvae	305						1		7
Paraeuchaeta spp.	305	2	2			1		4	
Parandania boecki	305				1	2			
Primno macropa	305		2		3	2			1
Rhincalanus gigas	305	15	20	15	20	20	20	15	20
Sagitta maxima	305		2						
Salpa thompsoni	305								10
Scaphocalanus sp.	305		2						
Themisto gaudichaudii	305						2	6	15
Thysanoessa spp.	305			2	8	15	15	15	10
Tomopteris spp.	305								1
Bibilia	315	2							
Calanoides acutus	315		30		30		30		30
Cephalopod paralarvae	315				3				1
Chaetognatha spp.	315	15	10	15	10	15	10		10
Cyphocaris richardii	315					1			
Euphausia triacantha	315				8	4			
Fish larvae	315								4

Table 2.63: continued

Species	Event	Net							
		2	3	4	5	6	7	8	9
Paraeuchaeta spp.	315	6	4	1	5	14			
Parandania boecki	315		1	1					
Primno macropa	315			7	5		3	3	7
Rhincalanus gigas	315	15	20	15	20	15	20	15	20
Scaphocalanus sp.	315				7		13		
Spongiobranchia	315		2						1
Themisto gaudichaudii	315					1		4	15
Thysanoessa spp.	315	1	1	1	3			13	10
Tomopteris spp.	315		1		2				

Table 2.64: Mesozooplankton sampled and preserved for ETS and stable isotope analysis from MAMMOTH hauls during cruise DY086

Event	Date	Time	Net	Depth range	ETS split	Biomass Split	Stable Isotope	Notes
110	21/11/2017	Day						Didn't fire
111	21/11/2017	Night	1	500-438	1/2	1/2		
			2	438-375	1/2	1/2		
			3	375-313	1/2	1/2		
			4	313-250	1/2	1/2		
			5	250-188	2 x 1/4	1/2		
			6	188-125	4 x 1/8	1/2		
			7	125-63	4 x 1/8	1/2		
			8	63-33	4 x 1/16	1/2		Phytoplankton in sample
			9	33-5	4 x 1/16	1/2		A lot of phytoplankton in sample
117	22/11/2017	Day	1	500-438	1/2	1/2		
			2	438-375	1/2	1/2		Sample bag split open in liquid N2, so in contact with foil
			3	375-313	1/2	1/2		
			4	313-250	1/2	1/2		
			5	250-188	2 x 1/4	1/2		
			6	188-125	2 x 1/4	1/2		
			7	125-63	4 x 1/8	1/2	1/4 < and > 500 μm size fractionated catch	
			8	63-33	4 x 1/16	1/2	1/4 < and > 500 μm size fractionated catch	Some phytoplankton in sample
			9	33-5	2 x 1/4	1/2		Some phytoplankton in sample
174	30/11/2017	Day	1			1/2	CA	20-30 specimens per species for si across all nets in Ev. 174 and 181
			2			1/2	CA	
			3			1/2	CA, PC, RG	
			4			1/2	PL	
			5			1/2	CA, ME, PL, RG	
			6			1/2	CA, ME, RG	
			7			1/2	CA, ME	
			8			1/2	CA	
			9			1/2	CA	

Table 2.64: continued

Event	Date	Time	Net	Depth range	ETS split	Biomass Split	Stable Isotope	Notes
181	30/11/2017	Night	1			1/2	ME	
			2			1/2	RG	
			3			1/2	RG, PL	
			4			1/2	RG	
			5			1/2	RG	
			6			1/2	RG	
			7			1/2	CA, ME, PL	
			8			1/2	CA, ME, RG	
			9			1/2	CA	
306	10/12/2017	Night	1	500-438	1/2	1/2		
			2	438-375	1/2	1/2		
			3	375-313	1/4	1/2		
			4	313-250	1/4	1/2		
			5	250-188	1/2	1/2		
			6	188-125	1/4	1/2		
			7	125-63	1/8	1/2		
			8	63-33	1/4	1/2		
			9	33-5	1/8	1/2		
316	11/12/2017	Day	1	500-438	1/2	1/2		
			2	438-375	1/4	1/2		
			3	375-313	1/8	1/2		
			4	313-250	1/8	1/2		
			5	250-188	1/8	1/2		
			6	188-125	1/8	1/2		
			7	125-63	1/8	1/2		
			8	63-33	1/8	1/2		
			9	33-5	2/32	1/2		

Table 2.65: Summary of fish species and numbers caught by RMT25 during DY086

Species	N
Bathylagus spp.	110
Benthalbella macropinna	1
Benthalbella sp.	1
Borostomias antarcticus	15
Electrona antarctica	91
Electrona carlsbergi	20
Electrona spp.	10
Fish larvae unident.	4
Gymnoscopelus braueri	129
Gymnoscopelus fraseri	36
Gymnoscopelus nicholsi	7
Gymnoscopelus opisthopterus	1
Gymnoscopelus piabilis	1
Gymnoscopelus spp.	3
Icefish larvae	29
Krefftichthys anderssoni	110
Lampanyctus achirus	1
Nansenia antarctica	3
Notolepis coatsi	3
Paradiplospinus gracialis	1
Protomyctophum andreyeshevi	7
Protomyctophum bolini	44
Protomyctophum choriodon	15
Protomyctophum gemmatum	6
Protomyctophum luciferum	1
Protomyctophum parallelum	5
Protomyctophum spp.	60
Protomyctophum tenisoni	57
Stomias sp.	5
Teleostei	1

Table 2.66: POM samples collected for stable isotope analysis on DY086

Station	Event	Sample depth (m)	Lat	Long	Comment
P3A	CTD7 Ev72	5, 25, Chl$_{max}$ (51), 75, 125, 200, 450, 750	-52.698	-40.168	CTD
P3B	CTD22 Ev230	Chl$_{max}$ (63), 75, 125, 200, 450, 750	-52.688	-40.344	CTD
P3B	CTD23 Ev252	5, 25,	-52.722	-40.327	CTD
P3C	CTD30 Ev318	5, Chl$_{max}$ (25), 50, 75, 125, 200, 450, 750	-52. 454	- 40 247	CTD
P3B	157	P7 - 500 m	-52.608	-40.332	PELAGRA sample, 50 mL filtered
P3B	158	P9 - 250 m	-52.594	-40.291	PELAGRA sample, 50 mL filtered
P3B	159	P6 - 150 m	-52.631	-40.31	PELAGRA sample, 50 mL filtered
P3B	165	P4 - 100 m	-52.75	-40.125	PELAGRA sample, 50 mL filtered
P3B	261	P9 - 250 m	-52.416	-40.344	PELAGRA sample, 50 mL filtered
P3C	301	P9 - 250 m	-52.389	-40.231	PELAGRA sample, 50 mL filtered
P3C	302	P6 - 160 m	-52.395	-40.218	PELAGRA sample, 50 mL filtered
P3C	304	P2 - 90 m	-52.402	-40.207	PELAGRA sample, 50 mL filtered

Table 2.67: Bongo nets sampled for ETS activity, each sample was size-fractionated (>2000, >1000, >500, >200, >100 μm) and dried onto 47-mm GF/F filters under gentle vacuum and stored frozen (-80°C). *Not size fractionated due to small sample size

Event	Date	Depth range (m)
64	18/11/2017	350-150
189	01/12/2017	150-5
190	01/12/2017	500-150
201	02/12/2017	150-5
202	02/12/2017	500-150
219	03/12/2017	150-5
220	03/12/2017	500-150
249	05/12/2017	150-5
251	05/12/2017	500-150
276*	09/12/2017	75-5
278*	09/12/2017	150-75
279*	09/12/2017	250-150
280*	09/12/2017	500-250
321	12/12/2017	150-5
322	12/12/2017	500-150

2.32.7 ETS Measurements for respiration

(A. Belcher, K. Cook and D. Mayor)

Zooplankton and micronekton samples were collected for estimation of respiration (RO2) via electron transfer system (ETS) activity. The ETS activity is the capacity of a living system to consume oxygen (or other electron acceptors), so can be thought of as the potential respiration (Φ) in the presence of surplus reactants (Owens & King, 1975; Packard & Christensen, 2004). To cover the size spectrum of zooplankton and micro nekton species samples for ETS activity were taken from Bongo (100 μm), MAMMOTH (300 μm), MOCNESS (330 μm) and RMT25 (4000 μm) nets.

The contents of individual Bongo nets (Tables 2.54 and 2.55) were size fractionated (>2000, >1000, >500, >200, >100 μm). Each size fraction was dried on 47-mm GF/F filters under gentle vacuum and stored frozen (-80°C) within 20 minutes of sample collection. The sister Bongo net was preserved in borax-buffered formaldehyde (3.7 %) for taxonomic analysis.

The contents of each of the MAMMOTH nets were split (folsom splitter) and half of each sample was dried onto a 47-mm GF/F filter under gentle vacuum without size fractionation and stored frozen (-80°C) within 30 minutes of sample collection (Table 2.67). The remaining half of each MAMMOTH net was preserved in borax-buffered formaldehyde (3.7 %) for taxonomic analysis.

For macrozooplankton and micronekton, replicate individuals of the main species present in the RMT25 and MOCNESS nets were picked and flash frozen in liquid nitrogen in cryovials or sample bags. Where necessary, individuals were first rinsed with filtered seawater to remove contaminating phytoplankton cells. Weights of all samples taken from the RMT25 were taken before freezing to include in total catch biomass estimates. Once frozen samples were transferred to a -80°C freezer. All samples were frozen within 1.5-hrs of the nets coming on board. Measurements of ETS activity in frozen samples will be made in the lab and respiration calculated using literature derived ratios of RO_2 to Φ.

Table 2.68: MAMMOTH nets sampled for ETS activity. The listed proportion (volume) of each net was dried onto a GF/F filter under gentle vacuum and stored frozen at -80°C.

Event	Date	Net	Proportion of net
111	21/11/2017	1	0.5
111	21/11/2017	2	0.5
111	21/11/2017	3	0.5
111	21/11/2017	4	0.5
111	21/11/2017	5	0.25
111	21/11/2017	6	0.25
111	21/11/2017	7	0.125
111	21/11/2017	8	0.0625
111	21/11/2017	9	0.0625
117	22/11/2017	1	0.5
117	22/11/2017	2	0.5
117	22/11/2017	3	0.5
117	22/11/2017	4	0.5
117	22/11/2017	5	0.25
117	22/11/2017	6	0.25
117	22/11/2017	7	0.125
117	22/11/2017	8	0.0625
117	22/11/2017	9	0.25
306	11/12/2017	1	0.5
306	11/12/2017	2	0.5
306	11/12/2017	3	0.25
306	11/12/2017	4	0.25
306	11/12/2017	5	0.5
306	11/12/2017	6	0.25
306	11/12/2017	7	0.125
306	11/12/2017	8	0.25
306	11/12/2017	9	0.125
316	12/12/2017	1	0.2
316	12/12/2017	2	0.2
316	12/12/2017	3	0.25
316	12/12/2017	4	0.125
316	12/12/2017	5	0.125
316	12/12/2017	6	0.125
316	12/12/2017	7	0.125
316	12/12/2017	8	0.125
316	12/12/2017	9	0.03125

References

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Packard, T. T., & Christensen, J. P. (2004). Respiration and vertical carbon Flux in the Gulf of Maine water column. Journal or Marine Research, 62, 93–115

2.32.8 Copepod grazing and physiology

(D. Mayor, K. Cook)

Rationale

Zooplankton are the vector through which energy and nutrition are passed from phytoplankton to higher trophic levels, including fish, birds and mammals. Their community activities play an important role in regulating the strength of the biological carbon pump (BCP) by concurrently (a) fragmenting large organic particles, (b) repackaging small organic particles, (c) producing dense and relatively fast-sinking faecal pellets, (d) remineralising organic matter, and (e) directly transporting matter to depth via vertical migration. Their effects on the BCP can therefore act in both shallow and deeper waters, and may occur both actively and passively.

The daily pattern of vertical migration typically includes ascending into surface waters to feed at night and returning to deeper, darker waters during the day time to avoid visual predation. Grazing on living phytoplankton at the surface provides zooplankton with access to food that is rich in labile substrates and micronutrients, such as omega-3 polyunsaturated fatty acids (PUFAs), which are essential for healthy growth and reproduction (Anderson & Pond, 2000). Feeding on detritus at depth may also occur, but this material typically consists of refractory substrates and is largely devoid of nutrition (Mayor et al., 2014). Fragmentation of detritus may stimulate the production of nutrient compounds by heterotrophic microbes (Mayor et al., 2014) but any nutritional gains must be balanced against the associated energetic losses (Anderson et al., 2017) and the increased risk of detection by their predators.

We have previously hypothesised that migrating zooplankton ingest sufficient material in the surface at night to sustain them at depth during the day, thereby negating the need to feed at depth (Giering et al., 2014). However, this hypothesis was derived solely on the basis of zooplankton carbon demands, rather than their requirements for nutrient compounds such as omega-3 PUFAs. Boreal species of copepods of the genus Calanus have elevated basal turnover rates of omega-3 PUFAs, relative to other, non-essential fatty acids, suggesting that the supply of these compounds may set an important constraint on daily feeding activities. We are unaware of any data on the basal rates at which fatty acids turn over in Southern Ocean species of zooplankton, and thus their influence on their patterns of feeding.

Experiments were conducted to quantify copepod grazing rates in surface waters and to determine the basal rates at which individual fatty acids turn over in the biomass-dominant species of copepod, *Calanoides acutus*. Additional samples were collected from all netting activities for biomarker analysis to better understand the structure of the mesopelagic zooplankton and nekton communities.

Hypotheses

H1: Zooplankton grazing in the surface ocean during the night is sufficient to meet their daily demands for carbon and omega-3 PUFAs.

H2: Zooplankton turnover rates of omega-3 fatty acids are high relative to other fatty acids.

Methods

All experimental work was undertaken in the Controlled Environmental Laboratory at the in situ temperature (2°C) and all of the experimental equipment was pre-soaked (>24 hrs) in seawater prior to its first use.

Experimental animals were collected with a motion-compensated bongo net (100 μm mesh) using a non-filtering cod end (Table 2.56) and were subsequently sorted under dim light using a dissection microscope. Experimental water was collected via the CTD or using a dedicated cast of the Marine Snow Catcher (Table 2.69) and was immediately transferred into HDPE carboys using wide-bore silicone tubing. Copepod grazing rates were examined using particle-removal experiments (Mayor et al., 2006). In brief, glass incubation bottles were filled with un-screened seawater a little at a time to maximise homogeneity. Visibly discernible copepods were removed from the incubation water via a dip-tube prior to the addition of experimental animals. Experimental animals were carefully introduced into triplicate bottles and incubated alongside triplicate control bottles in the dark on a plankton wheel rotating at 1 rmp for 24 hr. Microplankton samples (200 mL) from each of the incubated bottles were collected and preserved with acidified Lugol's iodine (1%).

Experiments to determine the basal rates at which carbon, nitrogen and fatty acids turnover in *Calanoides acutus* were conducted using a previously established methodology (Mayor et al., 2011). In brief, replicate groups of 5 *C. acutus* (CV) were transferred into sterile-filtered (0.2 μm) seawater and incubated in 500 mL HDPE bottles for up to 15 days. Triplicate bottles were sacrificed at the start of the experiment and every 72 hrs thereafter. Incubated animals were retrieved by gently pouring each bottle onto a 63 μm mesh filter, checked for signs of life, and transferred into 1 mL glass vials or tin cups for fatty acid or elemental analysis, respectively. Samples of zooplankton and nekton for biomarker analysis were picked from individual nets, either directly or using a dissection microscope, and stored frozen. All frozen material was stored at -80 °C

Table 2.69: Copepod grazing experiments conducted with *Oithona similis*, *Ctenocalanus* sp., *Rhincalanus gigas*, *Calanoides acutus* and *Metridia lucens*. *Vol.* is the incubation volume (in L), and depth is the depth from which water was collected (in m).

No.	Net	Net Event	Species	Stage	No. animals	Vol.	Water collection	Water Event	Depth	Start date	End date
1	Bongo	28	*O. similis*	CV-CVI	20	0.2	CTD (#23)	42	20	17/11/2017	18/11/2017
2	Bongo	28	*O. similis*	CV-CVI	20	0.2	CTD (#12)	42	350	17/11/2017	18/11/2017
3	Bongo	65	*C. acutus*	CIV-CV	5	1.1	Snowcatcher	67	30	18/11/2017	19/11/2017
4	Bongo	65	*Ctenocalanus*	CV-CVI	20	1.1	Snowcatcher	67	30	18/11/2017	19/11/2017
5	Bongo	65	*R. gigas*	CVI	1	1.1	Snowcatcher	67	30	18/11/2017	19/11/2017
6	Bongo	65	*O. similis*	CIV-CVI	20	0.2	Snowcatcher	67	30	18/11/2017	19/11/2017
7	Bongo	89	*O. similis*	CIV-CVI	25	0.2	Snowcatcher	83	30	20/11/2017	21/11/2017
8	Bongo	89	*R. gigas*	CVI	1	1.1	Snowcatcher	83	30	20/11/2017	21/11/2017
9	Bongo	89	*C. acutus*	CV	5	1.1	Snowcatcher	83	30	20/11/2017	21/11/2017
10	Bongo	89	*O. similis*	CIV-CVI	20	0.2	CTD (#18)	108	31	21/11/2017	22/11/2017
11	Bongo	89	*O. similis*	CIV-CVI	20	0.2	CTD (#3)	108	504	21/11/2017	22/11/2017
12	Bongo	136	*O. similis*	CIII-CVI	20	0.2	Snowcatcher	138	30	25/11/2017	26/11/2017
13	Bongo	136	*O. similis*	CIII-CVI	20	0.2	Snowcatcher	139	350	25/11/2017	26/11/2017
14	Bongo	148	*R. gigas*	CVI	1	1.1	Snowcatcher	138	30	26/11/2017	27/11/2017
15	Bongo	148	*C. acutus*	CIV-CV	7	1.1	Snowcatcher	138	30	26/11/2017	27/11/2017
16	Bongo	173	*C. acutus*	CV	7	1.1	Snowcatcher	177	30	01/12/2017	02/12/2017
17	Bongo	173	*R. gigas*	CVI	1	1.1	Snowcatcher	177	30	01/12/2017	02/12/2017
18	Bongo	191	*O. similis*	CIII-CVI	20	0.2	Snowcatcher	221	30	03/12/2017	04/12/2017
19	MOCNESS	234 (#8)	*M. lucens*	CVI	8	1.1	Snowcatcher	243	30	04/12/2017	05/12/2017
20	Bongo	271	*R. gigas*	CVI	1	1.1	Snowcatcher	266	30	09/12/2017	09/12/2017
21	Bongo	271	*C. acutus*	CV	5	1.1	Snowcatcher	266	30	09/12/2017	09/12/2017
22	Bongo	271	*O. similis*	CV-CVI	20	0.2	Snowcatcher	266	30	10/12/2017	11/12/2017
23	Bongo	323	*C. acutus*	CV	5	1.1	Snowcatcher	324	75	12/12/2017	13/12/2017
24	Bongo	323	*C. acutus*	CV	2	1.1	Snowcatcher	324	75	12/12/2017	13/12/2017
25	Bongo	323	*O. similis*	CV-CVI	20	0.2	Snowcatcher	324	75	13/12/2017	14/12/2017
26	Bongo	323	*O. similis*	CII-CIV	30	0.2	Snowcatcher	324	75	13/12/2017	14/12/2017

Table 2.70: RMT25 tissue samples for biomarker analysis

Species / Event	41		57		153		162		295		286	
Net #	1	2	1	2	1	2	1	2	2	1	1	2
Thysanoessa sp.	x		x	x	x			x	x	x	x	x
Euphausia frigida		x	x	x	x						x	
Prymnomacropa				x	x		x		x	x	x	
Themisto gaudichaudii	x	x	x		x				x	x	x	x
Vibelia												
Chaetognatha			x	x		x	x	x	x	x		
Hyperia					x	x	x		x	x	x	
Salpa thompsoni	x	x	x	x				x				x
Euphausia triacantha	x	x	x	x	x	x	x	x	x	x		x
C. richardii	x	x	x	x	x		x				x	x
Euphausia superba		x	x			x			x			
T. macrura		x										
Tomopteris		x	x						x	x		
Parandania boecki		x	x	x	x				x			x
Calycopsis sp.			x	x								
Euphausia vallentini			x									
Atolla				x								
Genadus (decapod)				x								
Acanthaphyra (decapod)				x							x	
Gigantacypris				x					x		x	
Pegohyperia princeps					x		x					
Eurythenes sp.					x				x	x	x	x
Sergia										x		x
Siphonophore yellow										x		
Pasiphaea											x	

Table 2.71: MOCNESS frozen tissue samples for biomarker analysis.

Event / Net #	**217**								**234**								**315**								**305**							
Species	9	8	7	6	5	4	3	2	9	8	7	6	5	4	3	2	2	3	4	5	6	7	8	9	2	3	4	5	6	7	8	9
Rhincalanus gigas CVI	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x		x	x	x	x	
Calanoides acutus CV	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x
Metridia sp. CVI										x	x	x	x	x	x							x	x		x	x						
Pleuromama sp.				x								x	x	x	x		x	x	x	x	x				x	x		x	x	x	x	
Paraeuchaeta CVI			x			x							x		x		x	x	x	x	x	x			x	x		x	x			
Aedidae CVI								x					x	x	x	x	x	x	x	x					x	x		x				
Ostracods				x										X	x	x	x	x	x		x	x	x		x	x		x	x	x	x	
Candacia CVI																	x		x	x						x						
Calanus similimus CVI																	x		x						x						x	
Clione																		x														
Thysanoessa sp.																														x		x
Chaetagnatha											x			x				x		x		x				x		x				
Themisto gaudichaudii	x								x																							x
Euphausia triacantha																				x		x		x								
Mysid (*Sergia*?)																				x												
Euphausia valentini																				x												
Thysanoessa sp.			x																													
Euphausia frigida	x																			x												x
Prymnomacropa									x		x		x		x																	
Vibelia									x																							

2.32.9 Gear report

(D. Ashurst)

DWNM

- Issues arose at the start of the cruise when the box containing the BAS fibre optic connections required to connect the bottom of the deep-tow cable to the fibre optic converter could not be found. Without these connections – and without a fusion splicer to directly slice two ends of FO cable – the use of the DWNM system would not be possible. As this system controls both the RMT 25 and the MOCNESS nets, it was decided that an NMF engineer with fibre optic expertise would be flown down ASAP with the required equipment and connectors to fix the issue.
- Before the arrival of the NMF engineer, the box with the BAS FO connectors was found – this box had been stored separate from the rest of BAS's boxes and behind cargo not specific to the cruise. These bayonet connectors had been previously recommended to BAS from an NOC engineer. However, upon discussion with NMF engineers, it was mentioned that these particular types of connector may start to degrade in oil over time. It was decided that flying the NMF engineer to Stanley was still worthwhile as he had a fusion splicer to directly connect the FO cables without bayonet connectors.
- The NMF engineer arrived and upon investigation, informed us that, whilst the deep-tow cable used single-mode fibre optic, the cable potted into the converter board was multi-mode. This meant that fusion-splicing was not viable and the original plan of using bayonet connectors was used. Two of the three fibre optic cables in the deep-tow were terminated with bayonet connectors – the grey cable (fibre 3) and the black cable (fibre 4). The red cable (fibre 2) was blanked off. This gave us one spare connection, should we damage the first connection. Coms was established using Fibre 3. With this, the NMF engineer left and the ship set off towards its first destination at speed to make up lost time. Before leaving he provided a splicing kit and some spares for use on the cruise.
- The following day, when preparing the FO housing to be filled with oil, it was discovered that only one of the end caps had been fitted with o rings in Cambridge. To fit these, the FO cables and power cables were disconnected and reconnected once the o rings were in place.
- A subsequent test through the deep-tow cable failed to establish coms through Fibre 3 or Fibre 4. Inspecting the integrity of Fibre 3 showed that it had been damaged at the termination during fitting of the o rings. This was concerning as upmost care had been taken during this process and there had been no obvious knocks to the system to cause the damage. Fibre 4 appeared to be in tact although coms could still not be established.
- In parallel to this problem, a bench test through a short length of cable highlighted that a connection between the 4-pin bulk head connector and the FO converter board had come loose and would not reliably stay in place. Rather than risk the wiring working its way loose during deployment, the connector was cut off and replaced by the ship's electrical engineer. This fix proved reliable. From this it was shown that we could produce coms through all off the BAS kit, thus removing it as a possible source of failure.
- The on-board NMF engineer terminated Fibre 2. Despite inspection of the connection producing good results, coms could still not be established. He then re-terminated Fibre 3 and produced a connection with the least noise of all terminations so far produced. Tests of the DWNM through the deep-toe Fibre 3 finally produced coms.
- The current thinking is that, unless a really strong connection is made, the attenuation of the signal through the cable is too great for the converter boards. According to the Focal Manual, the attenuation budget for the converter boards is 20dB. Any more than this and it is suspected that the connection is not strong enough to properly communicate.

- After one attempt to insert the converter into the housing, which resulted in a loss of coms, a splint was attached to the input fibre optic wire to reduce the bend radii. This addition was successful and coms was maintained once the board was housed and once the housing was filled with oil.
- The housing was mounted to the RMT25 cross and successfully triggered the motor release. When attached to the MOCNESS, the triggering produced the three-burst motor turn required and released each net. Deployment of the RMT25 produced successful net releases. Deployment of the MOCNESS, while all nine actions were logged by the DWNM software, proved to only be partially successful. Releases 8 and 9 failed to trigger. Upon investigation, a possible cause could be that whilst the motor is triggering 3 bursts, the motor shaft may be slipping, or the torque of the motor not sufficient in certain positions.
- It has also been noticed that if either the flow meter or T&C sensors were disconnected, the software would fail to search for other sensors and eventually time-out, causing loss of coms. This is a concern as if one of the sensor cables becomes damaged during deployment, a loss of coms is probable.
- For future cruises it would be worth investing in FO terminating/splicing kits and training up AME mechs.

RMT25
Set up
Set up of the RMT25 was completed without much issue. A couple of notes:

- For ease of assembly it is easier to imagine the mouth of the net facing down to the deck as forward rather than facing up to the sky. It makes assembling the second net easier without the risk of bunching the first net up incorrectly.
- It is also worth noting that feeding the release bars through the nets was difficult enough with only five people. The next COMICS cruise will not have GT aboard. I don't think it is a great idea to only have four people to assemble the net so taking an additional person may be necessary.
- Some of the cord holding the foam in place around the release bars has broken. We made a make-shift repair but this will want to be properly looked at when the net returns to BAS
- One of the release cables has a couple of loose wires. It has been left on but with extra attention being paid to it before and after each deployment.
- The carabiners that link the side wires to the cross had lost their spring mechanism. As these were spliced in, the whole rope lengths were replaced. It may be worth double checking the splice as it was DA doing them.
- The G-links that are at the ends of the new side wires are different to previous deployments and seem more likely to disconnect from each other when not under tension.
- The FO converter housing for the DWNM system was attached to the cross using jubilee clips on the back of the frame with the bulk head connectors facing upward. The wire from the deep tow cable fed round and under the frame from the mechanical termination to the underside of the converter housing. This kept the cable out of the way of potential snagging points and gave it a large bend radius.

Deployment

- 4 persons needed in the square + 1 deck crew operating the side wires, 1 deck crew coordinating deployment and 1 winch driver. Persons in the square were harnessed to eye bolts on the deck. Originally the fixing points to the sides of the square were used however the required harness line lengths were too long to feel safe working at the roller
- Use the fibre optic deep tow wire through the aft gantry
- Ship speed to 2 knots thru the water.

- Trail cod-ends over the back end of the vessel. Ensure that first cod end is trailed as far as possible before deploying second cod end to reduce chance of tangling the nets. Check to see that cod ends are trailing correctly
- Side wires hauled up to maximum extent without g-links going on to winches
- Pick up net by moving gantry out.
- With gantry out so the nets are vertical, lower side wires together (note Discovery gantry and side wires do not work at the same time!)
- Bring gantry in to switch over side wires to main towing wire
- Attach side wires to G-links on ropes in square. Enough slack is needed on these lines to allow the gantry to fully extend out
- Deploy at 0.1 m s^{-1} initially. Increase up to 0.3 m $^{-1}$ as required and possible to sink net
- There is a lot more room for it to swing compared to aboard the JCR so extra care must be taken.

Recovery

- 4 persons needed in the square + 1 deck crew operating side wires, 1 deck crew coordinating recovery, 1 winch driver and 1 auxiliary winch operator
- Ship speed to 1.5 knots thru the water
- Pull gantry with top towing bar is just above deck level (and rest of net below)
- Shackle over to side wires
- Put gantry out so net vertical, then haul in on both side wires at same time to raise net. As with on the JCR, the side wires often get stuck in the top bar, probably due to the position of the auxiliary wires being wider that the top bar and so making the wires pull at an angle. A convincing stick is usually required to free these wires. GT is happy to oblige
- Pull side wires up to maximum extent, put gantry in. Lower side wires if additional control need
- The position of the weight bar on recovery also meant that a lot more of the net still in the water. This meant there was greater possibility of the weight bar being dragged back, even when placed on the deck. To prevent this, a ratchet strap was put round the release cables and fixed to the deck.
- Pull nets in using auxiliary deck winch and haul lines
- On recovery, the weight bar only comes in a couple of feet from the aft end. This doesn't leave a lot of room to bring the nets in, meaning people in the square have to get close to the edge – which is uncomfortable given the harness situation. This also makes it more awkward to re-erect (lol) the aft end fence.
- In rougher conditions, steady lines were attached to the towing bridles and fed around cleats either side on the bulwarks to try and steady the net from swinging too much.

On the last recovery, one of the nets was torn near the top end. This was repaired by the Scientific Boson. For future deployments the following is recommended:

- RMT25 assembly manual
- Spare parallel D shackles
- Spare G links
- Spare carabiners
- Updated SOP

MOCNESS
Set up

- Some brackets for sensors appeared to be missing when compared to photos of the previous season. It may be that they were distributed to a different container or simply not found in the boxes that we had.

Deployment

- Deployment of the MOCNESS was straight forward,
  - 5 people required for deployment. 2 persons in the square, 1 winch operator, 1 crew operating gantry and 1 crew coordinating the deployment.
  - Speed through the water 2 knots
  - Two long steady lines to guide the top frame until it was in the water prevented it from spinning.
  - Pick up frame by hauling in deep tow wire and bringing out gantry
  - Lower net into water with gantry fully out
  - Veer out at 0.1 m s^{-1} until tension is consistently above 0.3 tonnes. Increase to a max of 0.3 m s^{-1} when possible
  - Once at depth, fire first net and haul in at 0.2 m s^{-1}
- Recovery of the net was more problematic. As those in the square didn't feel confident leaning over the aft end with the harness arrangement, getting steady lines on the frame was more of an issue. This first deployment was in calm seas and yet the frame still swayed a fair amount. It is thought that the guideline maximum sea states for all our gear has to be reduced for deployments on the Discovery. Ship speed was 1.5 knots thru the water for recovery

Net performance

- The first deployment of the MOCNESS came back on deck with two of the nets (8 and 9) not triggered. It isn't known whether this was due to a coms issue, an issue with the motor cable or an issue with the motor shaft. Further investigation couldn't replicate the situation. Each trigger from the software produced three turns in the motor, however on one occasion two of the three motor actions could be heard but didn't rotate the release shaft. This could be what happened during deployment, though we can't be sure at what depths these issues occurred so are unable to be sure of what depth each net was sampling.
- Originally the MOCNESS was meant to be deployed to a depth of 1000 m and take stratified samples to the surface. This had to be altered to a depth of 500 m as the net was not creating enough tension on the wire to pay out at the normal rate for fear of the cable jumping off of the sheath. Extra weight may need to be added to the frame to make it sink faster.
- A couple of the new motor cables were faulty, producing random numbers of motor turns. This issue could be looked into by BAS electronic engineers.
- A second deployment resulted in nets 6 through 9 not firing. The motor and release keys were removed to investigate a possible cause. On inspection, it appeared that the motor may have been slipping somewhere along the shaft. Grub screws on the shaft coupling that had been incorrectly installed were removed and replaced by cap head screws to allow greater clamping force to prevent slip. There was still an issue. Upon opening the housing, nothing obvious was loose so we concluded that the slippage was happening inside the motor.
- The cause appears to be the new acetal o ring retainer that was made in the summer. At certain angles in the rotation the turning the shaft becomes increasingly difficult, which may be too much for the motor. We tested this theory by taking the retainer off completely and the rotation became considerably smoother.
- It may be that the acetal retainer contracts a lot more in the cold than the previous aluminium one, making it clamp down on the shaft. Other possibilities include the bore of the retainer being measured incorrectly. Or alternatively the motor shaft being bent ever so slightly during installation.
- A test run to 150 m depth – the temperature minimum – resulted in all nets firing correctly. This either shows that our previous adjustments have fixed the issue or that the issue may be caused by depth rather than temperature.
- A full depth deployment ended with no nets firing at all. When investigated, the release wire

for net 1 was especially taut and turning the motor by hand was a real struggle.

- With the next deployment, once the nets were cocked, the release shaft was positioned further round than the markers suggest so that rather than releasing on turn 2, the net released on turn 1. I imagine it is supposed to have two turns before releasing as a safety against misfire. However when the nets came back on deck they had all fired. The first successful deployment of the trip

Mammoth

- As the net was to originally be deployed on the deep tow cable, a suitable place for the FO converter housing needed to be found. The Mammoth wasn't using the coms down the cable as it was running autonomously. However the FO housing couldn't be removed from the deep tow cable without having to re-terminate, which is an ordeal. The mammoth was also being deployed vertically, which means that a swivel had to be attached between the deep tow cable and the towing bridles. All of this means that the FO housing would have to have been doubled back on itself and mounted directly to the deep tow cable. This was too much of a risk to other net deployments.

- The decision was made to deploy the mammoth over the starboard side using the P frame. This had the main coring cable to lift the mouth of the mammoth and two auxiliary Rexroth winches to guide the bottom carousel over the side wall.

  Deployment was as follows:
  - Remove the front plate to gain access to the motor unit coms connector
  - Plug laptop into the motor unit and pressure program as required.
  - Turn off the motor unit and disconnect from the laptop. Put a banking plug on the exposed connector. **NOTE! Use a proper blanking plug and not the extension lead normally used to connect the mammoth to the JCR biowire. On our first deployment we did this and none of the nets fired and no data log was saved. It turns out that even though the motor was not connected, having a wired connector in place made it think it was still connected and prevented the motor switching to OFFLINE mode, which is essential for this type of deployment.**
  - Once net cod ends are correctly fastened to the bottom carousel, the CTD manoeuvring crane is used to flip the mouth of the net to its correct, upward looking orientation.
  - From this position, the motor unit can be switched on, and then the net bars can be cocked. Once cocked, the net is dangerous. Ensure the safety catch is engaged and that people stay clear of the spring mechanism throughout deployment.
  - Haul in the Rexroth winches to raise the carousel off the deck, hauling in on the main wire to raise the mouth as required to reduce strain on the nets. Tag lines attached to the side wall are used to steady the carousel so that people are not standing between it and the net mouth. Tag lines to the mouth are fixed to eyes either side of the hangar door. In larger swells it is necessary to feed the line back through the eye to allow greater control of the net mouth.
  - Bring out the gantry so the carousel is over the side and pay out on the Rexroth winches till the tension is taken on the carousel wires. Take car that ropes and wires don't get caught in the gaps and notches on the side wall.
  - Once the Rexroth winches have enough slack, shackle over to link the green ropes tot the green ropes on the net mouth. A hooked pole may be needed to reach the side lines. Note: At this stage the net mouth will be just over the side wall and the carousel will be at least partially in the water. Ensure that the steady lines on the net mouth are taught to prevent it swinging into people as they shackle over. This is a particular concern in a swell.

- – Attach a third tag line to the net mouth to spin it 90 degrees. The safety bar can now be disengaged.
    - – Bring out the gantry and pay out to depth.
- As with the Bongo Open/Close net, a trigger depth, deeper than the first sampling depth has to be reached before any actions will take place. For a sampling depth of 500m to the surface, a trigger depth of 520 m was chosen and 600m of wire was paid out. The pre-programmed depths as are detailed in Table 2.56.
- Things to consider on recovery:
    - – The mammoth is on a swivel so may not be in the same orientation as when deployed. Make sure to rotate the net mouth until back in its start position.
    - – Before handling the release side of the net mouth, ensure that all the nets have fired. If not, keep hands free and try to put the safety catch back on.
    - – Get tag lines on to the net mouth as soon as safely possible and ensure they are taught to minimise movement. The net swings more on recovery than deployment, so it's important to keep control of it to minimise risk when shackling back over.
- Don't forget to turn off the motor unit. If there are any misfires, it is good to examine the data log to determine why any issues occurred.
- On one recovery it was noticed that the nets were wrapped around each other, preventing samples from making their way to the cod ends. Care needs to be taken when setting up the cod end frame

Open/Close Bongo
Set up

Assembly of the Bongo net was relatively straight forward, save for a few issues.

- There were no markings along the poles to indicate the position of the motion compensator unit or the cod end bracket. This meant that positioning of these components was through trial and error.
- Most of the Stauff clamps were heavily seized, making assembly and adjustments laborious. It would be preferable to recondition these clamps after each season
- The floats that had new clamps added to them had the clamps in the wrong position, making them unusable. Placement of these clamps needs to be measured more carefully next time
- We had no 5-mm swage press die to make the top end lifting eye. The ship had a 4-mm die that we managed to make do with
- The CV joints used to link the motor shafts had their bolt holes drilled off centre, meaning that the holes had to all be opened up to fit. More care is needed when drilling these holes out to ensure they are centred correctly.
- The new updated motor shafts work well, making tweaks to the ball valve position easy.
- The sealing of the cod end buckets was not a great idea – it meant that samples had to be deposited through the bottom release valve, which potentially damages the animals. It also meant that adjustments and maintenance to the ball valve were more difficult. O rings would be preferential to silicone sealant.

Programming

Setup of the open/close software and connecting to the motor unit initially had issues. A number of steps were taken, including using a USB to serial converter that had up-to-date drivers, updating the software to the most recent version and by running the installation to the software as Administrator. Each AME member that will be using the Open/Close Bongo should have the software installed and updated prior to the cruise and should each have a USB to serial converter with driver CD.

Programming is straight forward and described in the Hydrobios manual. Before sending trigger depths to the motor unit ensure that the valve is in the correct starting position and the

"bottle" number in the software is zeroed. A couple of deployments had erroneous valve firing. It is possible that the software was not zeroed correctly.

Deployment

Deployment of the bongo aboard the Discovery has differed from on the JCR. Rather than using the midship's gantry, an auxiliary NMF winch mounted to the aft deck was used in conjunction with one of the ships aft-end cranes. This was due to the fact that up to 20m of cable comes out of the motion compensation unit during deployment. This meant that if the midships gantry was used, the bongo swivel and 5mm wire would have been wound onto the ships winch, which had Kevlar rope on – the worry being that the steel rope would damage the Kevlar.

The bongo had to be stowed horizontally after each deployment as there was no obvious suitable place to strap it to, vertically. This lead to the worry that the cod ends – which couldn't be removed – had too much stress on them. These need to be supported. Ideally a stand would be made up that would achieve this.

Deployment was as follows:
- Persons required - 1 crew member operating the crane, 1 crew member assisting in manoeuvring the net, 1 NMF winch operator, 1 person conducting set up and deployment
- Ship on DP
- Switch motor unit on.
- Ensure cod end taps are closed
- With crane in line with Bongo wire, winch haul in to take up compensation unit slack. Ensure that the top end of the net is controlled by person to avoid damage
- Once slack is taken up, keep hauling with winch and guide bongo to upright position. This requires two people to help manoeuvre
- Raise bongo so legs can pass over the bulwark
- Swing crane out till net is over the side. Persons guide net as needed.
- Pay out on winch till the swivel hits water surface.
- Pay out on winch to depth. Veer rate is dependent on how much slack is in the cable. Approx. 0.1 m s^{-1} for the first 100 m up to a max of approx. 0.3 m s^{-1}
- Once at depth wait for a minute or two to allow the net to settle.

It's worth noting that the deployments had the valve mechanism activated by depth rather than time. This lead to the first deployment not triggering correctly as it didn't reach its initial trigger depth. The trigger depth had been 375 m and the winch had paid out 400 m, however upon looking through the logged data afterwards, the bongo only reached a depth of 365 m before being recovered. A similar occurrence happened with a 500 m deployment. Care must be taken to ensure that enough cable is paid out to reach the required depth.

Recovery
- Haul in at approx. 0.3 m s^{-1}
- When swivel breaches water surface slow haul rate
- Raise net so legs can pass over bulwark
- Bring crane in so net is suspended over deck
- Keep net in the air enough to be able to fit sample buckets under the cod ends. Hold the net whilst samples are taken. During this time, motor unit can be switched off.
- Veer out of winch till feet of net are on deck and net is standing vertically. The net can now be reprogrammed to another depth horizon if needed. It was usual to do two deployments in a row – a 150 m to surface sample first followed by a 500 m to 150 m sample.
- If all deployments are concluded, persons pull at legs and walk net frame into stowing position as winch operator veers on the cable. Ensure person is keeping top and of net under control.

The deck winch used for deployments did not have a cable speed read out, just a cable out read out. Therefore all speeds mentioned are approximations based on timing 10 m of cable.

Issues and Improvements

- The stainless CV joints that had been installed over the summer were replaced by the original cv joints that had a roll pin. This greatly reduced the play along the shaft and meant that one of the ball valves performed as it should. The other however still had a very minor error. This isn't enough to cause a major issue when in BONGO orientation, however this wouldn't seal correctly in the MUDL configuration and would ultimately leak. It is not immediately apparent why there is a difference between the two ball valves and needs investigating.
- The drive shafts of the motor have play relative to the ball valve. Upon inspection, it was found that the clearance holes for the bolts in the CV joints along the shaft are too large. Each one has a couple of degrees play. This has a cumulative effect along the drive shaft, resulting in the large deviation of the ball valve.
- During pre-deployment testing, the motor unit was not responding to ACTION commands. Despite the voltage read-out being normal, we changed the batteries. However that did not solve the problem. Upon investigation, it was discovered that the M2 bolts holding the internal motor had come loose and fallen out – one of which was heavily bent also. The bolts were re-installed, with the damaged one replaced. It is worth noting that the replaced bolt is a cross-head whereas the original bolts are slot-heads.
- It may be worth opening up the motor housing after each cruise/season to ensure the internals are not coming loose.

Several improvements could be made:

- Change the shape of the drive shaft from square, to a shape that would reduce play
- Change the mating hole material from soft plastic to steel. This would improve tolerancing
- Change the ball material to nylon to reduce friction – adapt a bought ball valve?
- Reduce the ball size to reduce require torque
- Replace the sealing O rings with a shaped nylon/ptfe seal. This would reduce friction and also remove the issue of o rings being pinched and the ball valve rotates, which greatly increases the torque
- Update the gears on the motor unit to reduce backlash
- Use pins or shaft keys instead of through bolts. I realise through bolts are easier to assemble with but they aren't the ideal solution

2.33 Deep-tow termination

Nick Rundle*
*(National Oceanography Centre)

2.33.1 Overview

The fibre optic Deep Tow System (DTS) is part of the ODIM ship-fitted scientific winch suite. The drum holds approximately 13,000 m of TYCO triple armoured cable supplied with 3 conducting cores and 3 armoured fibre optic cores. The standard mechanical termination for the system is an Evergrip termination, the core of the DTS is stripped back to a suitable length for termination through the gland of an oil fill pressure housing.

In early discussions with British Antarctic Survey (BAS) scientists and technicians the RRS Discovery DTS was identified for use with two of the BAS nets, the RMT, and the Mammoth, both of which require power and comms from the surface. Both BAS systems were designed to work with the RRS James Clark Ross (JCR) ship fitted coaxial winch system which carries approximately 4000 m of wire.

At the end of DY077 PAP cruise, a short trial was arranged at which it was agreed that the BAS system would need to be modified to work with a fibre optic if it was to connect to the DTS. As this was likely to be the system used on the RRS Sir David Attenborough (SDA) it would be efficacious to do so. The modifications were done, and the electrical and fibre optic system was dry tested at the National Oceanography Centre (NOC) in Southampton while the Discovery was alongside. At this point, the internal electronics were not suitable for an oil-filled pressure-balanced system. The Evergrip termination, electronic and fibre optic ST connections were left for use on DY086 COMICS. During DY084 AMT, the DTS was utilised as a temporary Stainless Steel CTD wire and the fibre optic termination was removed.

Mobilisation for DY086 included preparing the DTS and connecting to the newly made oil-compatible BAS net electronics board inside the pressure-balanced housing. It was at this stage that three critical oversights were identified.

1. The newly made BAS electronics board had a potted flying fibre optic lead, which had been left terminated with a network style LC connector for testing purposes. This was not compatible with the ST connector required for the oil-filled housing.
2. There was no adequate kit or facilities on board the ship for performing fibre optic splicing or terminations.
3. None of the technical staff had been prepared for or tasked with the responsibility of supporting the fibre optic system.

During consultation discussions with Dave Turner of the NOC ROV team, the termination kit on board was described and discussed, and it was believed that this type of termination was not compatible with the oil-filled housing being used. Two test terminations were performed and left overnight. The next day, the terminations were removed from the oil and came apart whilst being handled, confirming that this system was not adequate for this application.

After a brief investigation of local companies in Port Stanley, it became apparent that the only way to rescue the scenario was to fly out a technically competent person with the required components from NOC. Fortunately, Russell Locke of the ROV group was able to provide this support and arrived on Sunday 12th of November while the ship waited out in the bay.

During his brief few hours on the ship, the ROV technician performed three spliced terminations on the DTS and tested them using an optical time domain reflectometer and an optical power unit. One of the splices was found to be faulty and removed.

Figure 2.63: Evergrip termination and core cable to BAS electronics housing
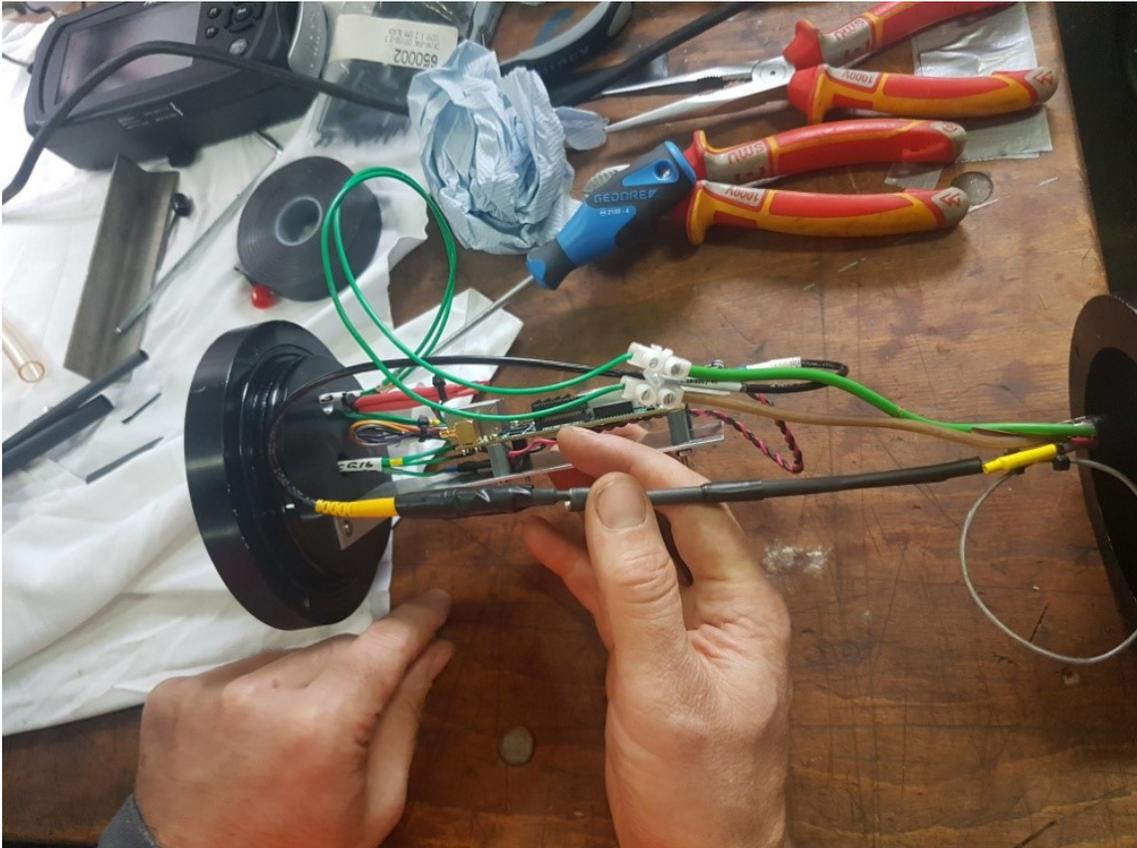
Figure 2.64: Metal rod inside oil filled housing protecting fibre tail

After an attempt was made to splice an ST connector to the flying lead on the BAS comms and control board, it was discovered that the lead was not compatible with the splice tails, most likely because it was a multi-mode fibre unlike the single mode tails. A manual termination was then performed with the supplies brought from Southampton and a successful connection was made through the system. The technician was piloted back to shore, and the cruise commenced.

The BAS team then proceeded to assemble their oil-filled housing. It was tested just before filling with oil only to discover it was no longer working. The DTS termination was then tested again with the OTDR and proved to be no longer viable indicating a break near the tail end. The process was then repeated with the second fibre optic termination and again failed after the first stage of assembly. The DTS fibres had to all be reterminated by the NMF technicians on board, who by then had had a crash training course in using the splicing kit.

After a successful splice had been performed, the assembly of the housing was then continued by NMF technicians with the assistance of BAS scientists. During this process it became clear that the much finer spliced tail was being deformed in favour of the stiffer armoured DTS cable and flying lead. To prevent this from happening and causing the spliced tail to fail, a piece of metal rod was used to protect the fragile area and keep a flexible coil in the armoured length.

This system proved an adequate temporary fix which lasted the duration of the rest of the cruise.