National Oceanography Centre

RRS *Discovery* Cruise 116

10 Nov – 27 Nov 2020

UK

Time-series studies at the Porcupine Abyssal Plain Sustained Observatory

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2021

Cruise report number 73

Document Data Sheet

Author	Publication Date
Andrew R. Gates et al.	*2021*

Title

RRS Discovery Cruise 116 / 10 Nov – 27 Nov 2020 / Time-series studies at the Porcupine Abyssal Plain Sustained Observatory / UK

Reference

Southampton, UK: National Oceanography Centre, Southampton, 115pp. (National Oceanography Centre Cruise Report, No. 73)

Abstract

RRS *Discovery* cruise 116 departed Southampton 10th November 2020, operated in the Whittard Canyon (12-13th November) and the Porcupine Abyssal Plain Sustained Observatory area (19-23 November), returning to Southampton 26th November 2020.

The goal of the cruise was to continue time-series observations of the surface ocean, water column, and seafloor at the site, as first studied by NOC (then the Institute of Oceanographic Sciences) in 1985. An additional goal was to service a mooring at Whittard Canyon. Operations were limited in scope because of the Covid-19 pandemic which affected all aspects of life in 2020. DY116 was delayed from June/July until November 2020 and proceeded with reduced personnel and limited scope. The specific aims were to recover data and infrastructure and deploy replacement moorings. The regular sampling programme at PAP-SO did not take place because of the need for social distancing. Shortly before departing the PAP1 surface buoy had become detached from the mooring and was recovered by the FS *Maria S. Merian.*

The PAP1 mooring was successfully deployed including replacement of the full ocean depth mooring. The surface buoy was upgraded to a Met Office Mobilis buoy. The 30 m sensor frame was not included in the first deployment but will return on in 2021. The PAP3 mooring, a sediment trap and current meter string, was successfully recovered and redeployed. Colonisation substrates and larval traps for the on-going LO3CAted (Larval Occurrences in Open Ocean: Connectivity studies in NE Atlantic and Mediterranean Sea) project were recovered from PAP3. The Bathysnap seafloor time-lapse camera, and associated LO3CAted samplers, was recovered but unfortunately it had flooded. A series of water column observation and sampling operations were successfully carried out with a CTD instrument package. The CTD deployments included pre-and post-deployment calibrations of PAP1 and PAP3 sensors. Underway data were collected and a Met Office Biogeochemistry Argo float was deployed. At Whittard Canyon the mooring was successfully recovered and replaced.

This cruise was a contribution to the Climate Linked Atlantic Section Science (CLASS) project supported by the UK Natural Environment Research Council (grant number NE/R015953/1).

Keywords

Porcupine Abyssal Plain, Whittard Canyon, Ocean Observation, ICOS, EMSO, Argo, Biogeochemistry, CTD, time series, Covid-19, FS *Maria S. Merian*

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1. Personnel

Scientific personnel

GATES	ANDREW RUSSELL	PI, NOC
HARTMAN	SUSAN ELIZABETH	Scientist, NOC
PEBODY	CORINNE ANNE	Scientist, NOC
FLOHR	ANITA	Scientist, NOC
RUNDLE	NICHOLAS JAN	Tech, NOC
COMBEN	DANIEL HOWARD	STO, NOC
SCOTT	JASON ERRINGTON	Tech, NOC
BENSON	JEFFREY RAY	Tech, NOC
WHITE	MICHAEL SIMEON	Tech, NOC
BALLINGER	THOMAS JOSEPH	Tech, NOC
HENDERSON	PAUL ROBERT	Tech, NOC
ARNOTT	JACK	Tech, NOC
BRIDGER	MARTIN JOHN	SST, NOC

Ship's personnel

MACKAY	STEWART MacDONALD	Captain
GAULD	PHILIP DOUGLAS	C/O
HOOD	MICHAEL PATRICK	2/O
MACLEAN	DUNCAN	3/O
MCCOY	GARRY THOMAS	C/E
HAY	DEREK BRIAN	2/E
NICHOLSON	GAVIN	3/E
LEE	JOHN EDWARD	3/E
FISHER	CHARLES GEORGE	ETO
BULLIMORE	GRAHAM	Purser
WILLCOX	SIMON PAUL	CPOS
COOK	STUART CLIVE	CPOD
STIVEY	MARK	POD
FRASER	GRANT FORBES	POS
CRABB	GARY	SG1A
PEPPIN	CHRISTOPHER	SG1A
PARIS	RYAN JOSEPH	SG1A
CONTEH	BRIAN	ERPO
LYNCH	PETER ANTHONY	H/Chef
LEIGH	MICHAEL WAYNE	Chef
CARRILHO	CLEMENTINA MARIA	Stwd

2. Itinerary

Scientists and Technicians join, 5 Nov 2020.

Awaiting Covid test results and social distancing, 5-10 Nov 2020

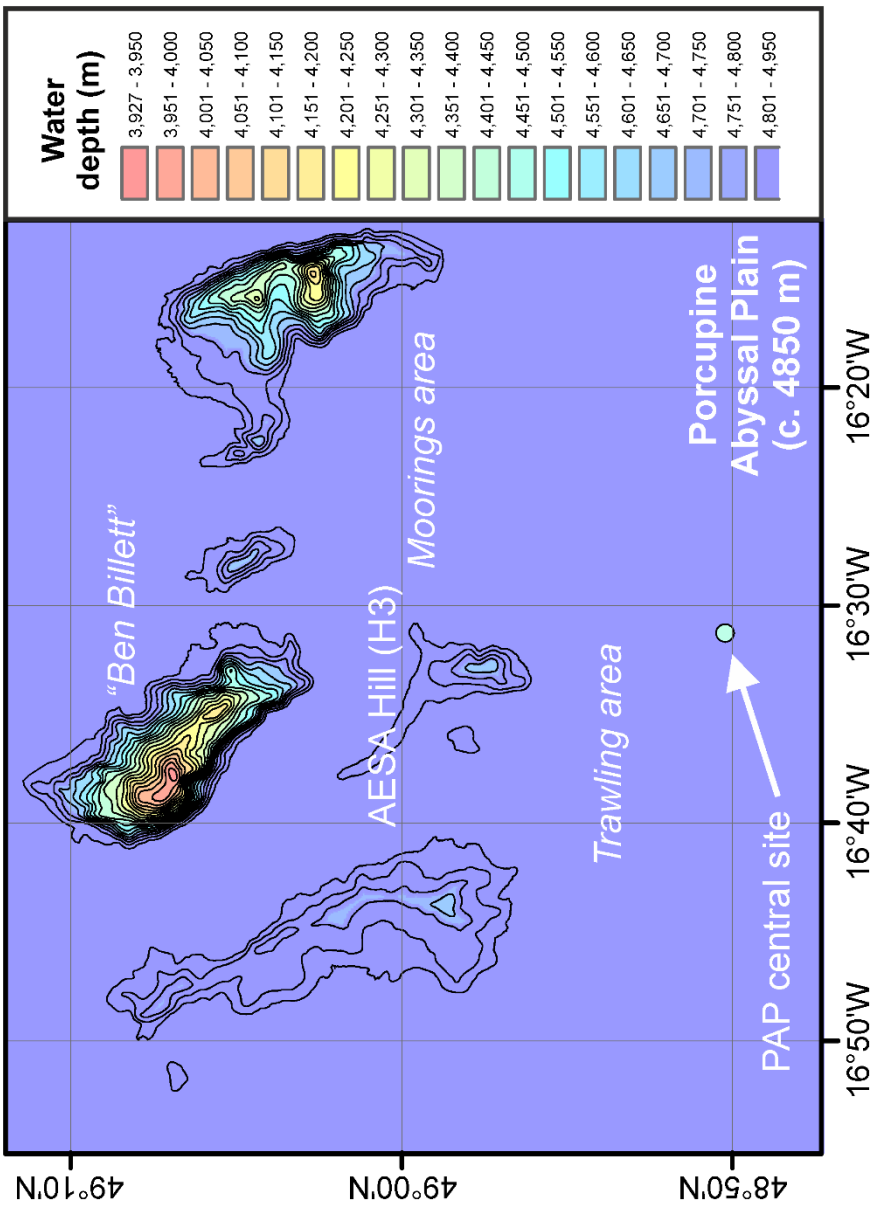
Sail NOC, Southampton, UK 10 Nov 2020.

Operations at Whittard Canyon, 12-13 Nov 2020.

Medivac and shelter from weather, Falmouth, 14-16 Nov 2020.

Operations at the Porcupine Abyssal Plain Sustained Observatory, 19-23 Nov 2020

Dock, Southampton, UK, 26 Nov 2020.



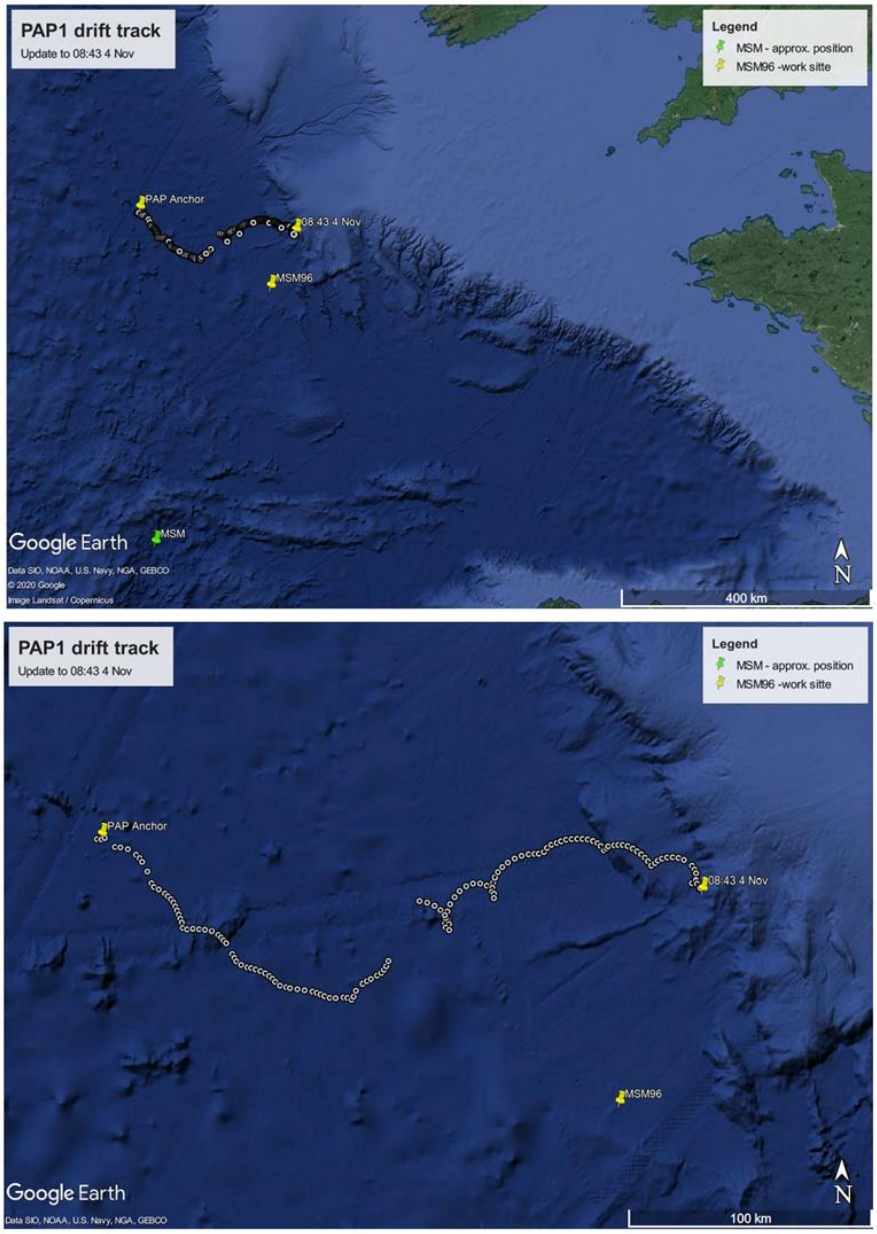
General chart of the Porcupine Abyssal Plain Sustained Observatory operations area for RRS Discovery cruise 116, indicating selected locations referred to in this cruise report.

3. Cruise background and aims

Research at the Porcupine Abyssal Plain Sustained Observatory (PAP-SO) and Whittard Canyon are a components of the UK Research and Innovation National Capability Long-term Single Centre Science Programme, "Climate Linked Atlantic Sector Science" (CLASS). PAP-SO is an open-ocean time-series site in the Northeast Atlantic (49.0 °N 16.5 °W, 4850 m water depth) where studies are made on ocean-atmosphere interactions and pelagic-benthic coupling using a range of mooring systems and direct sampling approaches. The Whittard Canyon system is on the Celtic Margin. It links the shelf to the deep ocean and is a key area for understanding sediment transport, habitat and species diversity and potential geohazards. The aims of the originally scheduled RRS *Discovery* cruise 116 (DY116) were to continue time-series observations at the PAP-SO and service moorings at Whittard Canyon ahead of a dedicated cruise to the site.

The Covid-19 pandemic reached the UK in early 2020 and led to national lockdowns and requirements for strict social distancing measures from March 2020. This caused a significant delay to the 2020 cruise programme. DY116 was delayed until November and proceeded with much reduced personnel and a more limited scope than a typical PAP-SO cruise. The primary aim was to recover data and infrastructure that had been impossible earlier in the year and, where possible, deploy replacement moorings. This would allow continuity of the PAP-SO and Whittard Canyon time series and ensure recovery of valuable data. The regular water column and seabed sampling programme at PAP-SO did not take place because of the larger teams working in close proximity that are needed for this work.

At the time of boarding RRS *Discovery* there was some uncertainty about the exact requirements for recovery of the PAP-1 mooring. On the 23/10/2020, 18 days prior to DY116 departure, the surface buoy from the PAP-1 mooring was adrift following high winds and waves associated with the remnants hurricane Epsilon. When the DY116 team boarded RRS *Discovery* we were awaiting news of an attempted recovery by the FS *Maria S. Merian*. This was successfully achieved on 5th November after 12 days adrift.



Positions of the drifting PAP-1 surface buoy in the lead up to recovery by the FS Maria S. Merian (lower map is zoom in on upper map).

4. Objectives

The aims of the cruise were addressed by the following specific objectives for DY116:

Whittard Canyon (Irish EEZ):

1. Recovery of Whittard Canyon mooring (sediment trap, ADCP and CTD sensors),
2. CTD for testing release for new mooring,
3. Deployment of replacement mooring at Whittard Canyon (sediment trap, ADCP and CTD sensors).

PAP-SO (International waters):

1. Recovery of sediment trap mooring at PAP-SO,
2. Recovery of time-lapse camera (Bathysnap) at PAP-SO,
3. Recovery of Met Office/NOC mooring with surface buoy (PAP-1),
4. Deployment of sediment trap and sensors (PAP-3),
5. Deployment of new Met Office buoy with surface ocean biogeochemistry sensors at PAP-SO (complete, full depth mooring replacement),
6. Other associated CTDs at PAP-SO,
7. Deployment of Met Office BGC Argo float (Euro Argo) at PAP-SO.

5. Narrative

DY116 is one of the first cruises after the programme restarted during the Coronavirus pandemic. Preparation has therefore been extremely unusual. To ensure social distancing we have had limited access to NOC and working together as been restricted to online meetings or very occasional socially distant working at NOC. Prior the cruise everyone has had to provide a negative Covid-19 PCR test taken at home in order to join the ship. The first task when on board is another PCR test followed by a period in which we remain in our cabins until the results come through. We then remain alongside for 5 days, adhering to social distancing rules to ensure no symptoms develop before departing. This is a challenging time but we recognise the importance of these measures to ensure safety of all on board.

We have also been tracking the ODAS buoy from the PAP-1 mooring. It has been adrift since 23/10/2020 following the remnants of Hurricane Epsilon passing over the PAP site. As we board RRS *Discovery* we are awaiting news from the German ship FS *Maria S. Merian* who have agreed to attempt a recovery if conditions are favourable while they are in the area.

Thursday 5th November 2020

The scientists and technicians arrived at NOC for 0900 to join RRS *Discovery* for the rescheduled DY116 cruise to the Porcupine Abyssal Plain Sustained Observatory (PAP-SO) and Whittard Canyon. The first task on board was to undergo the Covid-19 PCR swab test and then isolate in our cabins until we receive the results. We all agree that the medical professional carrying the tests was rather more invasive than our own attempts at testing at home a week previously.

During the day we hear good news from the FS *Maria S. Merian* who have recovered the Met Office ODAS buoy from the PAP-1 mooring that had been adrift for 12 days. Unfortunately the sensor frame is not beneath the buoy, meaning that it is likely at around 2000 m depth at PAP-SO. This is well beyond the depth rating of most of the sensors.

Friday 6th November 2020

The Covid-19 test results came through today and everyone had tested negative. We will continue to maintain social distancing on board, carry out daily temperature checks and stagger meal times until 19th November to meet with government guidelines and minimise the coronavirus risk. Now that we are able to begin moving around the ship and unload equipment as it comes aboard things begin to feel a bit more normal.

Saturday 7th November 2020

Today we officially sign on to the ship. We have some informal planning meetings and continue unloading and setting up equipment in the labs.

Sunday 8th November 2020

The new Mobilis buoy was brought on board the ship. It is an impressive sight and requires a lot of space on deck. Work on the buoy that had stopped to allow our period of self isolation before the cruise continues. Cabling is sorted and sensors are fitted. We hear some more news from the *Merian*, the sensors have all been located, including the tiny "Star Oddi" temperature sensors that are fitted to the chain beneath the buoy. At 11:00 everyone on *Discovery* observes two minutes silence for Remembrance Sunday. In the afternoon the science and tech teams gather for a safety briefing by Graham, the Purser.

We use the day to continue the lab set up, preparations and work on an article for the NOC website, to be published when we depart.

Monday 9th November 2020

Today preparations continue, we arrange the ship's engineering requirements for our work, mainly around non-toxic underway water sampling and a temperature controlled environment. Some good news from the Met Office on the availability of a buoy for the next PAP cruise in 2021 gives us more certainty in the planning of our operations at PAP on DY116.

Tuesday 10th November 2020

We are due to sail at 1400 today. We spend the morning ensuring everything is well fastened and prepare for departure. At 1330 we do a live link with Lane End School in Cowes IOW, organised by Nick Rundle. This is a great opportunity to talk to children about a range of topics including how we measure the oceans, the research ships, working at sea, climate change and deep-sea animals. Although our connection is not perfect, this event is a big success. We depart NOC shortly after 1400, the perfect end to our call with Lane End School. We pass the RRS *James Cook* alongside and head out into the Solent. At 1530 we have a muster drill. There is some extra excitement as we near the Needles, a Coastguard helicopter approached, flew alongside the ship for a several minutes before someone was lowered onto the back deck of *Discovery* as part of an exercise. He only stayed a minute or two before lifting back off to the helicopter. We had a science meeting at 1830 to discuss the work plan with scientists, technicians and crew, and explain more about PAP.

Wednesday 11th November 2020

The 0830 Captain's meetings began today to plan operations and discuss H&S. In the next 24 hours we expect to arrive at a CTD site in 3000 m water depth, approximately 30 nm past Whittard Canyon. Here we will do a deep CTD to test releases.

The weather has been poor (F.9) and progress has been slow so later in the day it becomes clear that we will not arrive in time to do CTD at WC in daylight so change plan and head straight to WC site. Aiming to arrive for recovery at 1000 if weather is suitable and potentially do the CTD in the afternoon/evening.

Thursday 12th November 2020

Weather is looking bad at PAP-SO over the weekend. With no immediate plans to head further west we decide to complete both recovery and deployment of the Whittard Canyon mooring in the coming days. The Whittard Canyon mooring (DY103-041) was ranged and released at 0944. It was spotted by the bridge on the surface at 1020. By 1135 the sediment trap was back on deck. The trap funnel was completely full of sediment and only one bottle appeared filled. There was settlement of organisms such as barnacles, anemones, hydroids and polychaetes on the various parts of the sediment trap.

A discussion with colleagues at NOC suggest the occurrence of a major sediment transport event in the canyon and all are excited to see the data from the ADCP and MicroCAT (CTD). After the mooring was recovered the CTD was off deck at 1530 for a test cast and to do a release test ahead of a potential WC mooring deployment tomorrow. The release test worked OK but there was an electrical problem with the CTD. The bottles could not be fired and the sensors were not responding when the CTD approached the bottom of its profile. This was fixed on recovery but we will need to do another test CTD. This does not have to be at WC.

The weather forecast at PAP remains bad. We decide to remain near Whittard Canyon and prepare for deployment of the new mooring tomorrow.

Friday 13th November 2020

The Whittard Canyon mooring was deployed by 1205. The weather was coming up through the deployment and was marginal by the time the anchor was finally dropped. The exact location of this mooring is important so the position was triangulated. The triangulation was a bit challenging because the southern-most point was difficult to reach in the wind and swell conditions. Triangulation was completed at 1345. By 1515 we were en route to Falmouth to drop off a crew member who had received bad news from home, ETA 0900 14th November.

Saturday 14th November 2020

We arrived at Falmouth by midday. Crew member was picked up by a launch just inside the harbour at Falmouth. We then went to an anchorage just off the Helford River where we remained to shelter from heavy seas and high winds coming toward the Channel.

Sunday 15th November 2020

There is no value in heading out to PAP-SO in the current weather conditions so we remain outside Falmouth, planning to depart at first light on Monday. The calm seas provide a good opportunity to do some final work on the CO_2 sensor on the mast of the buoy. Some work is required to ruggedize the system of lines and cables between the buoy's keel and mast. At 1630 a crew member is taken ashore because he is unwell. He is sent to the hospital and we await news of his condition. We prepare further outreach articles, this time for EMSO.

Monday 16th November 2020

The worst of the weather has gone through and it seems slightly better today, but we are still in the shelter of our anchorage. Seas will still be rough on the way to PAP so we expect to make slow progress directly into the strong wind and swell. We hear that the crew member has appendicitis and will not be coming back aboard. He will remain in hospital for an operation.

We depart Falmouth at 0930 and our progress is slow with speeds around 6-7 knts. We are hoping to arrive at PAP in time for an improved weather window on Thursday.

Tuesday 17th November 2020

At 0650 (49° 32.13 N 008° 48.64 W) we are still making slow progress (6.4 knts) into strong winds. At the 0830 meeting we discuss how best to work at PAP given the weather. The operations are all weather dependent and we need to match the possible operations with the appropriate weather window. The PAP-1 mooring work needs very calm seas that do not look likely at this stage. The ETA at PAP is Thursday between midnight and 6 am.

Wednesday 18th November 2020

Progress has improved (>8 knts overnight) and we expect to arrive at the PAP CTD site at 0200 on Thursday. Plan is to do a CTD and then aim to recover Bathysnap, the smallest mooring, if the weather is suitable. The CTD will be a pre-cal for the PAP-3 microCATs (3 long stops), full water column profile with water sampling at 10 depths, and release tests for PAP-1 and PAP-3. Friday looks less certain for the weather but Saturday, Sunday and Monday look better. Sunday morning might be the best window of the whole trip.

Thursday 19th November 2020

Arrived at PAP at around 0200 and started CTD shortly after, which was recovered to deck by 0630. Everyone is delighted to have started science at PAP-SO.

The first mooring work is to recover Bathysnap, it is not giving a range when interrogated but releases OK. Bathysnap is sighted from the bridge at 1004 and recovered by 1115. Unfortunately Bathysnap has flooded. Both the camera and flash pressure casings are full of water.

At 1203 we are on location for ranging the PAP-3 release. At 1351 the mooring is alongside the ship and by 1550 the 100 mab trap is on deck. CP processes the sediment trap samples, which look good, NR deals with the sensor data and AG looks after the Lo3cated samples.

Overnight we carry out an opportunistic mulitbeam survey over an abyssal hill NW of the PAP site where existing data are lacking (DY116-004).

Friday 20th November 2020

The multibeam survey is completed by 0500. In the morning we complete a CTD (DY116-005). At 1303 we deploy the Met Office BGC Argo float. It is deployed with guide ropes to ensure it is gently

lowered in to the water. Initially it lies horizontal but eventually moves into a vertical position and sinks slowly. It is deployed close to the CTD deployment site. We are awaiting the first data.

At 1425 we begin PAP-3 deployment (DY116-007) 49° 2.536 N, 016° 24.695 W, 4810 m, 2 km layback. A billings float sheared on deployment and floated away. It was efficiently recovered and replaced and long pay out and slow tow starts. Lay back is now further than intended because of the time spent sorting the float. 3 triangulation points at 1500 m radius from the expected location. TP2 is not giving a good range. We will try that range again later in the trip.

Overnight we had planned to do some mapping but we had switched off the MB to do the triangulation and it had got dark before we finished so we couldn't do a MMO observation before starting the MB. We hold station and wait for daylight.

Saturday 21st November 2020

The weather window we have been looking at for the last few days has certainly arrived. The seas are calm and the wind is light, when the sun is out it almost feels like summer. Some swell remains. This is the perfect weather for the PAP1 deployment. It looks like it might be similar tomorrow for an attempt to recover the remaining parts of the lost mooring.

The morning is taken up with some final preparations. The engineering team show their trademark ingenuity and fashion a water tight repair to the buoy tracker beacon at short notice. Final checks are made on the sensors and the CO_2 pump is switched on before moving the buoy into position. The plan is to steam 500 m past the intended deployment location on a heading of 280°, avoiding the old PAP1. The deployment runs smoothly (DY116-008).

To ensure the deck crew stay within hours of rest so we decide to postpone the planned shallow calibration CTD. Instead we try to triangulate the position of the anchor for PAP-1 but we only get one successful range despite trying the drop keel and the hand-lowered instrument. We abandon the triangulation at 2025. Overnight we run a Met Cal (DY116-009). This involves ship pirouettes and circles to calibrate the ship's met sensors against the newly deployed Met Office buoy.

Sunday 22nd November 2020

After the smooth deployment of the PAP-1 mooring yesterday the weather looks good again today. This bodes well for our attempt to recover the remains of the old PAP-1. We waited for the best possible day because of the uncertainty around what we will recover, what state it will be in and how we will get it on board the ship. We are expecting to recover everything from the 30 m sensor frame down. We think the frame is probably sitting at 2000 m water depth so everything will have been compromised.

At 0928 we arrive on location, interrogate release and hold station, releasing at 0933. It begins to come to surface at approx. 40 m min^{-1}. At 1020 the subsurface buoy is spotted from the bridge and we watch it for some time to assess the recovery options. Initially it looks like the rope is all streaming out to the

east of the float but later we notice large clumps of blue rope appearing either side of the float. There now seems to be quite a lot of rope on both sides but it is gradually moving to the east of the float.

We have discussions with the Captain, bosun and mooring team about how best to recover, we are uncertain if we can see all the rope on the surface, how close can the ship appraoch, would it be better to send the response boat out to recover one piece of rope? What are the risks associated with that?

Eventually we see long loop of rope that has separated from the main mass of rope and buoy. Some gulls are conveniently sitting amongst it. We decide that this is a good target to grapple and the captain begins to move the ship in to position. At 1155 the crew successfully grapple the loop of rope and we begin to steam away. Initially there are a few knots as the rope is brought on board but it comes in relatively smoothly. For a period two lengths of rope were being wound on together. At 1425 the subsurface buoy is on deck and rope continues to be wound on smoothly. The sensor frame is on deck by 1515. It is in a sorry state. Most of the housings have imploded and it looks like the batteries may have exploded, taking out some of the other sensors with them.

The recovery of the remains of PAP-1 is a big milestone. That means we have achieved all of our primary objectives. We now have a few more tasks to complete in order to finish all of our work.

We now steam to the newly deployed PAP-1 site to do the CTD cast that was not possible yesterday. The pelagic team wanted to do it in daylight to get some meaningful data from the PAR sensor. We don't get the CTD in until 1603 as the light was fading. The deployment is fine for the validation of the PAP1 sensors but we will try and do another shallow CTD in daylight (DY116-010) for the PAR data.

DY116-011 During the first part of the night we do some multi-beam to fill in more gaps in the PAP bathymetry map.

Monday 23rd November 2020

After the MB survey we carry out an early morning deep CTD to calibrate the recovered PAP-3 temperature and salinity sensors (MicroCAT), (DY116-012). This was back on deck by breakfast. At 0842 we return to TP2 from PAP-3 to try and triangulate the position of the mooring one more time. We complete a triangulation and the other points align well with our previous triangulation but again the attempt in the location for TP2 does not give good data. We then complete the daylight shallow CTD we hadn't been able to do the previous day at the PAP CTD station (DY116-012).

The workable weather at PAP-SO is coming to an end and we will need to find some shelter later this week. With the objectives of the cruise achieved we steam towards home a few days early.

Tuesday 24th – Wednesday 25th November 2020

As we continue our journey home everyone works hard on the usual end-of-cruise tasks including packing, tidying away and writing cruise reports. The internet goes down so some communications and online forms are a problem.

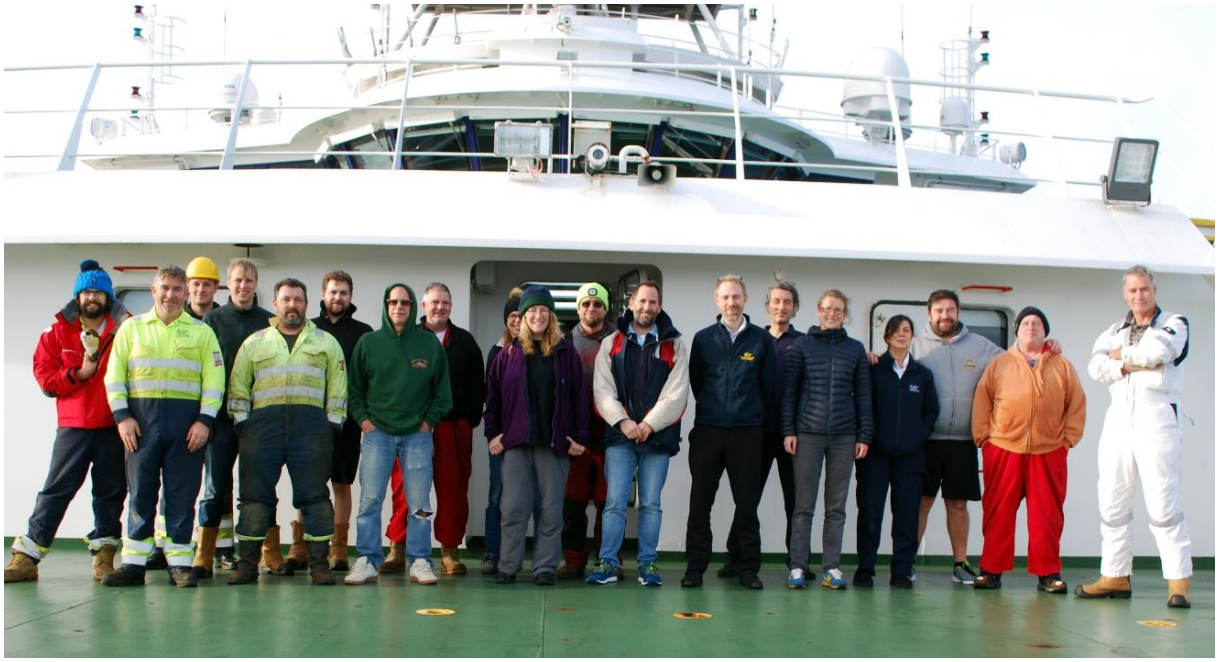
Thursday 26th November 2020

At 0830 we pass The Needles and enter The Solent. The ship stops at the Saltmead anchorage for testing the lifeboats and fast response vessel. 50° 45.50 N 001° 21.11 W

1245 Depart Saltmead anchorage and head to commercial dock 103/108 because RRS *James Cook* is alongside at NOC. The science and technician party stay on board overnight to demob in the morning.

Friday 27th November 2020

Equipment is de-mobbed from RRS *Discovery* by lorry and then the scientists and technicians are free to go home. The UK is reaching the end of a period of strict lockdown rules because of a rise in Covid-19 cases through the autumn months.



DY116 cruise photograph

6. NMF technical report

Nick Rundle (Senior Technical Officer) and Jeff Benson, Martin Bridger, Tom Berringer, Dan Comben, Mike White, Jason Scott, Jack (Trainee), Paul Henderson (Trainee)

Introduction

With the aim of the cruise primarily focussed on asset retrieval, the initial activities and preparation revolved around collecting three moorings at the PAP site and one at Whittard canyon, with the secondary aim if time and weather permitted to redeploy all except the BathySnap, which it was deemed could be delayed until the next PAP cruise at the end of March 2021.

In the fortnight leading up to the mobilisation of DY116 PAP-1 broke free and was tracked heading South Easterly where the buoy and 26 meters of chain were intercepted and retrieved by the FS *Maria S. Merian* and taken to Emden before being shipped back to NOC. This left just the instrument cage and the rope part of the mooring supported by the mid-water buoy and release to be retrieved.

With the weather at the PAP site and also the Whittard Canyon, being so unreliable for mooring operations and even CTD deployments in November, the objectives needed to be prioritised carefully with emphasis on asset value, likelihood of success and potential impact on future work. The only predefined order of activity was PAP 1 as the large ROMICA winch was already preloaded with the new rope for deployment meaning this would need to be deployed before the existing mooring could be retrieved there being no practical way or expendable time to unload the rope on the ship.

As part of DY103 the Whittard Canyon mooring had been deployed on the voyage back from PAP as a secondary priority to the primary objective. It was deemed preferable on DY116 to use the available weather window should it be there on the voyage out to the PAP site to retrieve the asset on the way and redeploy on the voyage home if possible.

Mooring Operations

Whittard Canyon

The conditions at Whittard on arrival were as workable as the forecast had suggested, predictions for the PAP site for the next week did not look good enough to start any work, it was therefore decided that a complete turnaround of the Whittard mooring would be the best use of time.

DY103 Whittard Mooring Recovery

The set up for recovery was to use a basic direct pull method through a sheave on the port pedestal crane to the 5 Tonne winch fitted forward and starboard on the work deck. Due to the position of the PAP1 winch and the MOBLIS buoy there were few options to this arrangement.

A recovery rope was attached to the 5T winch and run around the aft of the ship and up the starboard bulwark.

The mooring was released at 09:44 and took approximately 30 minutes to fully surface. With the pellet float streaming efficaciously from the top row of three glass spheres. The bridge carefully manoeuvred the ship to bring the top of the mooring and the pellet float within grappling distance of the starboard aft quarter. The pellet float was retrieved with a grapnel and removed from the recovery line and the line attached to the recover rope. The line was then slowly walked aft while the winch took the slack and the ship started to move off slowly at 0.5Knotts.

At this point only the three glass spheres and the top ADCP 75kHz floatation sphere were visible from the deck. The top glass spheres were brought on board and disconnected with the use of a chain stopper fitted in the red zone. The outboard line was then reconnected to the winch and the line hauled in to bring the first ADCP sphere out of the water.

Glass spheres from Whittard Canyon mooring on the surface

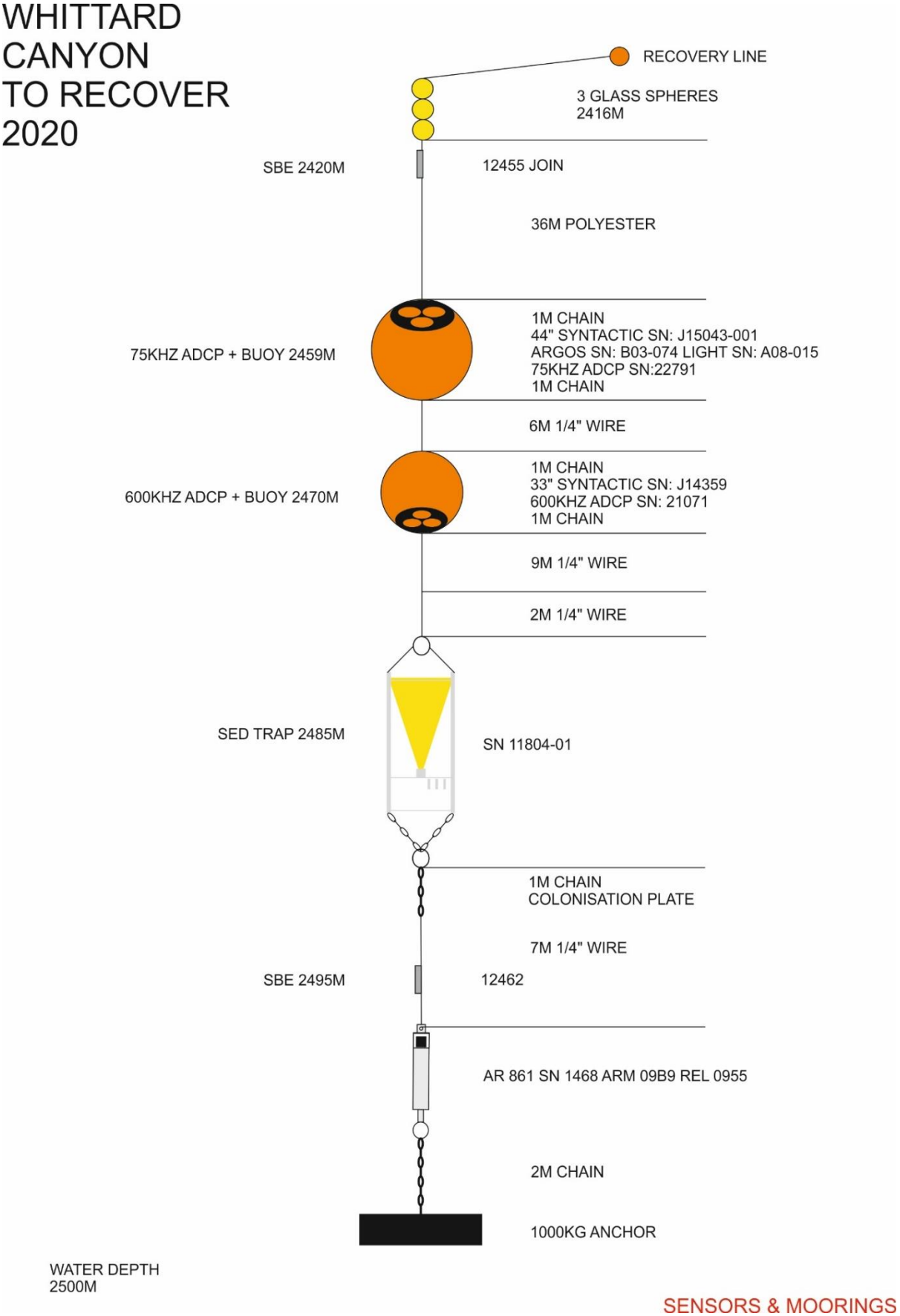
The 75 kHz ADPCP came in initially with a slight tangle which remedied itself outboard. The deck stopper was used to hold the outboard line while the two ADCP floats were retrieved on deck and also the sediment trap.

The sediment trap funnel was two thirds full with an unknown deposit on retrieval adding to its weight and negative buoyancy of the end of the mooring, this being the reason the 600 kHz buoy did not quite reach the surface.

Images of recovery of the ADCPs and sediment trap from the Whittard Canyon mooring

The Mooring release landed on deck at 1145 am. The two SeaBird 37 CTD sensors and the ADCPs were rinsed and taken into the deck lab to be downloaded. The sediment trap was left on deck for interrogation and assessed for marine growth along with the two ADCP floatation spheres.

Whittard Canyon Mooring recovered to deck



Whittard Canyon mooring as recovered (DY103-041)

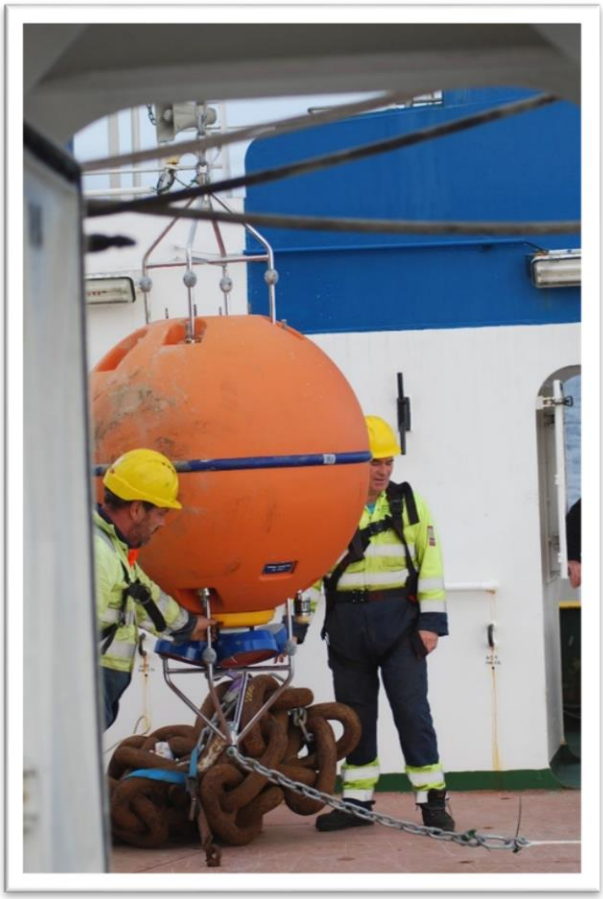
Whittard Canyon Mooring Deployment

The mooring rope was wound onto the starboard deck winch. The anchor chain was placed on the red zone in line with the winch. In hindsight this created an obstacle for the technicians engaged on the red zone during deployment and it would be better practice to move the anchor chain into position from behind the starboard pedestal when the mooring is ready to be released.

The polyester rope had stainless steel thimbles instead of galvanised. This is an error by the supplier, but needs to be picked up during pre-cruise prep. The ½" shackles were nut and split pin instead of euro-shackle, which is the preferred style for all moorings.

The 75kHz ADCP was assembled at base and programmed in the deck lab before deployment. The 600kHz ADCP had to be modified at sea to accommodate a lithium battery pack which involved replacing the M4 studs to allow for a slightly longer module.

The mooring was payed out buoy first with the first SeaBird just below the top 3 glass spheres. Whittard is quite a short mooring, the distance between the ADCP spheres especially requires careful positioning of the deck stoppers and crane use. The sea conditions were less than favourable and a strong current caused the mooring to stream starboard, but the mooring was released without incident.

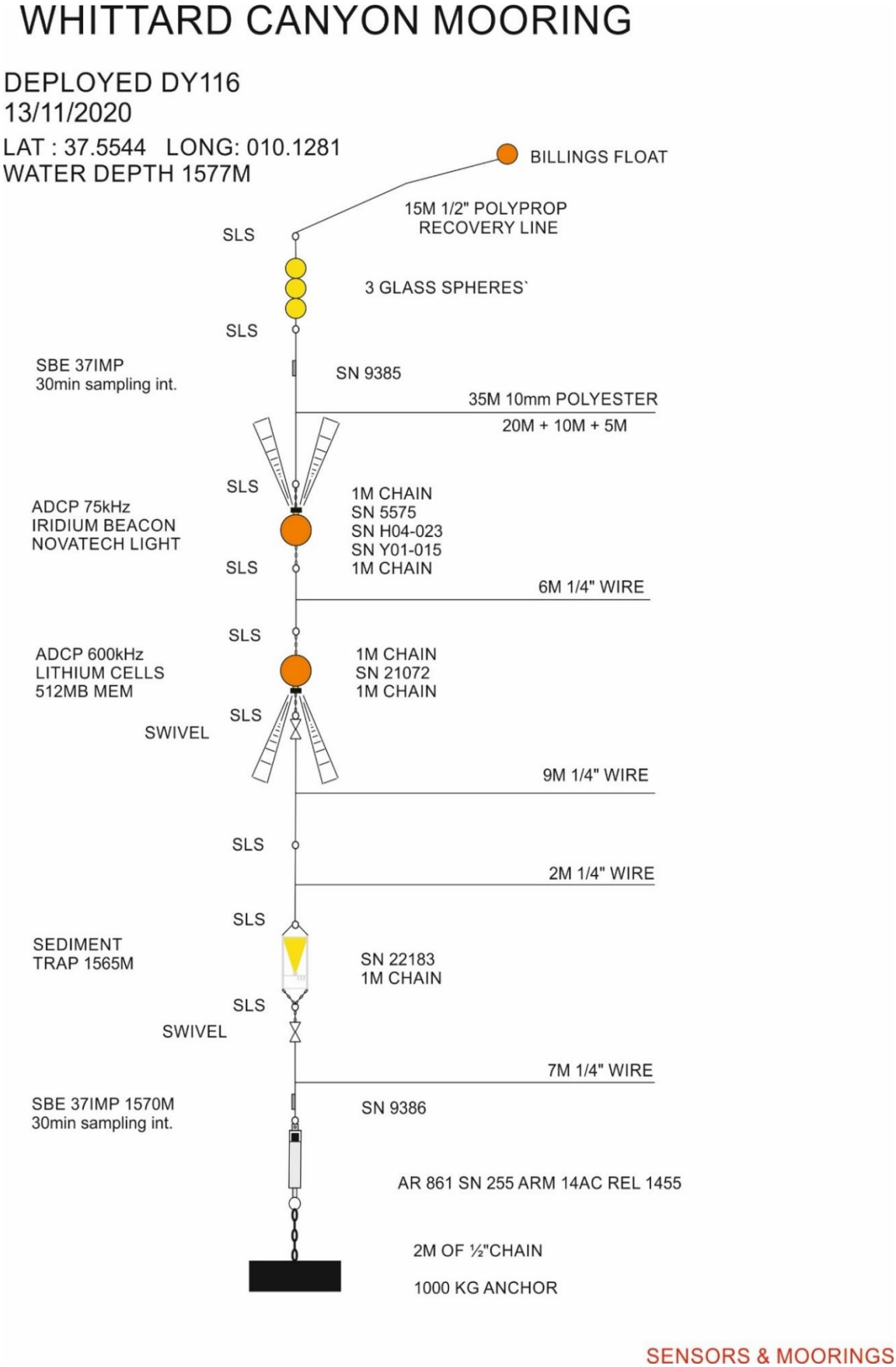


Whittard Canyon ADCP deployment

Buoy Anchor Position Calculator

Mooring Name:	Whittard Canyon					
Buoy Deployment Method:	Buoy First					
	LATITUDE			LONGITUDE		
	Degrees	Minutes	Quad	Degrees	Minutes	Quad
Planned Seabed Position For Anchor:	48°	37.5690'	N	010°	00.2240'	W
Water Depth At Planned Seabed Anchor Position:	1,577 m					
Calculated Fall Back Distance :	225 m					
Vessels Track:	280.0°					
	LATITUDE			LONGITUDE		
	Degrees	Minutes	Quad	Degrees	Minutes	Quad
Anchor Release Position (At The Stern):	48°	37.5740'	N	010°	00.2520'	W
	LATITUDE			LONGITUDE		
	Degrees	Minutes	Quad	Degrees	Minutes	Quad
Estimated Fall Back Seabed Position:	48°	37.5529'	N	010°	00.0708'	W
	LATITUDE			LONGITUDE		
	Degrees	Minutes	Quad	Degrees	Minutes	Quad
First Buoy Ranging Position:	48°	37.7844'	N	010°	00.4574'	W
First Ranging Position Ping Distance:	1,668 m					
Calculated Horizontal Distance:	543 m					
	LATITUDE			LONGITUDE		
	Degrees	Minutes	Quad	Degrees	Minutes	Quad
Second Buoy Ranging Position:	48°	37.6803'	N	009°	59.8444'	W
Second Ranging Position Ping Distance:	1,630 m					
Calculated Horizontal Distance:	412 m					
	LATITUDE			LONGITUDE		
	Degrees	Minutes	Quad	Degrees	Minutes	Quad
Third Buoy Ranging Position:	48°	37.3257'	N	010°	00.3115'	W
Third Ranging Position Ping Distance:	1,655 m					
Calculated Horizontal Distance:	502 m					
Arc Sampling Interval:	0.50°	=	4.2 m steps on the arc.			
Accuracy:	Low					
1st and 2nd Range Arc Intersection Calculated:	Yes					
2nd and 3rd Range Arc Intersection Calculated:	Yes					
3rd and 1st Range Arc Intersection Calculated:	Yes					
	LATITUDE			LONGITUDE		
	00°	00.'0000	Quad	000°	00.'0000	Quad
Calculated Seabed Position	48°	37.5544'	N	010°	00.1281'	W

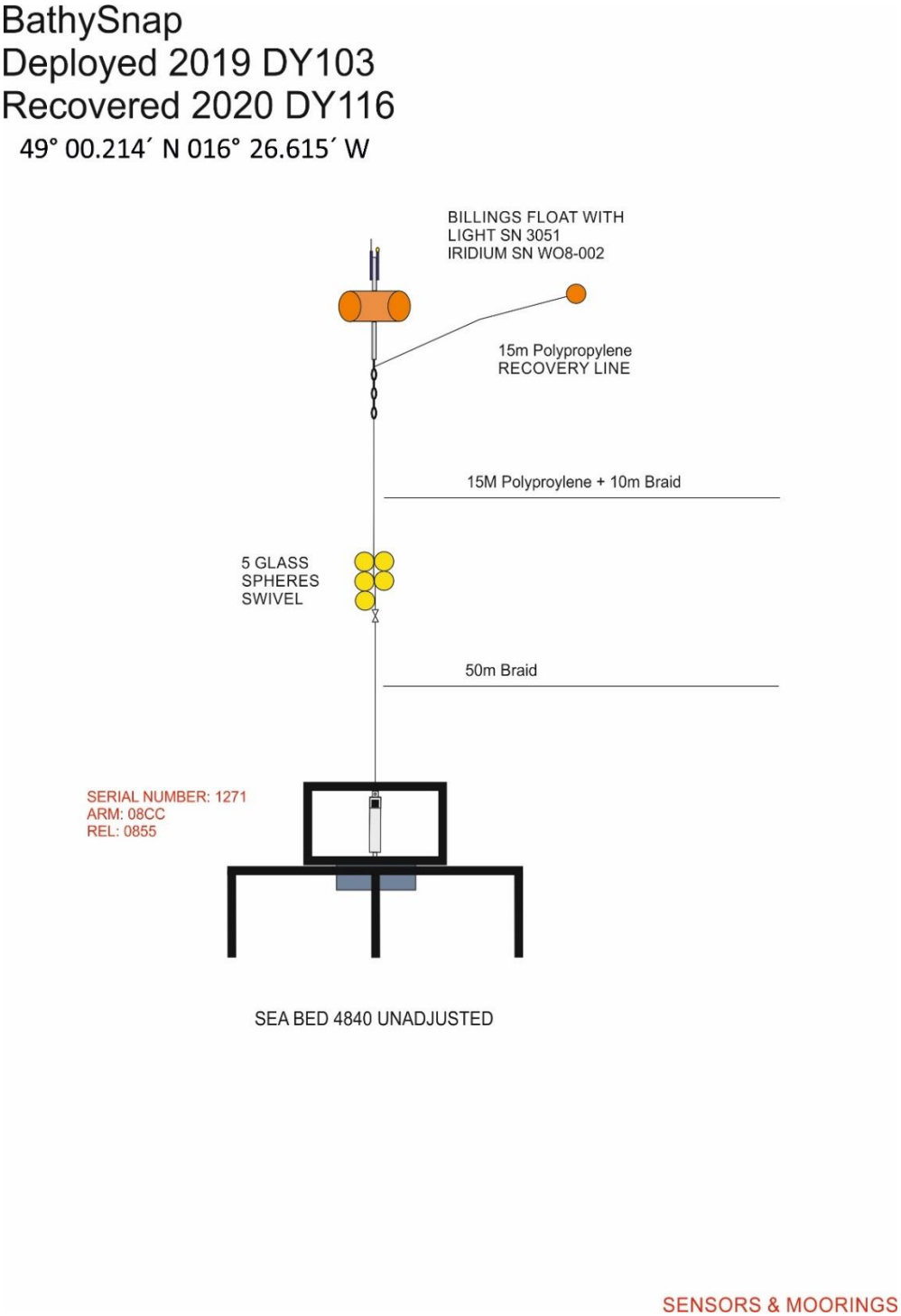
Screen short of position calculator for Whittard Canyon Mooring



Whittard Canyon Mooring as deployed (DY116-002)

Bathysnap

Bathysnap was recovered at approximately 11.30am on Thursday 19th. The Mooring was picked up by hook grapnel on the starboard aft quarter and retrieved onto the back deck with the use of a recovery line to the deck winch through a sheave on the starboard pedestal crane. Unfortunately, the pressure housings on the frame had all been compromised (details in scientific report, section 12).



Bathysnap mooring (DY103-039) recovered on DY116

PAP 1 Mooring

The recovered and deployed PAP moorings are both atypical of a PAP 1 mooring for either the old Balmoral or the new MOBLIS system. Due to the PAP 1 mooring parting shortly before DY116 sailed for the PAP site, we knew that there would be no surface expression. We also knew that the frame had not been retrieved with the buoy by the German research ship FS *Maria S. Merian* and that it was most likely still on the end of the rope at the PAP site.

PAP 1 Deployment

The rope for the new mooring had already been loaded onto the large PAP winch, this made a deployment followed by retrieval the preferred order of events. With the MOBILIS buoy in position all the final shackles were welded. The final shackle that fits the keel cross member is a galvanised double threaded hammer pinned type which was not welded. It is possible for the next deployment there could be a reserve shackle added in the cross member as a failsafe.

The MOBILIS was manoeuvred into position at the centre of the red zone from behind the port pedestal crane using that crane. The buoy was kept in contact with the deck for stability whilst dragging it into position, steadying lines were fed through the big eyes above the buoyancy and round the back of the pedestals through the fairleads to the capstans.

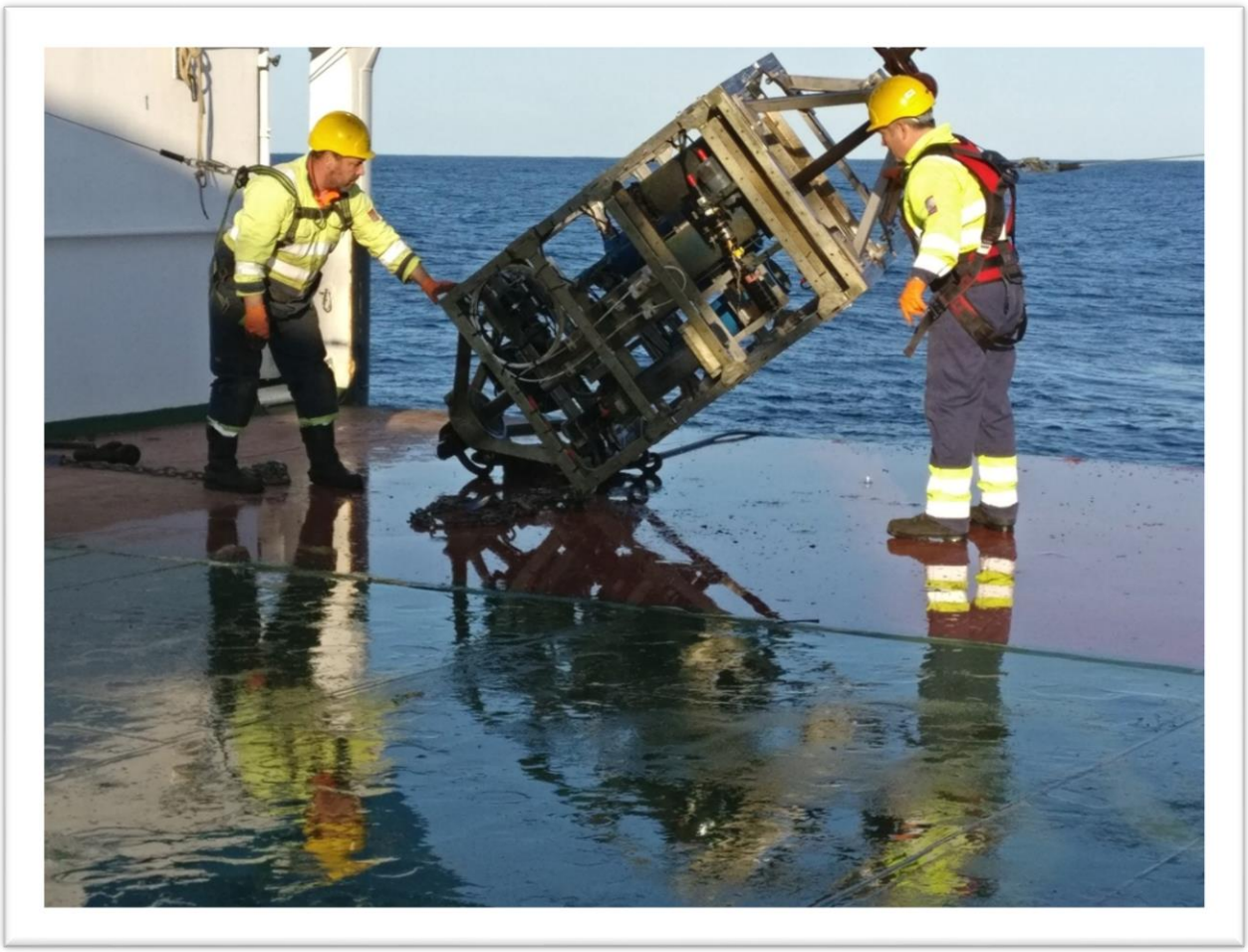
The buoy had been connected to the main warp through the centre sheave on the gantry and held on the large Seacatch. The Port crane was disconnected and stowed. At this stage the keel chain was leading from the keel straight up the deck through the scroll with a couple of turns on the PAP winch. The wire barrier on the red zone was then removed for deployment. The Buoy was lifted on the main warp and steadied into the sea with the two ropes. Once in the water and buoyant, the ship started ½ knot ahead and the winch payed out. The process continued until the line was broken to add the mid-water float and the last shackles were welded in position. The float and the rest of the line was then payed out until we were ready to release the anchor, which was done shortly after 6pm. Triangulation was attempted, but no useful acoustic responses could be detected.

First deployment of the new Met Office Mobilis buoy

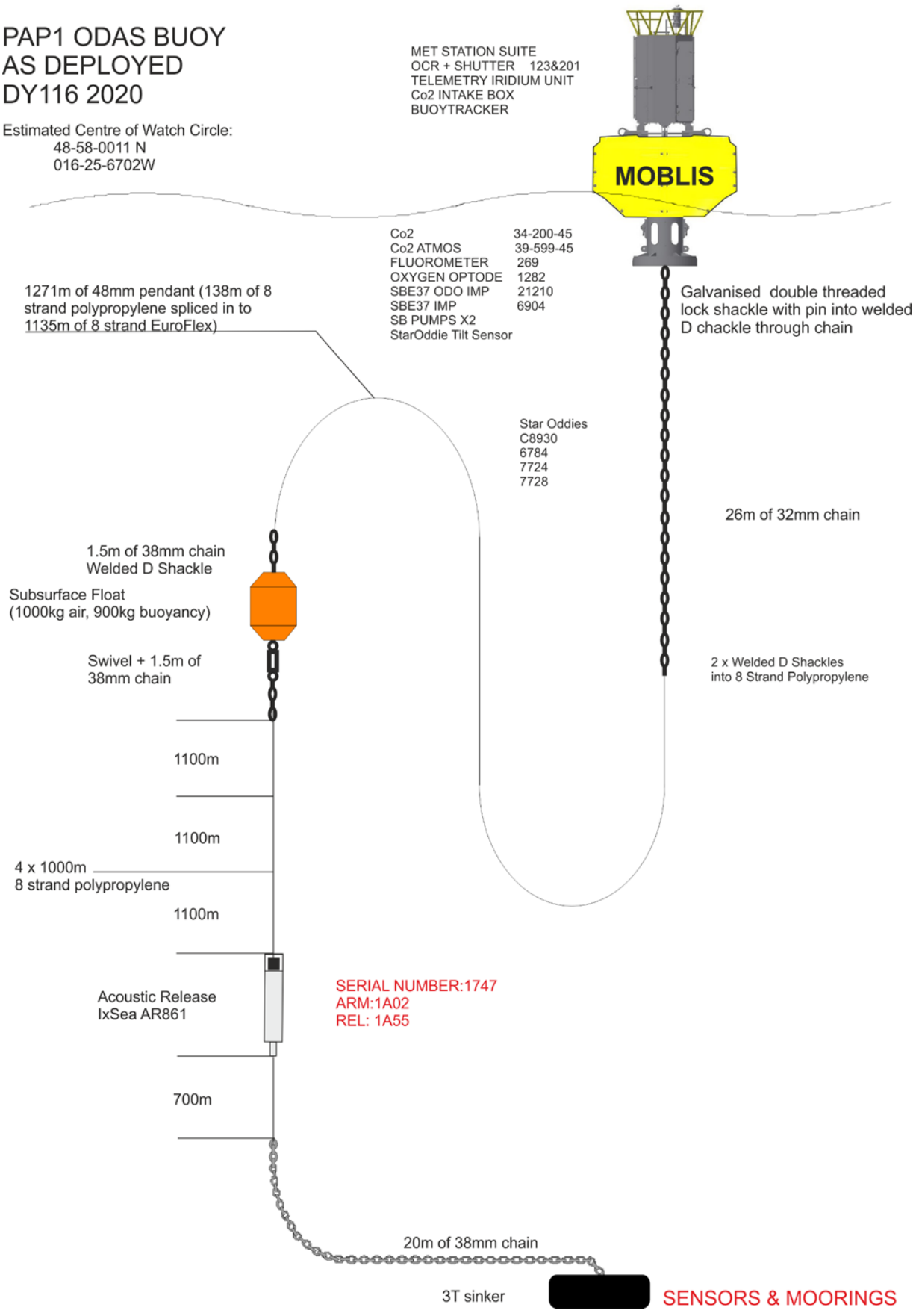
The new Mobilis PAP-1 buoy shortly after deployment (DY116-008)

PAP 1 Recovery

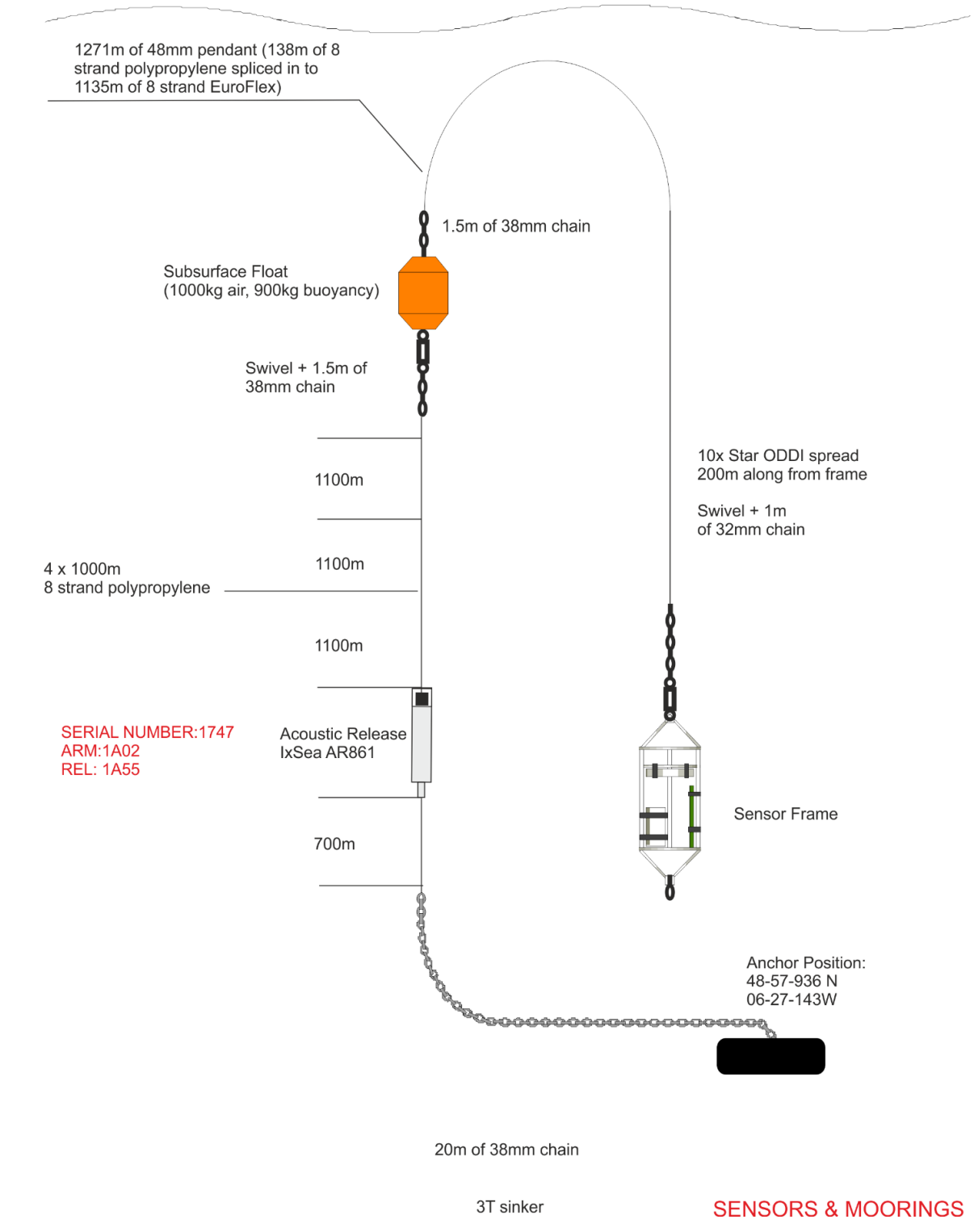
The PAP 1 mooring was released about 9:30 am and the subsurface buoy was spotted on the surface around 10:30 am. The rope spread over a distance running northwest, with a significant loop highlighted by birds at the surface at one end. This loop was where it was eventually decided to grapnel the line and begin recovery. The line was doubled up onto the winch and reeled in until the mid- water buoy came on deck about 14:45. The buoy was removed from the live line and the rope reconnected to wind in the remainder of the mooring. Star Oddis were removed from the last 200 m of rope before the instrument frame was retrieved to the deck at about 15:15 when over-side mooring work ended. At this point it became clear that the failure point of the mooring had been an un-welded shackle above the strain gauge link. The shackle was not welded on deployment because the requested weld set had not been supplied on the previous cruise.



Recovered sensor frame from PAP-1 (DY103-028)



PAP-1 as deployed (DY116-008)



PAP-1 as recovered following loss of surface buoy (sensor frame – DY103-028, remainder of mooring - JC165-058)

PAP 1 Deployment Plan

Set up

- Seacatch on 20m Plasma fixed to GP cable.
- Taglines tied off through fairleads back to capstans.
- 30m buoy chain connect to main rope and scrolled onto PAP ROMICA winch to control buoy keel on deployment.
- 5T deck winches for transferring load and paying out chain.

Procedure

Step 1. Using stern gantry and GP/main warp buoy lifted just off the deck and controlled with chain/PAP winch and stay lines through capstans.

Step 2. Gantry deploy whilst paying out GP and controlled via PAP winch and stay lines round capstans.

Step 3. Remove tag lines then release buoy start ship ahead and paying out chain on PAP winch.

Step 4. Continue to pay out once all chain deployed moving ahead.

Step 5. Pay out rope until mid-water buoy link. Stopper outboard line. Connect and weld shackles.

Step 6. Lift and deploy mid-water buoy with starboard crane and seacatch.

Step 7. Pay out rest of rope to 700m connection and stopper. Attach acoustic release. Continue to deploy 700 m final length of rope.

Step 8. Stopper at end of last length. Connect 30 m anchor chain and 3T anchor.

Step 9. 3T anchor to be lifted using crane (or deck winch through gantry?) and seacatch. 30m chain to be paid out from 5T deck winch under tension.

Step 10. Release.

PAP 3 Mooring

Normal best practice would be to deploy the new PAP 3 mooring before recovery of the current mooring for continuity of the data, however in accordance with the primary cruise objective of asset recovery and also due to the delayed cruise program there was already a gap in the sediment data, the recovery was attempted first.

PAP 3 Recovery

The PAP3 mooring was released on the morning of Thursday 19th and spotted on the surface before lunch. It is estimated that the billings float reached the surface in about 45 minutes. The sea conditions were between a 2 and a 3 at this point with slight white crests on some bits of the swell.

The ship manoeuvred the billings and pellet float to the hind starboard quarter, where it was grapnel hooked. The retrieval was a direct pull with the recovery line connected to the 5T deck winch and passed through a crane sheave and through the gantry and round the starboard side.

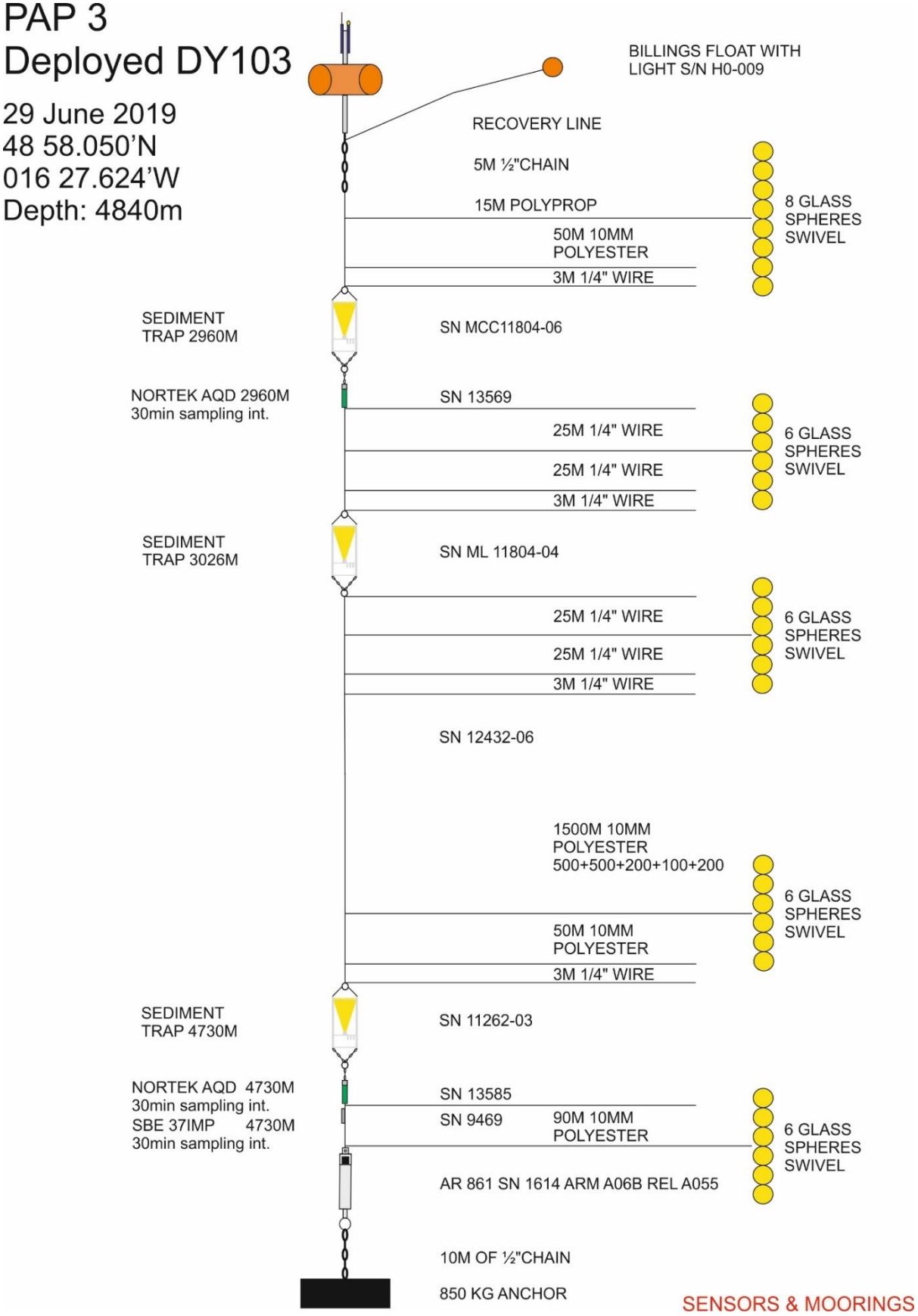
The mooring came in without incident, all three sediment traps intact, two NORTEKs and SBE37 in position. All data retrieved and logged.

PAP 3 Deployment

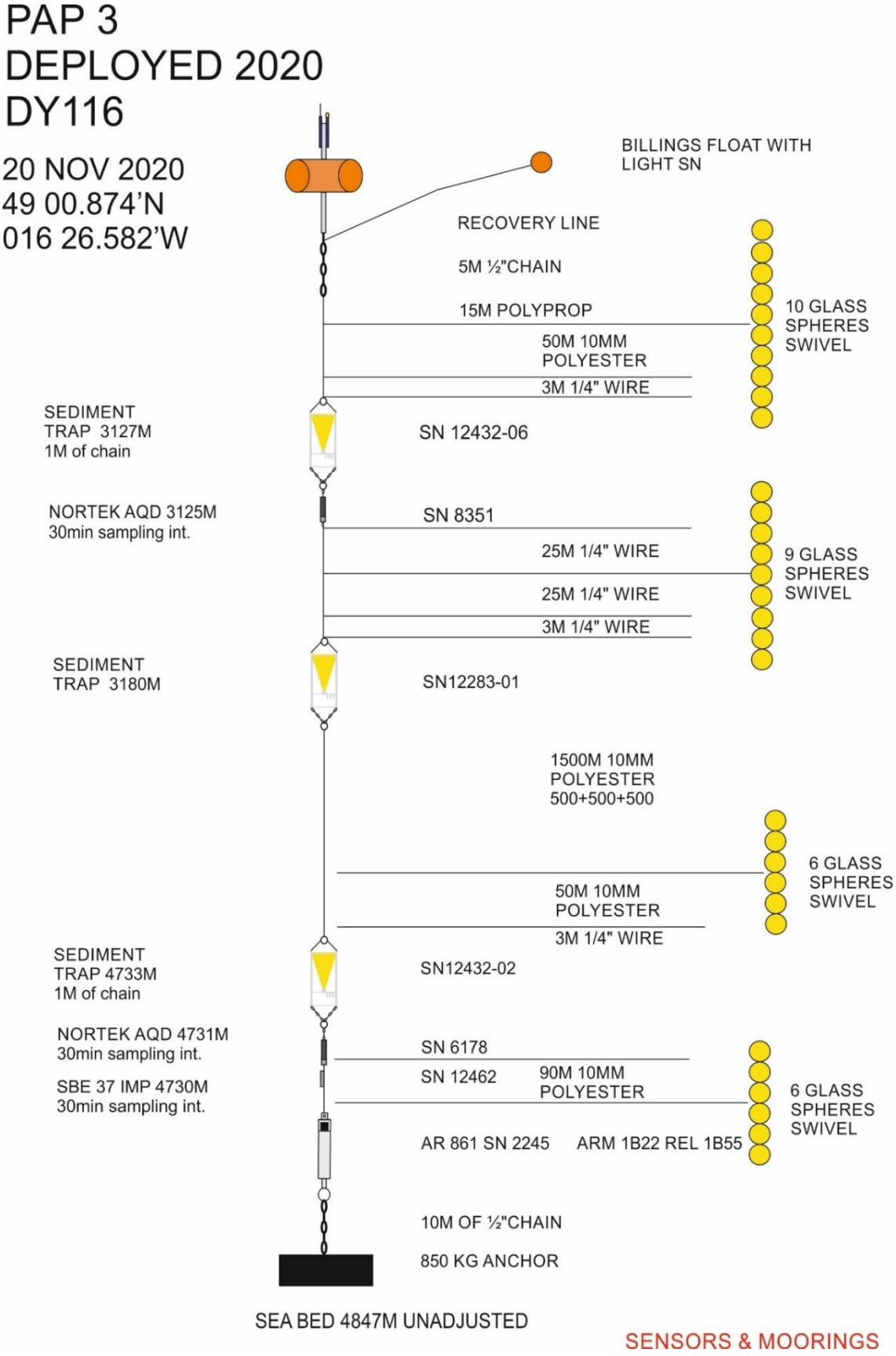
PAP 3 is deployed float first, the billings and pellet float going in to start. On this occasion the bottom of the mast which attaches the mooring to the billings float which contains the NOVATECH light and iridium beacon (added on this occasion), snapped at the point of deployment and the fell off the red zone. The crew were confident they could retrieve the disembodied billings and this was indeed done by manoeuvring the float on the starboard after quarter and grapnel hooking as per a normal mooring retrieval.

The billings float from the retrieved 2019 PAP3 mooring was utilised as a replacement and the procedure continued without further incident. The PAP 3 mooring was released 17.34 on Friday 20th November. The sea was starting to build a bit but the conditions were expected to remain workable for the next two days.

Triangulation was attempted twice on the PAP 3 mooring. Once the mooring had reached the seabed we attempted the first triangulation, but were unable to get the geometry to intersect.



PAP-3 (DY103-009) recovered on DY116



PAP-3 as deployed on DY116 (DY116-007)

PAP 3 Triangulation Attempts

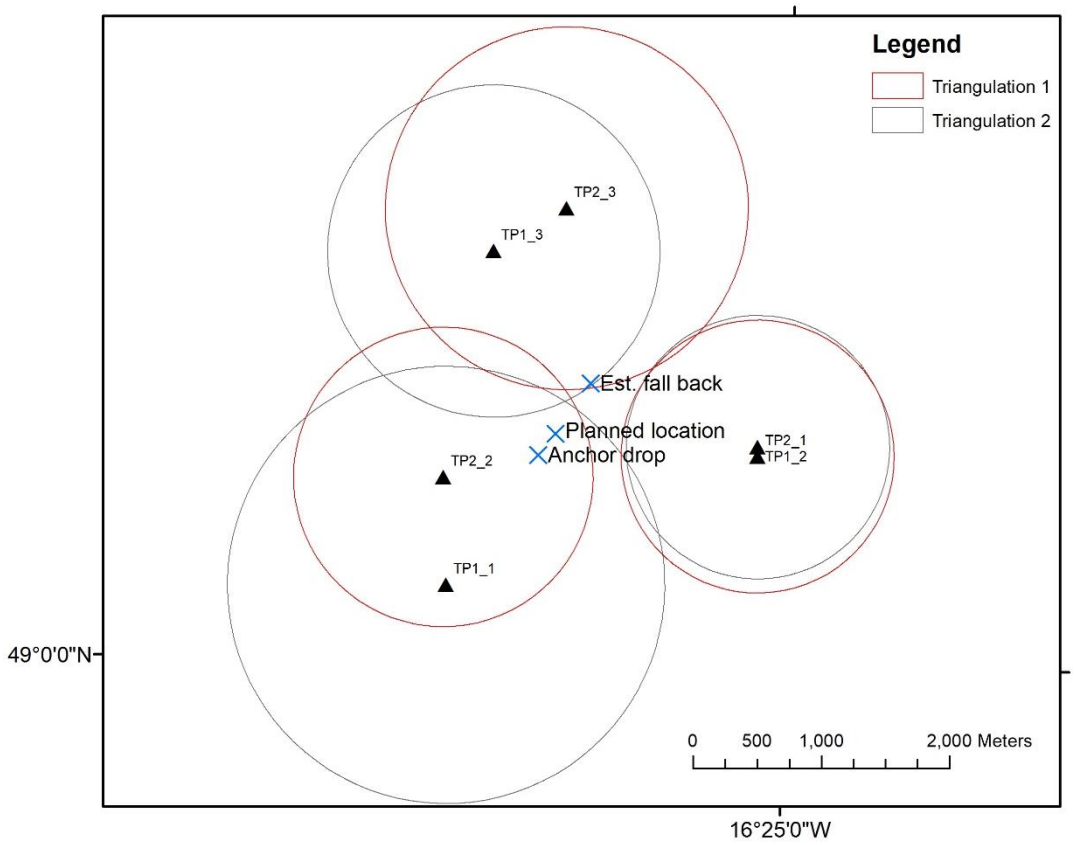


Chart showing attempted triangulation of PAP-3 mooring (TP = triangulation point)

CTD systems

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CTD System Configuration

One CTD system was prepared. The water sampling arrangement was a 24-way stainless steel frame system (s/n SBE CTD6) fitted with 24 of 10ltr OTE water samplers and MDS titanium CTD swivel s/n 1246-2. The initial sensor configuration was as follows:

- Sea-Bird 9plus underwater unit, s/n 09P-54047-0943,
- Sea-Bird 3P temperature sensor, s/n 03P-4380, Frequency 1 (primary)
- Sea-Bird 4C conductivity sensor, s/n 04C-4065, Frequency 2 (primary)
- Digiquartz temperature compensated pressure sensor, s/n 110557 Frequency 3
- Sea-Bird 3P temperature sensor, s/n 03P-4782, Frequency 4 (secondary)
- Sea-Bird 4C conductivity sensor, s/n 04C-4138, Frequency 5 (secondary)
- Sea-Bird 5T submersible pump, s/n 05T-6916, (primary)
- Sea-Bird 5T submersible pump, s/n 05T-6320, (secondary)
- Sea-Bird 32 Carousel 24 position pylon, s/n 32-31240-0423
- Sea-Bird 11plus deck unit, s/n 11P-24680-0589 (main)
- Sea-Bird 11plus deck unit, s/n 11P-34173-0676 (back-up logging)

The initial auxiliary input sensor configuration was as follows:

- Sea-Bird 43 dissolved oxygen sensor, s/n 43-0862 (V0) (Primary)
- WETLabs Light Scattering sensor, s/n BBRTD-5466 (V2)
- Tritech PA-200 altimeter, s/n 6196.112522 (V3)
- CONTROS Hydro-C CO2 sensor, s/n CO2T-0319-001 (V4)
- Chelsea Aquatracka MKIII fluorometer, s/n 8-2615-124 (V6)
- Chelsea 2Pi PAR sensor, s/n PAR07

Sea-Bird 9plus configuration file DY116_SS_nmea.xmlcon was used for cast 001. Configuration file DY116_PAR_noCO2_nmea.xmlcon was used for casts 002, 003 & 005. Configuration file DY116_PAR_noCO2_UWIRR_nmea.xmlcon was used for casts 004 & 006.

Additional sensors mounted on the frame:

- CONTROS Hydro-C CO2 battery housing, s/n 20C-001 (cast 001)
- CONTROS re-chargeable battery pack, s/n 20S-001 (cast 001)
- Sonardyne WMT acoustic positioning beacon, s/n 312366-006 (cast 002)
- Sonardyne WMT acoustic positioning beacon, s/n 312390-004 (casts 003 – 006)

Total number of casts - 6

Casts deeper than 2000m - 4

Deepest cast – 4707m

Technical Report

S/S CTD on Wire CTD1

All casts were carried out using CTD6, which was terminated using the potting method during the mobilisation of DY120. Before electrically terminating the wire it had a Megger value of 160 MOhms. The wire had been potted and streamed prior to the cruise.

The CTD cable was electrically tested after terminating and had a 'Megger' value of > 550 MOhms. The wire resistance through the CTD wire only was 65.4 Ohms. It was tested again and had a Megger value of >550MOhms and 65.0 Ohms. At the beginning of DY116 the readings were Megger value of >550MOhms and 65.5 Ohms

It was then load tested as per standard CTD load test of 5 minutes at 05.T, 1.0T, 1.5T and 2.0T.

The mechanical termination did not slip under load.

No issues were encountered with any of the standard CTD sensors that were mounted on the frame. The swivel seemed to work fine with no problems. The mechanical termination was checked with a torque wrench after most casts and no slipping of the mechanical termination was observed.

The primary T, C and Oxygen sensors were on the vane.

The Active Heave Compensation system (AHC) was engaged for casts 002, 003 & 005.

Cast 001 was a test cast to 3000m to correct minor spooling issues on CTD1, to test acoustic release s/n 255 and to obtain data from the CONTROS Hydro-C CO_2 sensor, as well as to check water sampler integrity and the performance of the Sea-Bird 43 dissolved oxygen sensor. Unfortunately the PAR sensor (s/n 07) failed at approximately 2700m during the down cast which caused an open circuit on the CTD sea cable. As a result no water samples were taken. The CO_2 sensor is internally logging, and

a complete data set for the deployment was obtained. Unfortunately the CO_2 sensor head again appears to have water ingress as % humidity readings from maximum depth and on the up cast were off scale.

The CONTROS CO2 sensor was connected to the 9plus for data logging, display and analog voltage output, and powered by an external battery pack.

A recently purchased Sonardyne WMT was installed on the CTD frame beginning cast 002. The beacon appeared to function normally during the deployment; range, bearing and depth all were output consistently throughout. Upon recovery the beacon was connected to the Sondardyne 6G software for diagnostics and battery re-charging. During the normal communication tests the Hardware Test failed. The communications log indicates a Real Time Clock failure, and a return to the manufacturer for repair. A spare, older WMT was installed on the CTD frame as a replacement for casts 003 onwards.

AUTOSAL

A Guildline 8400B, s/n 68958, was installed in the Salinometer Room as the main instrument for salinity analysis. The Autosal set point was 21C, and samples were processed according to WOCE cruise guidelines: The salinometer was standardized at the beginning of the first set of samples, and checked with an additional standard analysed prior to setting the RS. Once standardized the Autosal was not adjusted for the duration of sampling.

A standard was analysed after each crate of samples to monitor & record drift (second standard analysed after sample 24, third standard analysed after sample 48, etc).

Standards were labelled sequentially and decreasing, beginning with number 999. Standard deviation set to 0.00002. The electronic standby value after the standardisation was stable at 5660 to 5661 for the duration of the cruise. The spare salinometer, s/n 65764, was not used.

In total 2 CTD crates were run and 2 TSG crates.

Configuration files

Cast DY116_001 (Station number: DY116-001)

Date: 11/12/2020
Instrument configuration file: Q:\CTD\DY116\SeaSave setup files\DY116_SS_nmea.xmlcon
Configuration report for SBE 911plus/917plus CTD

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

1) Frequency 0, Temperature
Serial number : 03P-4380
Calibrated on : 14 June 2018
G : 4.37208689e-003
H : 6.54988408e-004
I : 2.37424960e-005
J : 1.86148776e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity
Serial number : 04C-4065
Calibrated on : 14 March 2018
G : -9.85576737e+000
H : 1.48758413e+000
I : -2.41871604e-003
J : 2.63830958e-004
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 : 21 September 2018
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 : 1.00002000
Offset : 2.14950
AD590M : 1.280700e-002
AD590B : -9.299640e+000

4) Frequency 3, Temperature, 2
Serial number : 03P-4782
Calibrated on : 13 March 2018
G : 4.34998383e-003
H : 6.36619788e-004
I : 2.09700604e-005
J : 1.78036895e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2
Serial number : 04C-4138
Calibrated on : 14 March 2018
G : -9.84094910e+000
H : 1.45317113e+000
I : -2.13516384e-003
J : 2.55747427e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

6) A/D voltage 0, Oxygen, SBE 43
Serial number : 43-0862
Calibrated on : 13 March 2019
Equation : Sea-Bird
Soc : 5.47800e-001
Offset : -5.02600e-001
A : -4.97970e-003
B : 1.74410e-004
C : -3.03980e-006
E : 3.60000e-002
Tau20 : 1.50000e+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, OBS, WET Labs, ECO-BB
Serial number : BBRTD-5466
Calibrated on : 2 April 2019
ScaleFactor : 0.003307
Dark output : 0.051000

9) A/D voltage 3, Altimeter
Serial number : 6196.112522
Calibrated on : 11 July 2013
Scale factor : 15.000
Offset : 0.000

10) A/D voltage 4, User Polynomial
Serial number : CO2T-0319-001
Calibrated on : 21 January 2020
Sensor name : CONTROS Hydro-C
A0 : -0.40056080
A1 : 200.28040000
A2 : 0.00000000
A3 : 0.00000000

11) A/D voltage 5, Free

12) A/D voltage 6, Fluorometer, Chelsea Aqua 3
Serial number : 88-2615-124
Calibrated on : 1 August 2019
VB : 0.251540
V1 : 1.835380
Vacetone : 0.597430
Scale factor : 1.000000
Slope : 1.000000
Offset : 0.000000

13) A/D voltage 7, PAR/Irradiance, Biospherical/Licor
Serial number : PAR07
Calibrated on : 16 July 2018
M : 0.47477300
B : 1.05881300
Calibration constant : 100000000000.00000000
Conversion units : Watts/m^2
Multiplier : 0.99950000
Offset : 0.00000000

Scan length : 41

Casts DY116_002 (Stn. no. DY116-003), DY116_003 (Stn. no. DY116-005) & DY116_005 (Stn. no. DY116-010)

Date: 11/18/2020
Instrument configuration file: Q:\CTD\DY116\SeaSave setup files\DY116_PAR_noCO2_nmea.xmlcon
Configuration report for SBE 911plus/917plus CTD

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

1) Frequency 0, Temperature
Serial number : 03P-4380
Calibrated on : 14 June 2018
G : 4.37208689e-003
H : 6.54988408e-004
I : 2.37424960e-005
J : 1.86148776e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity
Serial number : 04C-4065
Calibrated on : 14 March 2018
G : -9.85576737e+000
H : 1.48758413e+000
I : -2.41871604e-003
J : 2.63830958e-004
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 : 21 September 2018
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 : 1.00002000
Offset : 2.14950
AD590M : 1.280700e-002
AD590B : -9.299640e+000

4) Frequency 3, Temperature, 2
Serial number : 03P-4782
Calibrated on : 13 March 2018
G : 4.34998383e-003
H : 6.36619788e-004
I : 2.09700604e-005
J : 1.78036895e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2
Serial number : 04C-4138
Calibrated on : 14 March 2018
G : -9.84094910e+000
H : 1.45317113e+000
I : -2.13516384e-003
J : 2.55747427e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

6) A/D voltage 0, Oxygen, SBE 43
Serial number : 43-0862
Calibrated on : 13 March 2019
Equation : Sea-Bird
Soc : 5.47800e-001
Offset : -5.02600e-001
A : -4.97970e-003
B : 1.74410e-004
C : -3.03980e-006
E : 3.60000e-002
Tau20 : 1.50000e+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, OBS, WET Labs, ECO-BB
Serial number : BBRTD-5466
Calibrated on : 4 February 2019
ScaleFactor : 0.003307
Dark output : 0.051000

9) A/D voltage 3, Altimeter
Serial number : 6196.112522
Calibrated on : 11 July 2013
Scale factor : 15.000
Offset : 0.000

10) A/D voltage 4, Free

11) A/D voltage 5, Free

12) A/D voltage 6, Fluorometer, Chelsea Aqua 3
Serial number : 88-2615-124
Calibrated on : 1 August 2019
VB : 0.251540
V1 : 1.835380
Vacetone : 0.597430
Scale factor : 1.000000
Slope : 1.000000
Offset : 0.000000

13) A/D voltage 7, PAR/Irradiance, Biospherical/Licor
Serial number : PAR06
Calibrated on : 8 January 2018
M : 0.47125500
B : 1.13672300
Calibration constant : 100000000000.00000000
Conversion units : Watts/m^2
Multiplier : 0.99930000
Offset : 0.00000000

Scan length : 41

Casts DY116_004 (Stn. no. DY116-012) & DY116_006 (Stn. no. DY116-013)

Date: 11/21/2020
Instrument configuration file: Q:\CTD\DY116\SeaSave setup files\DY116_PAR_noCO2_UWIRR_nmea.xmlcon
Configuration report for SBE 911plus/917plus CTD

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

1) Frequency 0, Temperature
Serial number : 03P-4380
Calibrated on : 14 June 2018
G : 4.37208689e-003
H : 6.54988408e-004
I : 2.37424960e-005
J : 1.86148776e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

2) Frequency 1, Conductivity
Serial number : 04C-4065
Calibrated on : 14 March 2018
G : -9.85576737e+000
H : 1.48758413e+000
I : -2.41871604e-003
J : 2.63830958e-004
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 : 21 September 2018
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 : 1.00002000
Offset : 2.14950
AD590M : 1.280700e-002
AD590B : -9.299640e+000

4) Frequency 3, Temperature, 2
Serial number : 03P-4782
Calibrated on : 13 March 2018
G : 4.34998383e-003
H : 6.36619788e-004
I : 2.09700604e-005
J : 1.78036895e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

5) Frequency 4, Conductivity, 2
Serial number : 04C-4138
Calibrated on : 14 March 2018
G : -9.84094910e+000
H : 1.45317113e+000
I : -2.13516384e-003
J : 2.55747427e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

6) A/D voltage 0, Oxygen, SBE 43
Serial number : 43-0862
Calibrated on : 13 March 2019
Equation : Sea-Bird
Soc : 5.47800e-001
Offset : -5.02600e-001
A : -4.97970e-003
B : 1.74410e-004
C : -3.03980e-006
E : 3.60000e-002
Tau20 : 1.50000e+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, OBS, WET Labs, ECO-BB
Serial number : BBRTD-5466
Calibrated on : 4 February 2019
ScaleFactor : 0.003307
Dark output : 0.051000

9) A/D voltage 3, Altimeter
Serial number : 6196.112522
Calibrated on : 11 July 2013
Scale factor : 15.000
Offset : 0.000

10) A/D voltage 4, Free

11) A/D voltage 5, PAR/Irradiance, Biospherical/Licor
Serial number : PAR05
Calibrated on : 2 October 2020
M : 0.47353300
B : 1.11774500
Calibration constant : 100000000000.00000000
Conversion units : Watts/m^2
Multiplier : 0.99890000
Offset : 0.00000000

12) A/D voltage 6, Fluorometer, Chelsea Aqua 3
Serial number : 88-2615-124
Calibrated on : 1 August 2019
VB : 0.251540
V1 : 1.835380
Vacetone : 0.597430
Scale factor : 1.000000
Slope : 1.000000
Offset : 0.000000

13) A/D voltage 7, PAR/Irradiance, Biospherical/Licor, 2
Serial number : PAR06
Calibrated on : 8 January 2018
M : 0.47125500
B : 1.13672300
Calibration constant : 100000000000.00000000
Conversion units : Watts/m^2
Multiplier : 0.99930000
Offset : 0.00000000

Scan length : 41

SENSOR INFORMATION

SHIP: RRS DISCOVERY	CRUISE: DY116
FORWARDING INSTRUCTIONS / ADDITIONAL INFORMATION: **Main Stainless Steel 24-way CTD frame on board at end of DY116**	
Checked By: Tom Ballinger / Paul Henderson	DATE: 21 November 2020

Instrument / Sensor	Manufacturer/ Model	Serial Number	Channel	Casts Used
Primary CTD deck unit	SBE 11plus	11P-24680-0589	n/a	All casts
CTD Underwater Unit	SBE 9plus	09P-54047-0943	n/a	All casts
Stainless steel 24-way CTD frame	NOCS	SBE CTD6	n/a	All casts
Primary Temperature Sensor	SBE 3P	03P-4380	F0	All casts
Primary Conductivity Sensor	SBE 4C	04C-4065	F1	All casts
Digiquartz Pressure sensor	Paroscientific	110557	F2	All casts
Secondary Temperature Sensor	SBE 3P	03P-4782	F3	All casts
Secondary Conductivity Sensor	SBE 4C	04C-4138	F4	All casts
Primary Pump	SBE 5T	05T-6916	n/a	All casts
Secondary Pump	SBE 5T	05T-6320	n/a	All casts
24-way Carousel	SBE 32	32-31240-0423	n/a	All casts
Primary Dissolved Oxygen Sensor	SBE 43	43-0862	V0	All casts
Light Scattering Sensor	WETLabs LSS	BBRTD-5466	V2	All casts
Altimeter	Tritech PA-200	6196.112522	V3	All casts
CO2 Sensor	CONTROS HydroC CO2	CO2T-0319-001	V4	Cast 001
CO2 Battery Housing	CONTROS HydroB 20C	HydroB-Housing-20C-001	n/a	Cast 001
CO2 Re-chargeable Battery Pack	CONTROS HydroB 20S	HydroB-Cell-20S-001	n/a	Cast 001
CO2 Pump	SBE 5T	05T-8831	n/a	Cast 001
PAR Downward-looking UWIRR	CTG 2pi PAR	PAR 05	V5	Casts 004 & 006
Fluorometer	CTG Aquatracka MKIII	88-2615-124	V6	All casts
PAR Upward-looking DWIRR	CTG 2pi PAR	PAR 07	V7	Cast 001
PAR Upward-looking DWIRR	CTG 2pi PAR	PAR 06	V7	Casts 004 & 006
10L Water Samplers	Ocean Test Equipment	1A-24A	n/a	All casts
Titanium EM CTD Swivel	Machinery Development Services/V2_2	1246-2	n/a	All casts
Acoustic Positioning Beacon	Sonardyne WMT 8190-7212-A4	312366-006	n/a	Cast 002
Acoustic Positioning Beacon	Sonardyne WMT 8190-7212-A4	312930-004	n/a	Casts 003 - 006

Data Processing

The table below lists the Sea-Bird processing routines run by NMF staff (if any). Note this is only the modules that were run by NMF, not by scientific staff.

Module	**Run?**	**Comments**
Configure	N	
Data Conversion	Y	As per BODC guidelines Version1.0 October 2010 (Oxygen Concentration umol/l and umol/kg, Latitude and Longitude (degrees), Scan Count, Time and Pressure Temperature preferred by S. Hartman)
Bottle Summary	Y	As per BODC guidelines Version1.0 October 2010, with above variables added (except not averaging Scan Count and Time)
Mark Scan	N	
Align CTD	Y	As per BODC guidelines Version1.0 October 2010 **(dissolved oxygen advanced 6 seconds)** (appended file name)
Buoyancy	N	
Cell Thermal Mass	Y	As per BODC guidelines Version1.0 October 2010 (appended file name)
Derive	Y	As per BODC guidelines Version1.0 October 2010 (appended file name)
Bin Average	Y	As per BODC guidelines Version1.0 October 2010 **(1 metre depth bins preferred by S. Hartman)** (appended file name)
Filter	Y	As per BODC guidelines Version1.0 October 2010 (appended file name)
Loop Edit	Y	As per BODC guidelines Version1.0 October 2010 (appended file name)
Wild Edit	N	Not applicable.
Window Filter	N	
ASCII In	N	
ASCII Out	Y	As per BODC guidelines Version1.0 October 2010 (SVP Chen-Milero for EM122 calibration requested by M. Bridger) (appended file name)
Section	N	
Split	N	
Strip	Y	As per BODC guidelines Version1.0 October 2010 (appended file name)
Translate	N	
Sea Plot	N	
SeaCalc II	N	

Scientific Ship Systems

Martin Bridger

Ship Scientific Systems (SSS) is responsible for operating and managing the Ship's scientific information technology infrastructure, data acquisition, compilation and delivery, and the suite of ship-fitted instruments and sensors in support of the Marine Facilities Programme (MFP).

SCIENTIFIC COMPUTER SYSTEMS

UNDERWAY DATA ACQUISITION

Data from the suite of ship-fitted scientific instrumentation was aggregated onto a network drive on the ship's file server. This was available throughout the voyage in read-only mode to permit scientists to work with the data as it was acquired. A Public network folder was also available for scientists to share files.

A copy of these two drives are written to the end-of-cruise disks that are provided to the Principal Scientist and the British Oceanographic Data Centre (BODC).

The data acquisition systems used on this cruise are detailed in the table below. The data and data description documents are filed per system in the Data and Documentation directories respectively within Ship Systems folder on the cruise data disk.

In addition to the following NetCDF and raw NMEA files, legacy Level-C column delimited text file format data is available in in Ship_Systems/Data/Level-C/Pro_Data/ascii/{datafile}.txt

Files included:

bestnav.txt, gyro_s.txt, pro_wind.txt, surfmet.txt, ea640.txt, gyropmv.txt, relmov.txt, winch.txt, gps_cnav.txt, posmvpos.txt, sbe45.txt

Data acquisition systems used on this cruise.

Data acquisition system	*Usage*	*Data products*	*Directory system name*
Ifremer TechSAS	Continuous	NetCDF ASCII pseudo-NMEA	/TechSAS/
NMF RVDAS	Continuous	ASCII Raw NMEA SeaDataNet NetCDF	/RVDAS/
Kongsberg SIS (EM122)	Intermittent	Kongsberg .all	/Acoustics/EM-122/
Kongsberg SIS (EM710)	Unused	Kongsberg .all	/Acoustics/EM-710/
Kongsberg SBP	Unused	None	/Acoustics/SBP-120/
Kongsberg EA640	Intermittent	None, redirected to Techsas/RVDAS RAM	/Acoustics/EA-640/
Kongsberg EK60/80	Unused		/Acoustics/EK-60/
UHDAS (ADCPs)	Intermittent	ASCII raw, RBIN, GBIN, CODAS files	/Acoustics/ADCP/
VMDAS (ADCPs)	Unused		/Acoustics/ADCP/
Sonardyne Ranger2	Intermittent	None, redirected to Techsas/RVDAS RAM	/Acoustics/USBL/

INTERNET PROVISION

Satellite communications were provided with both the VSAT and Fleet Broadband systems.

While underway, the ship operated with bandwidth controls to prioritise business use.

VSAT operated well until 10pm 23rd November, when it stopped working. Despite liaising with SIRM (whom we have the contract with), and Speedcast (their partner who provide the service to us) this was not resolved until an engineer joined the ship on arrival back in Southampton.

OUTREACH AND STREAMING

During the mobilisation Nick Rundle and members of the scientific party engaged with a school on the Isle of Wight, this was achievable by the use of the NOC WiFi, and good weather.

7. PAP1 - Observatory scientific report

Sue Hartman, et al

General Description

The PAP1 system comprises sensors connected to either a buoy telemetry electronics unit or a frame data hub unit and their data is sent using Iridium to our server at NOC. The telemetry communication is intended to provide remote quasi-real time data. The buoy also hosts an entirely separate system provided by the UK Met Office, which has its own telemetry unit and a suite of meteorological sensors measuring wind velocity, wave spectra and atmospheric pressure.

The last PAP1 system was deployed July 2019 on RRS *Discovery* cruise DY103 and was recovered by FS *Maria S. Merrian*.

Recovered PAP1 (FS *Maria S. Merian*)

Met Office Odas buoy with NOC sensors deployed on DY103. PAP1 ODAS buoy was adrift from ~23rd October 2020, after over 15 months deployment. It headed east towards the Channel and was tracked using the external GPS Tracker (4 hourly alerts). The priority was to retrieve the buoy and get the data back as there was no near real time data transmission. Maps were plotted daily (with thanks to Jon and Brian, see start of this cruise report) so that the buoy could be collected by German colleagues working in the area. Dan Comben liaised with the ship and the buoy was retrieved on the FS *Maria S Merian* (5th Nov 2020). We are very grateful to them for the recovery, cleaning, dismantling and for shipping the buoy back to us.

DY103 PAP1 buoy onboard FS Maria S Merian, showing the extent of biofouling

DY103 buoy CO_2 (SN 34-201-45) and microcat ODO (SN 16503) back at NOC

DY103 SeaFET pH sensor and battery pack (SN63) at NOC

There was some puzzling damage to the buoy's main hatch (to be investigated). The equipment was inspected by Jon (and where possible data was downloaded). The following were moved to the NMF 341 area for download of data in December (once the necessary leads and logger returned to NOC). Equipment will be shipped back to seabird for calibration, repair and replacement as appropriate.

- Seabird 5P pump
- SeaBird SBE 37IMP-ODO MicroCAT (s/n 16503) (requires recalibration)
- SeaBird SBE-37IMP MicroCAT (s/n 9475) (requires recalibration)
- Satlantic OCR-507 ICSA (buoy) (s/n 226) (requires recalibration)
- Bioshutter II (s/n 230) (at the time of writing it was not clear if this was functional)
- Satlantic SeaFET pH (s/n 63)
- Grey plastic OceanSonics battery housing (s/n 2303)
- BPA-50 battery housing (s/n 252)
- 5 x Star-Oddi sensors

- C8928 on the Buoy
- S6782 on the chain at 5m
- S7562 on the chain at 10m
- S7565 on the chain at 15m
- S7566 on the chain at 20m

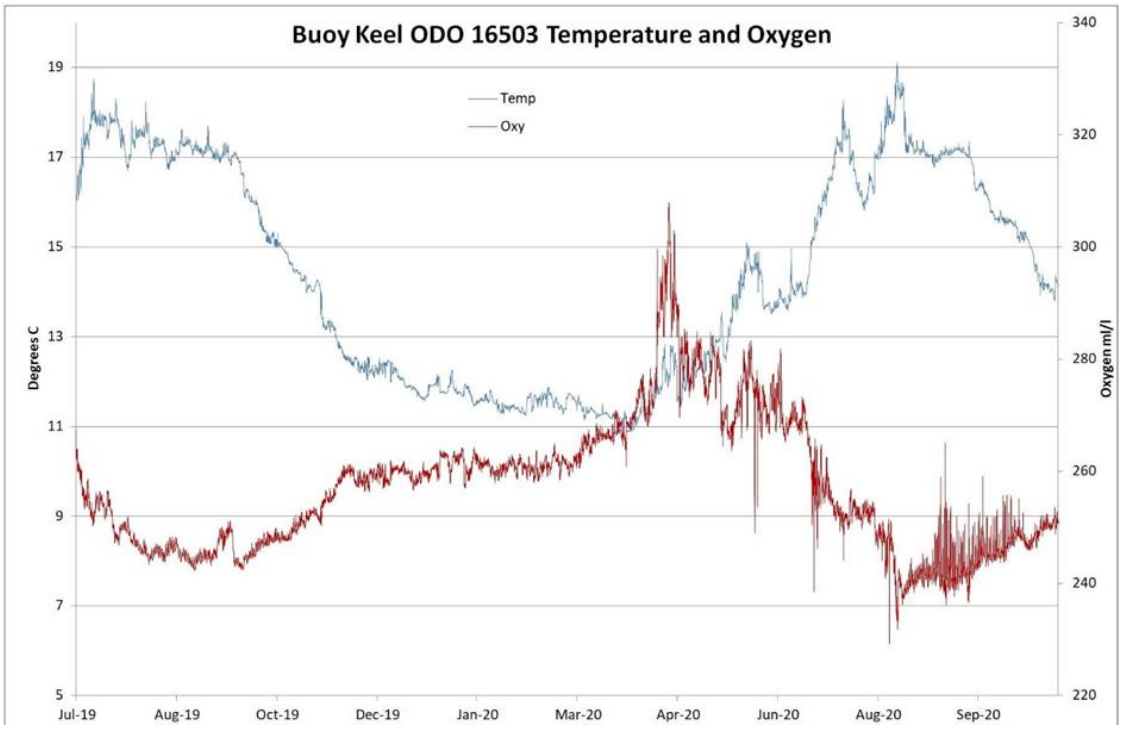
The Pro-Oceanus CO2-Pro- atmospheric sn 34-201-45 had flooded and very little data were retrievable (~1 month) suggesting that the flooding happened early in the deployment.

'Dry box' section of Pro-CO2 atmos sampler

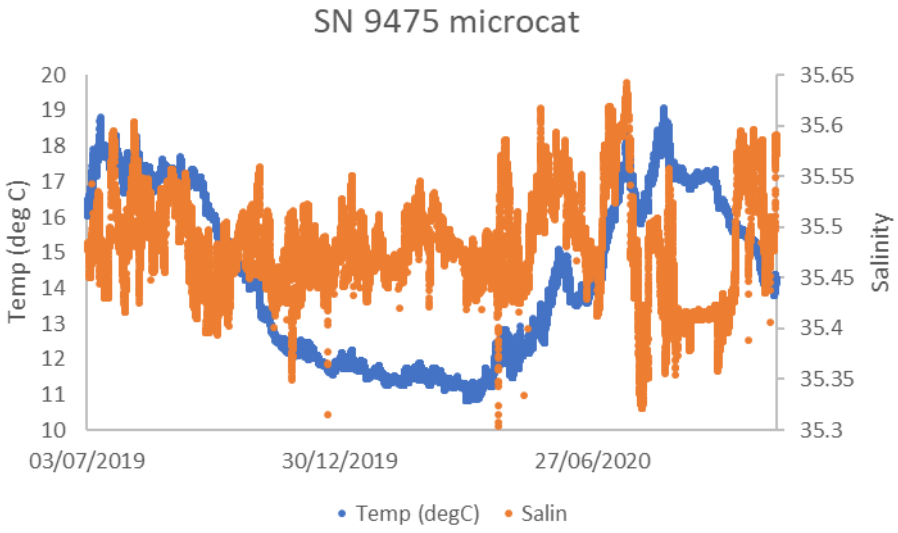
Photos of the Pro-CO2 atmos back at NOC (water side of the instrument)

At the time of writing the air-side box may be salvageable and has been returned to Pro-Oceanus. If water was able to get past the water trap and hydrophobic filters in it, there are two additional hydrophobic filters inside the submersible sensor portion of the sensor to prevent water ingress this way. The damaged bulkhead looks more problematic on the ATM sensor. Also, the ATM tubing had a connector part way up from the sensor. This was added on DY103 as the ATM was turned around at

sea from the previous deployment. It is best to avoid having these in the sensor as it adds an additional failure point. The next one should be prepared with an extra meter of tubing (especially now we are using the taller Mobilis buoy). Jon downloaded and cleaned the two PAP1 Buoy keel MicroCATS.

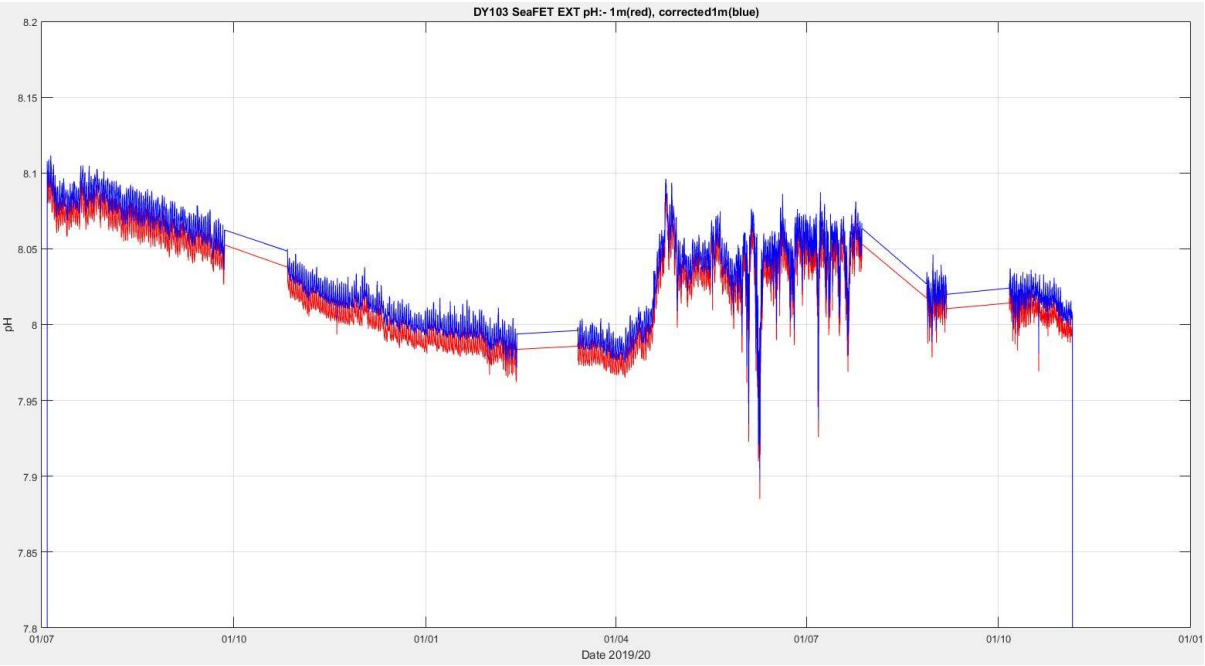


Microcat ODO SN16503 temperature and oxygen data from DY103 deployed buoy



Microcat SN9475 T/S data from DY103 deployed buoy (3/7/19-5/11/20)

When the cables and loggers were back at NOC after DY116 other data were downloaded from Star Oddi and SeaFET sensors.



pH data from the buoy SeaFET deployed on DY103

PAP-1 sensor frame recovery on DY116:

The mooring broke above the sensor frame (which then sank below the midwater buoy at 1000 m). The frame went deeper than most of the sensors are pressure rated to. The sensors (data and batteries) are mostly lost. These will all have to be reported as a write off on IMS.

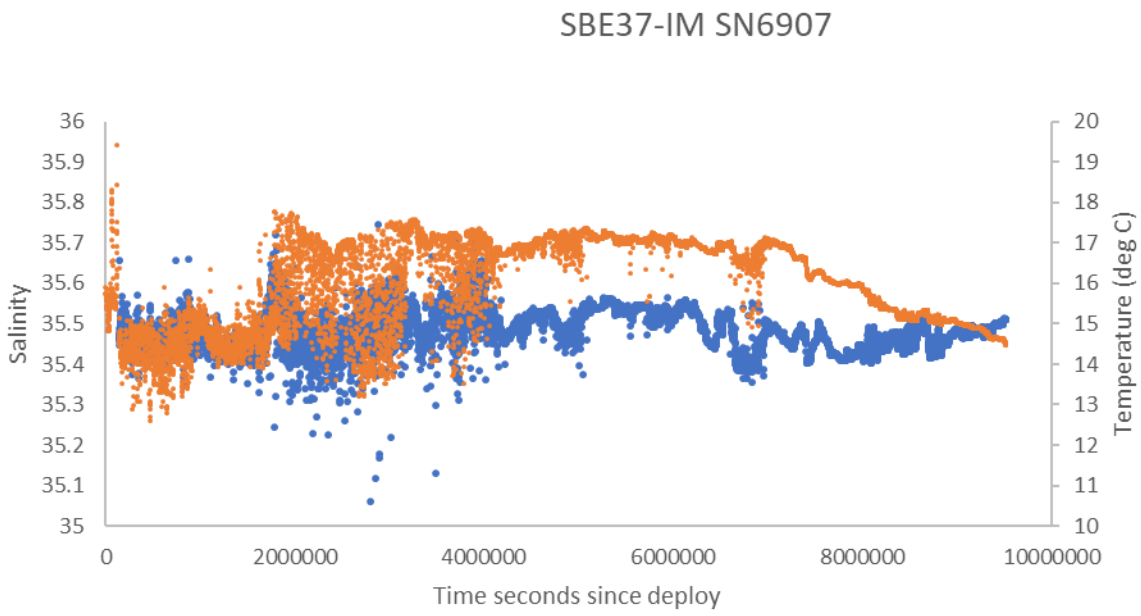
Some of the PAP1 frame sensors at NOC. SBE SN 6907 was functional and possibly the PO_4 cycle.

Sensors where no data is expected:

Sensor	SN
SeaFET pH	257
OCR upward light and biowiper	1428 and 219
OCR downward light and biowiper	95 and 124
Pro-CV CO2 and pump	38-560-75
FLNTSUB chl	3050
SUNA nitrate	745
SeaGuard logger	1614
Optode Oxygen	1278
Turner flurometer and zebratech wiper	
GTD gas tension	38-505-31
SeaBird ODO T/S/O2	10315

The **Hydro PO4 SN 458** looked to be intact. However, when hooked up to a power supply it still would not communicate (to be investigated at NOC).

The **MicroCAT SN 6907** (temperature and salinity), was rated to 1000 m. Despite going below this depth it was possible to retrieve some data, though the battery was low. The instrument had been set up at 15-minute intervals from 02/07/2019 00:00:01 on DY103. However, it only ran for 4 months, until 20/10/2019 05:00.



Data retrieved from SBE37-IM SN 6907 microcat

Star Oddis

These were still cable tied and taped onto the rope and frame. The additional red tape survived on all but the 75 m sensor. Biofouling was clear on all, especially shallower than 250 m. Star Oddis were on both parts of the separated PAP1 mooring, the buoy recovered by the FS *Maria S. Merian* and the frame, chain and ropes recovered by Discovery on DY116.

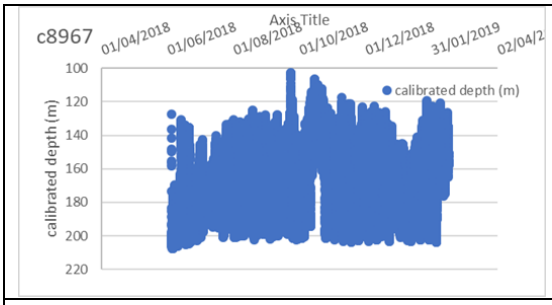
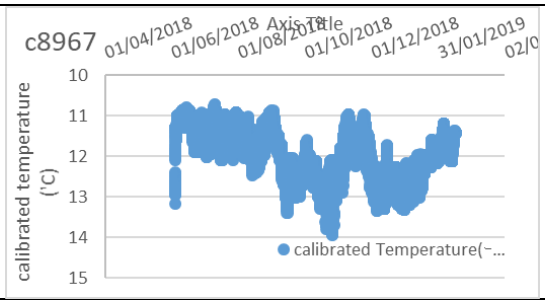
From the recovered buoy (FS *Maria S. Merian* recovery):

type	Serial number	Deployment depth	Depth rating	Survived?	Battery remaining	File start date	File stop date	calibrated
	12C8928	1m	52	OK	Not known yet	03/07/19	27/11/2020	No but can be done on DY130
	15S6782	5m	2045	OK	Not known yet	03/07/19	12/07/2019	Cal from DY103 but don't make sense when applied to recovered data
	S7562	10m	521	OK	Not known yet	03/07/19	27/11/2020	Cal from DY103 but don't make sense when applied to recovered data
	7S7565	15m	521	OK	Not known yet	03/07/19	27/11/2020	Cal from DY103
	7S7566	20m	521	OK	Not known yet	03/07/19	27/11/2020	Cal from DY103

From the frame and below (DY116 recovery):

Type	Serial number	Deployment depth	Depth rating	Survived?	Battery remaining	File start date	File stop date	calibrated
DST CTD	6789	1000	2047	OK	22%	22/05/18	24/05/18	Not deployment dates probably not programmed correctly
DST CENTI	8969	450	3000	OK	65	04/06/18	31/01/20	Temp only, depth not good
DST CENTI	8967	350	3000	OK	65	04/06/18	15/02/19	yes
DST CTD	6788	150	2049	OK	1	04/06/18	30/01/20	Temp only, depth not good
DST TILT	H0786	1000	2000	OK	59	04/06/18	02/04/19	Temp only, depth not good
DST CENTI	8991	250	500	imploded				
DST CENTI	8990	100	500	imploded				
DST CENTI	8994	75	500	imploded				
DST CTD	7727	30	500	imploded				
DST TILT	H0833	30	500	imploded				
DST TILT	H0457							

Calibrations

	
6789	Unable to calibrate due to depth error
8969	Unable to calibrate due to depth error
6788	Temp = -0.0429x + 13.568 (R^2 = 0.9627)
H0786	Unable to calibrate due to depth error

Next Cruise:

As DY130 is scheduled to go to PAP in March/April there is less than 6-months to prepare for the loss of sensors. There is now only 1 data hub (deployed on DY116). We are hopeful that the MO will provide a 2nd Mobilis buoy for March. The NOC team are keen to have the maximum possible PAP-SO infrastructure fully operational in Spring 2021 to ensure best possible collaboration with EXPORTS (USA, NASA). This includes full BGC data from the PAP mooring and sensor frame.

However, at the time of writing there is no back up for the SeaFET pH sensors (buoy or frame), the Atmos CO_2 (buoy) or the CO_2 (frame – note that this has been deployed as our back up buoy CO_2 sensors). Likewise we do not have a backup for PO_4, OCR light or the FLNTSUB chlorophyll (as our spare 30 m one has been used on the buoy this year). We do have a SUNA nitrate and a Seaguard unit to deploy at 30 m, plus we would hope to get microcats from the NMF pool.

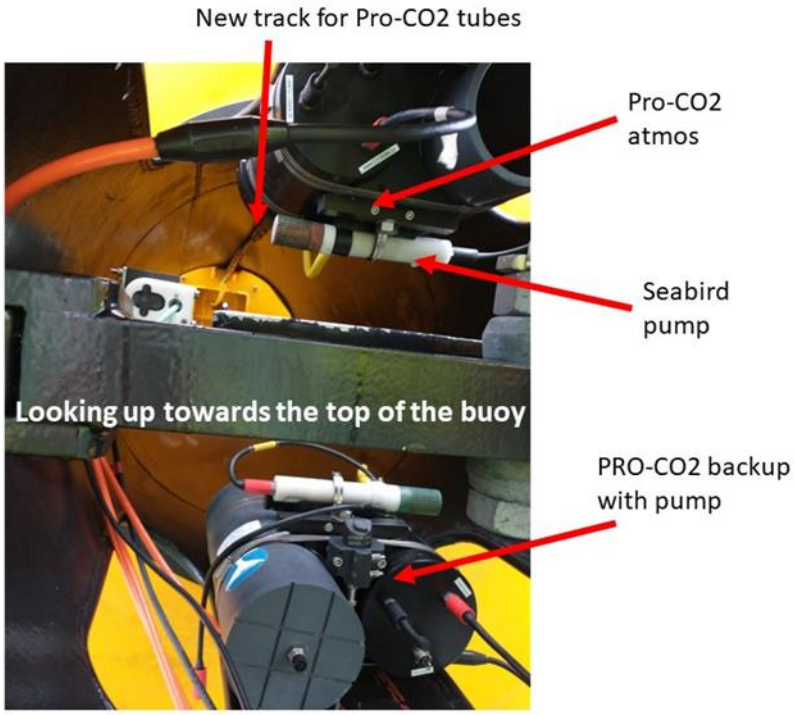
DY116 Deployed Observatory Description

Note that the New Mobilis buoy was deployed without a sensor frame on DY116, in 2020.

PAP1 buoy in the water at 13:28 on Sat 21st November (pumps connected at 12:35).

PAP1 Buoy DY116 Sensor schedules were similar to last year, but there was an increased frequency of the spare CO2 sensor and the FLNTUSB in the expectation that the deployment will probably be less than 12 months (currently DY130 is scheduled for March 2021).

It's important to avoid having the two CO_2 sensors sampling at the same time because they're quite power hungry. Initially planned to power the CO_2 sensors from the buoy when they are sampling, and from their battery packs when they are asleep. If the buoy batteries start to get drained over the winter, the plan was to send a command so that the CO_2 sensors run entirely from their dedicated battery packs. However, this didn't happen and the CO_2 sensors have been deployed with dummy battery packs (tubes).



View from under the buoy, showing two Pro-CO_2 sensors with associated pumps (and O_2 optode)

Aanderaa oxygen optode and Satlantic OCR are only powered and logged by buoy controller, and their schedule can be altered remotely. SeaBird MicroCATs, Pro-Oceanus CO_2 sensors and WETLabs FLNTUSB record internally and CANNOT be re-scheduled remotely. CO_2 sensors (and pumps) switch on 20 minutes before sampling and outputing data. Configure CO_2 sensors to sample at 59th minute every 12 hours but different hours for the 2 sensors. Configure WETLabs FLNTUSB to sample every 3 hours.

Duty Cycles and schedules PAP1 Buoy DY116:

CO_2 sampling can now be varied remotely. Note that there is no real time data from the SBE microcats. Here is an explanation of the CO_2 sampling and the actual timings suggested to start the deployment with.

CO_2 sampling

CO2-Pro 39-599-50A is configured to sample every hour at 27 minutes past, WHEN IT IS POWERED. Power needs to be present at least 20 minutes before sampling to allow the sensor to warm-up, and once deployed the sampling minutes-past-the-hour cannot be changed.

The sensor does not have an external battery for the DY116 deployment and so only gets power from the telemetry unit (aka buoy controller).

This means that it is possible to remotely control when power is switched to the sensor.

The command CO2=6,5,30,5 will switch power to the sensor as follows:-

4 sample sessions per day at:

ON at 05:05:00 - OFF at 05:35:00

ON at 11:05:00 - OFF at 11:35:00

ON at 17:05:00 - OFF at 17:35:00

ON at 23:05:00 - OFF at 23:35:00

Similarly, the second CO2-Pro 34-200-45 is configured to sample every hour at 58 minutes past.

The command CO3=6,2,30,35 will switch power to the sensor as follows:-

4 sample sessions per day at:

ON at 02:35:00 - OFF at 03:05:00

ON at 08:35:00 - OFF at 09:05:00

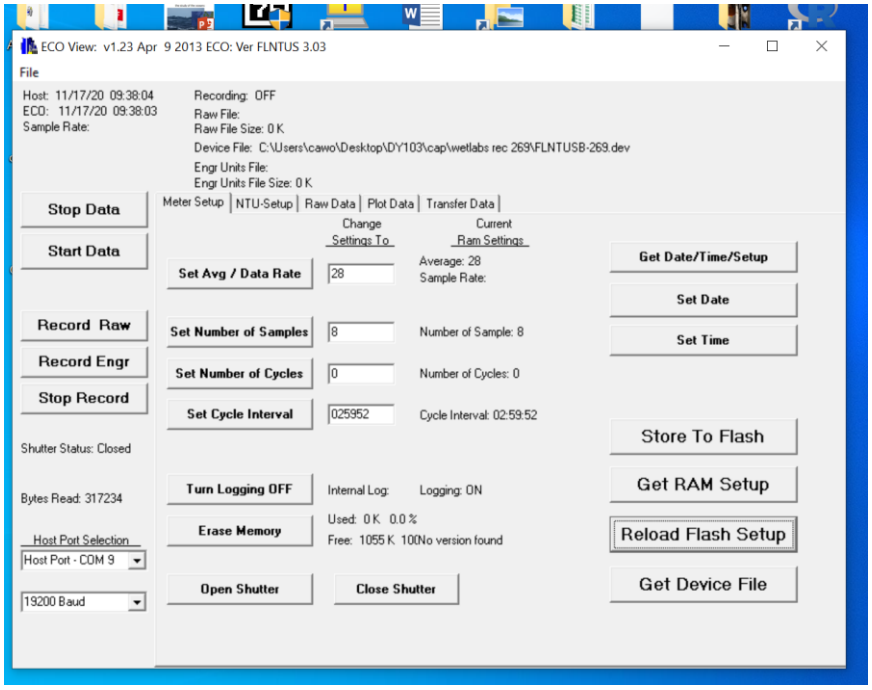
ON at 14:35:00 - OFF at 15:05:00

ON at 20:35:00 - OFF at 21:05:00

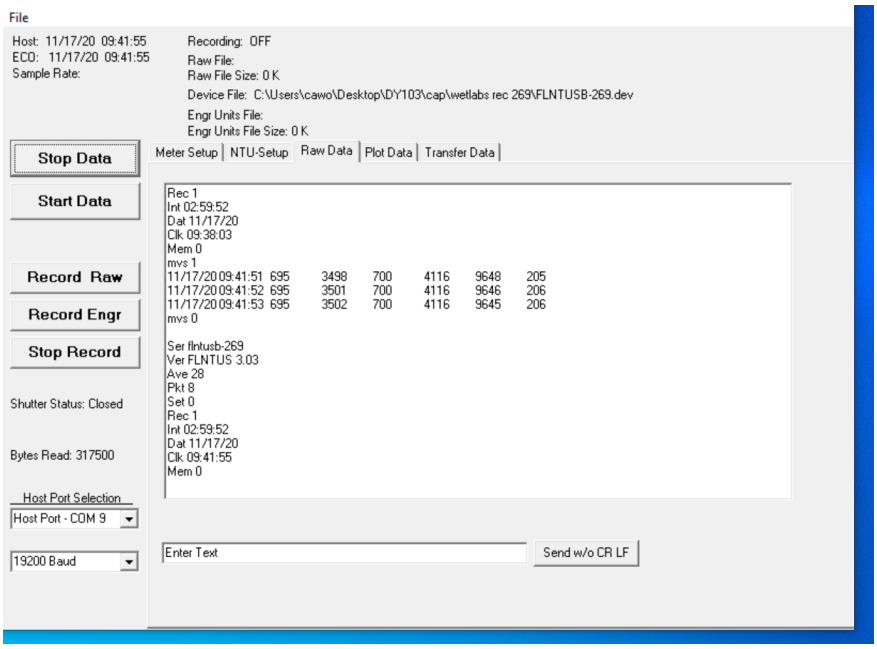
Wetlabs flntusb

The Wetlabs was set up at NOC and tested on the hub and telemetry system prior to sailing. Onboard it was connected to the hub in the keel; the jumper was connected at 15:25 and the instrument worked over night. The jumper plug was then removed, memory offloaded and erased, then set up for a three-

hourly deployment, setting as below. Note the settings are under the current RAM settings column, not the change settings to.



The flunusb was then disconnected and reconnected to display the settings as per below. Note it is the settings on the bottom two thrds of the display.



The instrument was not calibrated on CTD prior to deployment. This is to reduce risks by;

1. Key skills to reconfigure hub etc were not on board,

2. November cruise offers short weather windows so opportunity for shallow CTDs to calibrate are few and any weather windows that do occur should be used for high priority events such as deploying the entire buoy,
3. November cruise also potentially comprises staff on board by sea sickness, so any opportunity to reduce error at sea should be taken,
4. If possible a CTD will be deployed near to the buoy to calibrate the sensor. The sea state is well mixed so there is unlikely to be much patchy biology as this time of year.

Star Oddis

The following sensors were attached with cable ties and gaffer tape to be recovered in March/April 2020. There was too little battery remaining in the deeper depth rated sensors to deploy below the frame where they would not be recovered for another two years.

Type	Serial number	Deployment depth (m)	Depth rating (m)	Frequency (hours)	% Battery remaining	File start date
DST CENTI	8930	30	100	4	65	28/11/2020
DST CTD	7724	20	300	4	26	28/11/2020
DST CTD	6784	15	???	4	18	28/11/2020
DST CTD	7728	10	300	4	15	28/11/2020
DST CTD	5761	05	???	4	60	28/11/2020
DST TILT	H0833	30	100	4	51	28/11/2020

The following Star Oddis were written off on the IMS system.

Star oddi serial number	Write off date	Reason
8991	26/11/2020	Imploded – see above
8990	26/11/2020	Imploded – see above
8994	26/11/2020	Imploded – see above
7727	26/11/2020	Imploded – see above
7725	26/11/2020	0% battery remaining
6790	26/11/2020	0% battery remaining
6792	26/11/2020	0% battery remaining

Summary of deployed Sensors on PAP-1 **(DY116-008)**

PAP1 DY116 Buoy sensor list 2020	**Serial number**	**Battery housing**	**Notes**	**Schedule**
Pro-Oceanus CO2-Pro atmos	39-599-50A	Old grey OS (part remote)	Recal Oct 2019.	6 hours at 05:27, 11:27, 17:27, 23:27
Pro-Oceanus CO2-Pro	34-200-45	Old grey OS (part remote)	Recal Nov 2019.	6 hours at 02:58, 08:58, 14:58, 20:58
SeaBird SBE 37IMP-ODO MicroCAT	21210	internal	New (260006425)	30 mins at 00 and 30
SeaBird SBE 37IMP MicroCAT	6904	internal		15 minutes at 00, 15, 30, 45
Satlantic OCR-507 ICSA (Bioshutter)	201 (122)	None (remote operate)	last cal 29 Sep 2017	30 mins at 17 and 47, sampling at 1Hz for 2 mins
WETLab FLNTUSB Fluorometer	269	internal	On buoy skirt	3 hours at 25 past
Aanderra oxygen optode	1282	None (remote operate)	Full cal spring ‘19, 2 point 20th nov ‘19. Power & log @ controller	30 mins at 14 and 44, sampling every 15 sec for 65secs
Star Oddi Tilt (+5 others between 5m and 30m)	H0833 8930 7724 6784 7728 5761	none	Temperature and tilt, mounted inside buoy	4 hours starting on 28/11/2020
LinkQuest Accoustic modem	15763	none	Powered and controlled by buoy controller.	

For the deployment, decoded data are located in

\noc\ote\remotetel\ascdata\PAP\PAP_2020_deploy\PAP_Nov2020. *(see NOCS Telemetry Data Formats below).

PAP 1 Mooring November 2020 – NOCS Telemetry Data Formats

These files are produced by the LabWindows CVI program "PAP_2020_Iridproc.exe" running on the Iridium server PC located in room 251/20.

For the deployment in November 2020 the decoded data are located in
\noc\ote\remotetel\ascdata\PAP\PAP_2020_deploy\PAP_Nov2020.*

The binary data arriving via Iridium are decoded using the 3-byte header code for each data type. This code is also used as the file extension to distinguish the different types of data file.

Note that ALL these files are text files with space-delimited variables.

Code	Data source
GPS	Buoy GPS position fixes
IRD	Iridium performance
ST1	Buoy status
PWR	Buoy power monitor
BTT	Buoy compass, pitch, roll and accelerometer
SBE	Sea-Bird SBE37-IMP MicroCATs
SBO	Sea-Bird MicroCATs with oxygen
FET	Satlantic SeaFET pH sensors in frame + keel
COA	Pro-Oceanus atmospheric CO2 on buoy
COB	Pro-Oceanus CO2 on buoy keel (in water CO2)
COC	**Pro-Oceanus self-logging CO2 in frame**
COD	Second Pro-Oceanus CO2 on buoy keel
OXY	Aanderaa oxygen Optode on keel
HUB	**Data Hub status**
ATT	**Hub compass, pitch, roll and accelerometer**
WET	WETLabs FLNTUSB fluorometer sensor on keel
SUN	**Satlantic SUNA V2 nitrate sensor**
OC3	Satlantic OCR on buoy looking up
OC1	**Satlantic OCR on frame looking up**
OC2	**Satlantic OCR on frame looking down**
SEA	**Aanderaa Seaguard instrument**

TDG	Pro-Oceanus TDGP sensor in frame
PO4	WETLabs HydroCycle phosphate sensor
LCD	DLM Load Cell at top of frame - data
LCS	DLM Load Cell at top of frame - status
MET	Met Office sensors on buoy

Messages not used for Nov 2020 deployment are greyed out.

Note that this is the estimated position of the acoustic release, approximately 705m above the sea floor. This has a watch circle of around 290m radius on top of the triangulation uncertainty of 50m.

Best estimate of water depth is 4830m.

GPS files giving the location of the buoy e.g. PAP_Nov2020.gps

These contain 7, space-delimited fields:-

1) The year
2) The day fraction time stamp for this fix
3) The latitude for this fix
4) The longitude for this fix
5) The distance in km from the nominal anchor position
6) The bearing in degrees from the anchor position
7) The time difference in seconds since the last fix

e.g.

```
2019 185.25925967  48.958164 -16.383162   1.323 231.3    120
```

Note that fields 5, 6 and 7 are computed by the processing program not the buoy.

PWR files - Engineering monitor data from the buoy electronics housing

e.g. PAP_Nov2020.pwr

These contain 9, space-delimited fields:-

1) The year
2) The day fraction time stamp for these samples
3) The battery voltage in volts
4) The current in mA being drawn from the battery
5) The supply current to the Data Hub in mA
6) The total power in watts being taken from the battery
7) The buoy housing internal temperature in º C
8) The buoy housing humidity %
9) The time difference in seconds since the last sample

e.g.

```
2020 290.24792889   13.54  518.15    0.82   7.02  10.95  56.31    900
```

ST1 Buoy Telemetry unit status files e.g. PAP_Nov2020.st1

These contain, space-delimited fields:-

1) The year
2) The day fraction time stamp that this message was generated
3) The difference between GPS time and Persistor clock in seconds
4) The remaining space on the flash card in MB
5) The number of GPS fixes received in last GPS ON period
6) The number of Buoy compass readings received in last sampling period
7) The number of Buoy accelerometer readings received in last sampling period
8) The number of OCR3 readings in the last hour
9) The number of buoy CO2 readings in the last hour
10) The number of buoy secondary CO2 sensor readings in the last hour
11) The number of Oxygen Optode readings in the last hour
12) The number of WETLabs fluorometer readings in the last hour
13) The time difference in seconds since the last interrogation

```
e.g.

2020 275.71875062    0.457 1901.312  209  713    0    0   20    0    2    0 3600
```

IRD Iridium files e.g. PAP_Nov2020.ird

These contain 9, space-delimited fields:-

1) The year
2) The day fraction time stamp that the Iridium transceiver was switched on for this connection attempt
3) The total number of seconds that the Iridium transceiver was powered on
4) The number of seconds the transceiver took to register with the Iridium system
5) The number of bytes transmitted
6) The number of SBD re-try attempts (normally zero)
7) The number of connection attempts (up to 4)
8) A status value as a 2-byte hex number (see below for possible values)
9) The time difference in seconds since the last dial up attempt

```
e.g.

2019 122.00069472  78.24  33     0 0 1 02   9000

2019 122.00277805  55.40  16  2116 0 2 00    180
```

Status value (field 8) decode of bit settings:-
No bits set – 0x00 No problems encountered
Bit 1 – 0x01 The Iridium transceiver did not respond correctly to an AT command
Bit 2 – 0x02 The transceiver was unable to connect to the NOC server
Bit 3 – 0x04 An incorrect BLKSIZE message (or no message) received from NOC server
Bit 4 – 0x08 An incorrect RCVD message (or no message) received from NOC server
Bit 5 – 0x10 The transceiver was unable to register correctly with the Iridium system
Bit 6 – 0x20 An error occurred while sending or reading a SBD message

SBE Sea-Bird MicroCAT 37IMP files e.g. PAP_Nov2020_6907.sbe

These sensors log internally and have been programmed to record every 15 minutes. They are interrogated by the buoy every 30 minutes for the latest reading.

There are two sensors of this type distinguished by their serial number in their filename.

6907 is in the sensor frame at 30m.

9475 is attached to the buoy keel.

These contain 10, space-delimited fields:-

1) The year for instrument interrogation
2) The day fraction time stamp for instrument interrogation
3) The year for the sampling instant
4) The day fraction time stamp for sampling instant from MicroCAT
5) Serial number of MicroCAT
6) The temperature °C [ITS-90]
7) The pressure dbar
8) The conductivity S/m
9) Salinity PSU [PSS-78] (computed at NOC)
10) The time difference in seconds since the last interrogation

e.g.

```
2019 184.78484995 2019 184.78126199  6907 14.2843   30.814  4.27675  35.4995   1800
```

SBO Sea-Bird 37IMP-ODO MicroCAT files e.g. PAP_Nov2020_16503.sbo

These sensors log internally and have been programmed to record every 30 minutes. They are interrogated by the buoy every 30 minutes for the latest reading.

There are two sensors of this type distinguished by their serial number in their filename.

10315 is in the sensor frame at 30m.

16503 is attached to the buoy keel.

These contain 11, space-delimited fields:-

1) The year for instrument interrogation
2) The day fraction time stamp for instrument interrogation
3) The year for the sampling instant
4) The day fraction time stamp for sampling instant from MicroCAT
5) Serial number of MicroCAT
6) The temperature °C [ITS-90]
7) The pressure dbar
8) The conductivity S/m
9) The dissolved oxygen in ml per litre
10) Salinity PSU [PSS-78] (computed at NOC)
11) The time difference in seconds since the last interrogation

e.g.

```
2019 184.78489625 2019 184.77090319 16503 16.4527    1.661 4.49076  5.901  35.4895      3
```

WET – WETLabs FLNTUSB fluorometer sensor files e.g. PAP_Nov2020.wet

This sensor logs internally and takes a set of 8 readings every 4 hours. These 8 readings are also logged in the hub and averaged. Only the averaged values are telemetered.

These contain 12, space-delimited fields:-

1) The year for hub time stamp
2) The day fraction time stamp for hub time stamp
3) The year for the sampling instant
4) The day fraction time stamp for sampling instant from WETLabs sensor
5) Sensor identification string (added at NOC)
6) Emission wavelength of Chlorophyll signal
7) Chlorophyll µg/litre (computed at NOC from calibration coeffs)
8) Emission wavelength of NTU signal
9) NTU signal Nephelometric Turbidity Units (computed at NOC from calibration coeffs)
10) Temperature °C (computed at NOC from calibration coeffs)
11) Pressure dbar (computed at NOC from calibration coeffs)
12) The time difference in seconds since the last message

```
e.g.
2020 271.40013949 2020 261.51530151 FLNTUSB-269  695  0.23  700  6.00 23.72  0.57      8
```

COA, COB, COC - Pro-Oceanus self-logging CO2-Pro sensor files e.g. PAP_Nov2020.cob

COA = Buoy atmospheric reading

COB = Buoy water reading

COC = Frame water reading

COD = Buoy 2nd CO2 sensor water reading

These sensors log internally and are configured to sample every 6 hours.

The buoy CO2 sensor samples the water (via a membrane) and the air. Air records are stored as 'COA', water records as 'COB'.

The records contain 12, space-delimited fields:-

1) The year time stamp
2) The day fraction time stamp from the Persistor clock
3) The 16-bit Auto Zero Point Calibration (AZPC) reading
4) The 16-bit raw CO2 reading
5) The CO2 concentration [ppm] NOTE CHANGE IN FIELD POSITION!
6) The CO2 IRGA cell temperature °C
7) The internal gas humidity [mbar]
8) The internal gas temperature °C
9) The internal gas stream pressure [mbar]
10) Supply voltage [volts]
11) Number of samples used to compute averages NEW FIELD
12) The time difference in seconds since the last telemetered record

e.g. `2020 290.27010481 56064 52250   430.46  45.00  12.69  25.20 1038 13.71 10   7200`

OXY – Aanderaa 4330 Oxygen Optode sensor files e.g. PAP_2020_deploy.oxy

This sensor is controlled by the buoy controller which provides power, logs and time stamps the records. The Optode is typically set to sample every 15 seconds and is switched on for 90 seconds during every sampling session. The buoy controller averages the readings over the sampling session.

These contain 7, space-delimited fields:-

1) The year from buoy controller clock
2) The day fraction time stamp from buoy controller clock
3) The dissolved oxygen concentration [µM]
4) The oxygen saturation [%]
5) Temperature [°C]
6) The number of samples used to compute the averaged values
7) The time difference in seconds since the last message

```
e.g. 2020 290.38524370 332.226  90.582  8.3060 5   1800
```

ATT – Hub Compass, pitch, roll and 3-axis accelerometer files e.g. PAP_Nov2020.att
BTT – Buoy Compass, pitch, roll and 3-axis accelerometer files

The hub contains an OS5000 compass/pitch/roll sensor and a 3-axis accelerometer. The compass is programmed to output data at 4Hz. The accelerometer has a range of +/- 4g and is programmed to output data at 25Hz. The hub logs all data output from these sensors, but only telemeters max, min and average data over 3-minute periods

These contain 22, space-delimited fields:-

1) The year for hub time stamp
2) The day fraction time stamp for hub time stamp for start of averaging period
3) The seconds over which the data were averaged
4) The maximum pitch value recorded during the averaging period in degrees
5) The minimum pitch value
6) The average pitch value
7) The maximum roll value
8) The minimum roll value
9) The average roll value
10) The maximum magnetic heading value
11) The minimum magnetic heading value
12) The average magnetic heading value
13) The maximum X-axis g-value from the accelerometer
14) The minimum X-axis g-value value
15) The average X-axis g-value value
16) The maximum Y-axis g-value from the accelerometer
17) The minimum Y-axis g-value value
18) The average Y-axis g-value value
19) The maximum Z-axis g-value from the accelerometer
20) The minimum Z-axis g-value value
21) The average Z-axis g-value value
22) The time difference in seconds since the last set of readings

```
e.g.

2018 155.77914387 59   3.29  -0.60   0.87  -0.40  -5.90  -2.78  293.7  286.5  290.2   0.101
0.019   0.050   0.050  -0.081  -0.016  -0.955  -1.170  -1.061     59
```

```
2018 155.77982674 59   2.20  -0.69   0.95  -0.20  -5.30  -2.47  294.0  285.6  290.4   0.097
0.019   0.053   0.042  -0.081  -0.022  -0.967  -1.189  -1.061     59
```

OC3 – Satlantic OCR-507 Upward-looking Irradiance sensor on the Buoy

These contain records from the Satlantic OCR-507.

These contain 15, space-delimited fields:-

1) The year for hub time stamp
2) The day fraction time stamp for hub time stamp
3) The number of seconds over which the data were averaged
4) The instrument identification string including serial number
5) 412.4 nm optical channel Es output in µW/cm2/nm
6) 434.3 nm optical channel Es output in µW/cm2/nm
7) 470.2 nm optical channel Es output in µW/cm2/nm
8) 531.6 nm optical channel Es output in µW/cm2/nm
9) 555.5 nm optical channel Es output in µW/cm2/nm
10) 589.8 nm optical channel Es output in µW/cm2/nm
11) 682.7 nm optical channel Es output in µW/cm2/nm
12) Regulated input voltage
13) Analogue rail voltage
14) Internal temperature °C
15) The time difference in seconds since the last set of readings

e.g.

```
2018 155.63680590 29  DI70201   108.710071 119.900831 129.123448 132.376721 125.337860
103.622906 103.461988 8.42 5.31 16.80   1742
2018 155.63714155 29  DI70201   104.407718 115.437722 123.143206 126.081319 118.530759
98.061297  98.146502 8.46 5.31 17.36     29
```

MET – Met Office sensor files e.g. PAP_Nov2020.met

This data arrives by a completely different route from all the other files as it comes from the Met Office Short Burst Data emails. The file format is also different, being comma-separated rather than space separated.

1) The Matlab time stamp for this record (from the Met Office buoy system)
2) The year
3) The day fraction time stamp
4) The date time as yyyy-mm-dd hh:mm:ss
5) Latitude [degrees]
6) Longitude [degrees]
7) Average wind speed [knots]
8) Average wind direction [degrees]
9) Max wind Gust [knots]
10) Sea temperature [degrees C]
11) Air temperature [degrees C]
12) Humidity [%]
13) Dew point
14) Air Pressure [mbar]?
15) Significant wave height [m]
16) Maximum wave height [m]
17) Peak wave period [seconds]
18) Mean wave direction [degrees]
19) Mean Spread
20) Battery volts?
21) ?
22) ?
23) ?
24) ?
25) Record number
26) ?
27) ?
28) ?
29) ?
30) The time since the last record [seconds]

e.g.

```
737618.54513889,2019,193.54513889,2019-07-12 13:05:00,48.95397833,-
16.36359667,5.3,86,7.1,18.5,17.1,70.3,11.7,1024.94,1.21,1.68,9.5,281,35,13.68,13.89,0.06,0.22,
0.22,37226,133,0,122.28,22.87,3600.0
```

8. CTD Sampling

Calibration CTD profiles and water sampling

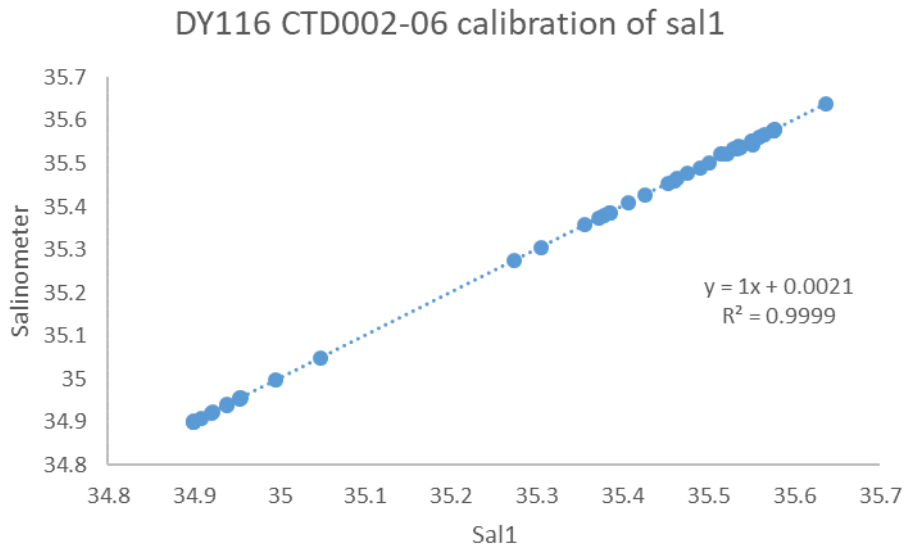
The CTDs were used primarily to test sensors and releases although samples were also taken to look at typical profiles in area. The first cast was in the first deep water off the shelf and was used to test the CTD and ship side systems. Although we had planned to take samples the bottles did not fire. On subsequent casts whenever microcats were tested Niskin bottles were removed for this and there were at least 2 x 10 minutes stops for sensor validation. A total of 6 CTDs were done on DY116 for the various purposes of testing releases, calibrating instruments and taking water samples as noted in the table.

CTD (station number)	CTD depth (water depth) m	Notes
1 (001)	900 (3389)	CO2 Contros & PAR failed at depth. No bottles fired. Release test Whittard Canyon sediment trap.
2 (003)	4700 (4707)	Canyon post (and pre PAP3) microcat SN 12462 cal so took one of the Niskins off (23 Niskins, fired at 12 depths). Release test PAP3 and PAP1.
3 (005)	4700 (4810)	PAP3 post cal microcat (still at deployment interval), this CTD also used to calibrate the Navis Bio-Argo float.
4 (010)	450 (4810)	Add down PAR, cast at last light. Post deploy cal for PAP1.
5 (012)	4700 (4800)	PAP3 post cal microcat SN 9469. 3x 10 min stops. PAR sensors removed.
6 (013)	500 (4810)	Add up and down PAR. SBE microcat 6907. 3 star Odis. 2x 10min stops

On each occasion that samples were taken then the order of sampling followed was: Dissolved oxygen, Dissolved Inorganic Carbon (DIC), inorganic nutrients, salinity and associated parameters from the top 200 m. The associated parameters from the surface samples were chlorophyll, SFC and PIC. These surface samples were filtered and frozen as appropriate. The PIC samples will be analysed ashore.

DIC samples were preserved with 100ul of saturated mercuric chloride and will be analysed on the NOC Vindta at NOC for Dissolved Inorganic Carbon (DIC) and Total Alkalinity (TA). Duplicates were taken from each station (usually from the deepest Niskin fired). Nutrient samples were collected in small white (acid washed) nutrient pots and frozen for analysis of inorganic nutrients (NO2+NO3, phosphate and silicate) using the Quattro auto-analyser at NOC. Sufficient sample was taken for duplicate analysis.

Generally, 3-12 salinity bottle samples were taken from each cast. Jeff Benson ran CTD002/CTD003 bottle salts on the Salinometer 21st November 2020 and CTD004-006 on 25th November. Calibration of Sal1 (to salinometer samples) based on 5 casts, see below.

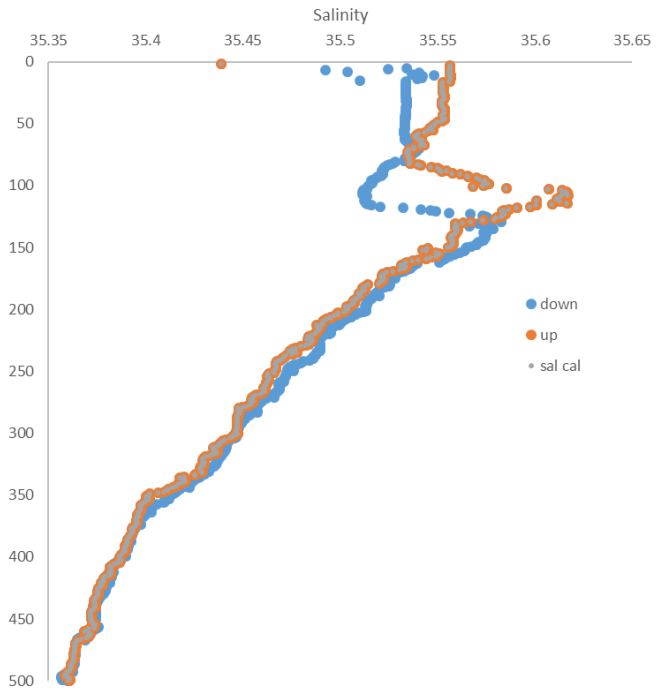


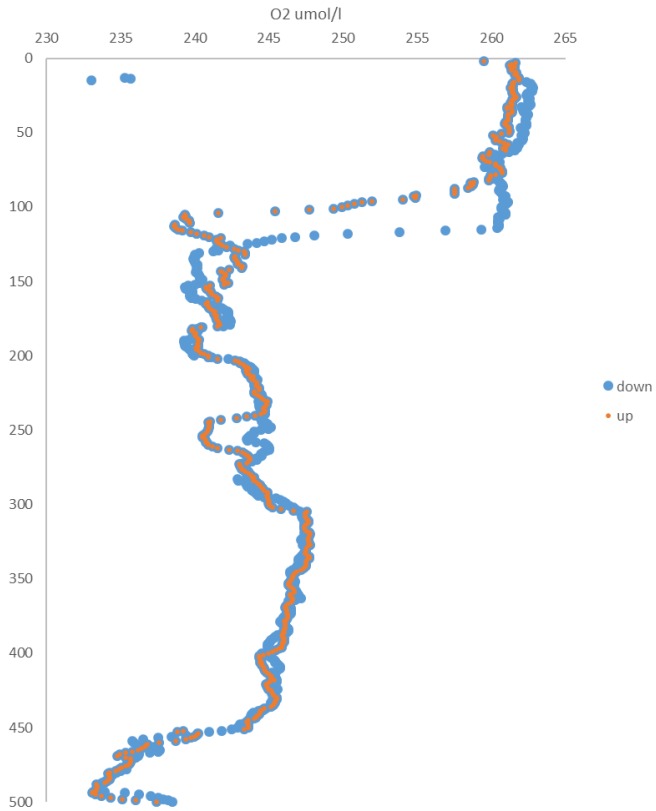
CTD number (station)	Depth	Approx. time
2 (003)	4000	04:10
	2000	05:10
	960	05:40
3 (005)	4000	10:30
	1500	11:40
	960	12:05
5 (012)	950	05:50
	850	06:40
6 (013)	500	12:02
	15	12:41

10 minute stops on CTDs

Shallow CTD casts:

Example of shallow casts a) salinity and b) oxygen:





Chlorophyll samples were filtered and frozen for analysis on board during DY116.

Dissolved oxygen analysis on board

The oxygen bottle samples were fixed on deck, returned to the deck laboratory and analysis was started within 6 hours of collection. The Oxygen sensor calibration is in the Oxygen analysis report. The SBE O_2 sensor on the CTD was SN 0862. Charlotte and Anita will work on CTD Oxygen calibration back at NOC.

Sampling

Dissolved oxygen (DO) samples were collected to calibrate the DO data of the CTD SBE oxygen sensor (SN0862) and sensors of the PAP buoy. Full duplicates were taken on cast 02; 1-2 duplicate samples were taken on subsequent casts (usually from the deepest depths).

Seawater was collected directly into pre-calibrated Pyrex titration flask avoiding formation of air bubbles and allowing >3 times the bottle volume to overflow. The bottles were flushed several times before the sample was drawn. The temperature of the water was recorded with a handheld thermometer (FisherScientific, RTD Pt Thermometer, S/N: 140212361) during subsequent DIC sampling to speed up the DO sampling process. The temperature was taken to account for any changes in oxygen bottle volume (and is also useful to identify the misfires). The sample was immediately fixed using manganous chloride and sodium hydroxide/sodium iodide solutions, thoroughly shaken, stored dark, and shaken again after approximately 30 mins. Analyses were carried out as soon as possible and normally within three to four hours of sample collection.

Analysis

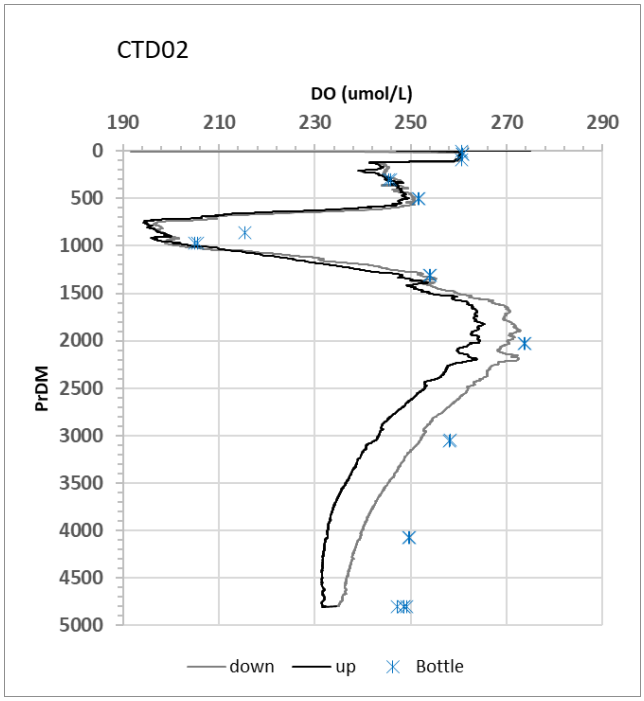
Except for the sodium thiosulfate ($Na_2S_2O_3$) all chemicals were prepared at NOC following Dickson (1994). DO was measured using an amperometric end point method, following the titration using an electrode to a set end point (Metrohm Ti-touch 916 instrument (S/N: 30107)). For titration, the stopper of the flask was carefully removed, a clean magnetic stirrer was added and the flask was placed on the stir plate. Once the precipitate was well mixed, 1 mL of 5 M sulphuric acid was added to the flask and the electrode and burette were carefully inserted. The resultant volume of $Na_2S_2O_3$ titrant was recorded both by manual logging on the Metrohm Ti-touch 916. This value was then then converted to DO concentration using oxygen calculation.xls.

At least 3 blank checks of the reagents and 4 standardisations of the sodium thiosulfate were measured using 5 mL additions of a 1.667 mol/l certified iodate standard (OSIL) for each set of analyses.

The Metrohm Ti-touch 916 setup used for oxygen analysis system on DY116.

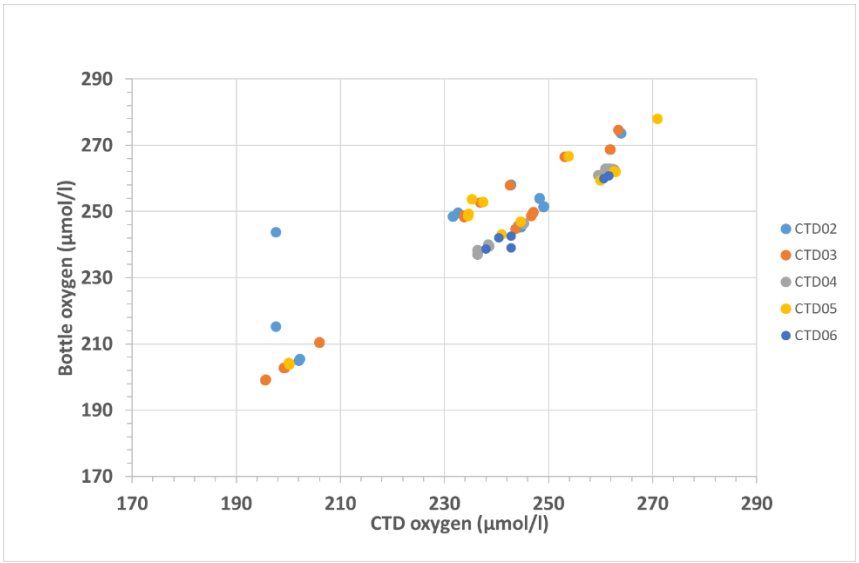
Results

In total 82 samples were analysed for dissolved oxygen using a modified Winkler technique. Approximately 2.5 bottles of OSIL standard were used during DY116. The average normality of the $Na_2S_2O_3$ was 0.0907±0.001 mL (n=36). Average titre of the iodate standard was 0.4540±0.0029 mL (n=12). Standard deviations of duplicates were on average 0.23 µmol/l (=0.1%) (n=20). The new style open neck bottles were used.

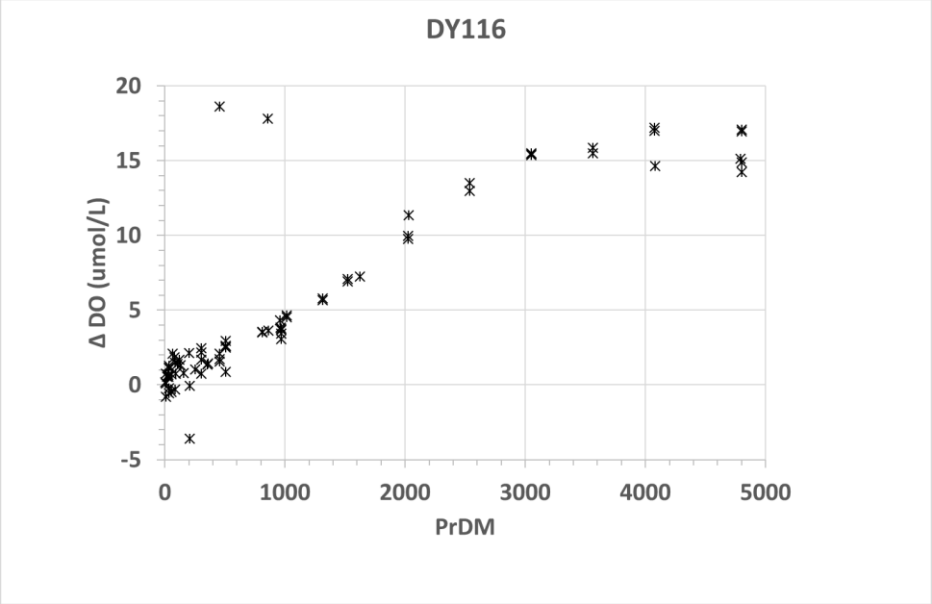


Example cast (CTD02) shows extent of hysteresis between up (black line) and down casts (grey line) for Sbeox O2 sensor (SN 0862). Bottle values are indicated (blue asterisks). No corrections applied yet.

The CTD SBE oxygen data (SN0862) was converted into µmol/l for comparison with the bottle data. It should be noted that there was considerable hysteresis on the CTD oxygen sensor (above). The 10 minute mirocat calibration stops carried out may help to improve the CTD to bottle calibration fit.



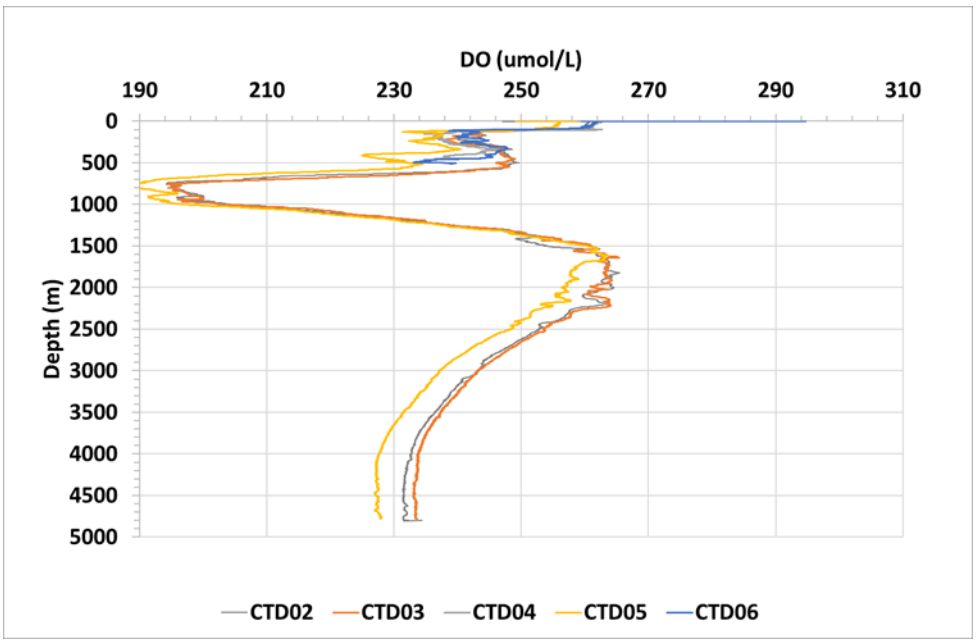
Relationship between bottle oxygen and CTD oxygen data. No corrections applied.



Residuals between bottle oxygen and CTD oxygen data as a function of depth. No corrections applied.

The final merged bottle oxygen data are available in a file called: 'DY116_all_btl_files.xlsx'. Offsets between bottle and CTD oxygen data increased with depth maximising to +17 µmol/l at deepest depths (above) suggesting an influence of pressure. This will be reviewed at NOC as we need to adopt the calibration procedures used on the previous DY120 cruise (MPOC) and check that the same procedure is used by BODC.

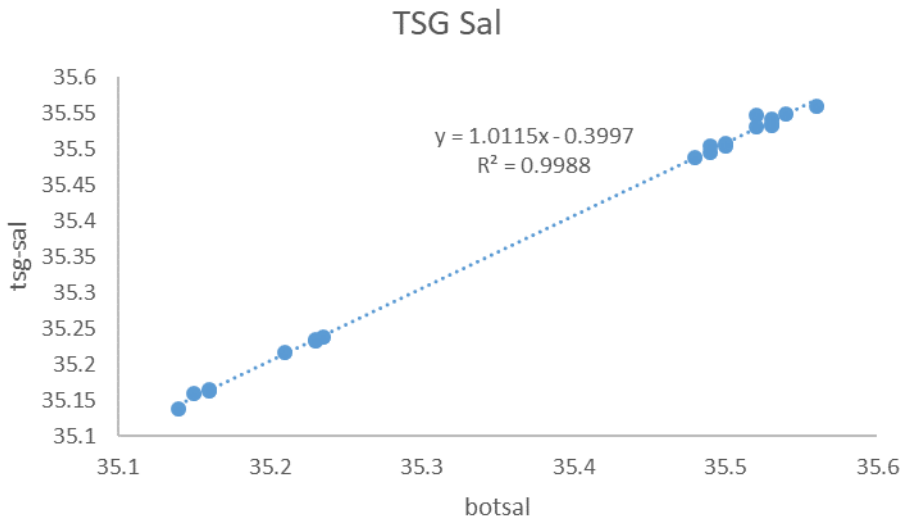
The full depth profiles show a clear oxygen minima around 850 m (Med water influence) and oxygen increases again around 2000 m before decreasing in the Lower deep water (below).



Vertical DO profiles of upward CTD casts during DY116. Nor corrections applied.

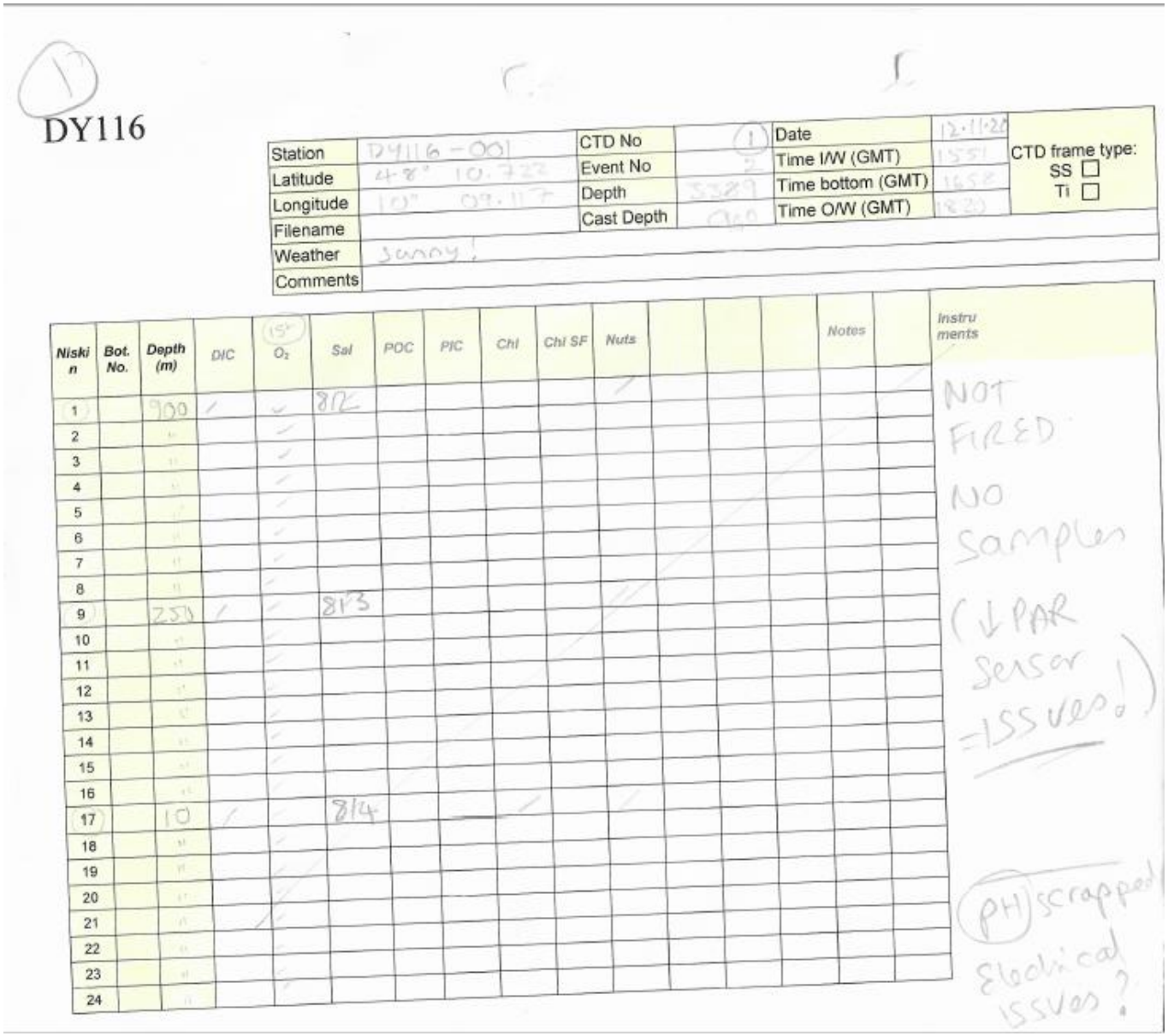
Bio-geochemical samples from the TSG non-toxic supply

Bottle samples were taken from the non-toxic (NT) supply seawater at the sampling point next to the thermosalinograph (TSG) 2-3 times per day. See calibration below.



A 1L sample was taken and filtered for chlorophyll analysis ashore. Another was preserved (for DIC and TA analysis) at NOC - then calculations will be made of pCO_2 for comparison with the NOC underway SubCtech pCO_2 systems. Frequent salinity samples were also taken throughout DY116, and salinity analysis was done on the salinometer on-board at the end of DY116 (25th November). This will be used to calibrate the TSG. Samples were also taken (and frozen) for nutrient analysis on the Quatro (by Ed Mawji ashore).

Scans of the CTD log sheets are shown below:



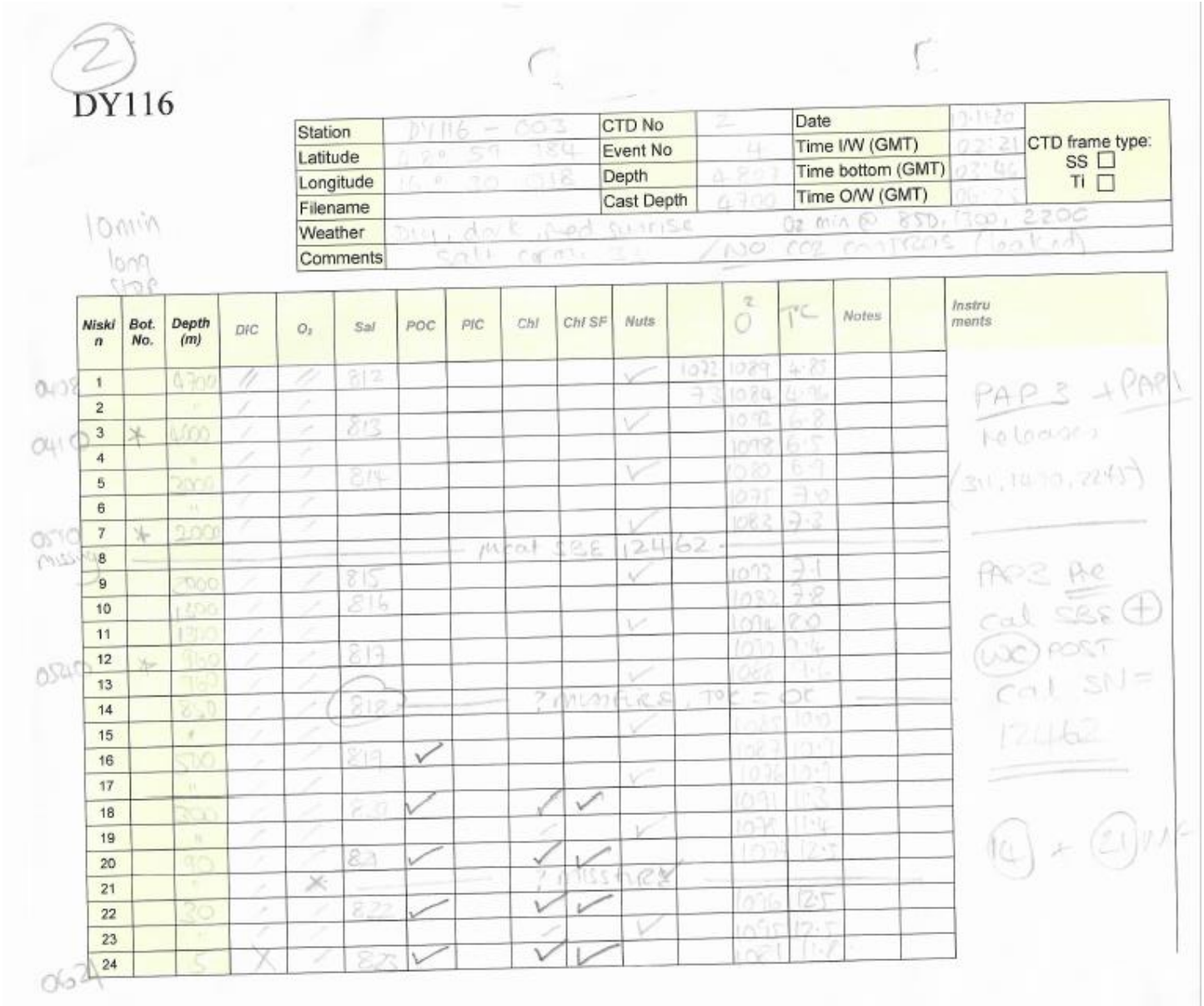
DY116

Station	DY116-001	CTD No	1	Date	12.11.20
Latitude	48° 10.723	Event No	2	Time I/W (GMT)	1551
Longitude	10° 09.117	Depth	5329	Time bottom (GMT)	1652
Filename		Cast Depth	949	Time O/W (GMT)	1820
Weather	Sunny!				
Comments					

CTD frame type: SS ☐ Ti ☐

Niskin	Bot. No.	Depth (m)	DIC	15N O_2	Sal	POC	PIC	Chl	Chl SF	Nuts				Notes		Instruments
1		900	/	~	8R					/						NOT FIRED NO Samples (↓PAR Sensor =ISSUES!)
2		"		~												
3		"		~												
4		"		~												
5		"		~												
6		"		~												
7		"		~												
8		"		~												
9		250	/	~	8R3											
10		"		~												
11		"		~												
12		"		~												
13		"		~												
14		"		~												
15		"		~												
16		"		~												
17		10	/	~	814					/						
18		"		~												
19		"		~												
20		"		~												
21		"		~												
22		"		~												
23		"		~												
24		"		~												

pH scrapped Electrical issues?



DY116

Station	DY116 – 003	CTD No	2	Date	03/12/20
Latitude	62° 59.184	Event No	4	Time I/W (GMT)	22:21
Longitude	16° 30.018	Depth	4803	Time bottom (GMT)	02:46
Filename		Cast Depth	4700	Time O/W (GMT)	03:23
Weather	Dull, dark, mod sunrise				
Comments					

CTD frame type: SS ☐ Ti ☐

Niskin	Bot. No.	Depth (m)	DIC	O_2	Sal	POC	PIC	Chl	Chl SF	Nuts		^2O	T°C	Notes		Instruments
1		4700	//	/	812					✓	1023	1028	4.83			
2		"	/	/							3	1028	4.96			
3	*	4500	/	/	813					✓		1028	6.8			
4		"	/	/								1028	6.9			
5		3000	/	/	814					✓		1028	7.0			
6		"	/	/								1028	7.2			
7	*	2000	/	/						✓		1028	7.3			
8								meat SSE 124.62								
9		1000	/	/	815					✓		1028	7.1			
10		800	/	/	816							1028	7.8			
11		600	/	/						✓		1028	8.0			
12	*	400	/	/	817							1028	8.4			
13		200	/	/						✓		1028	8.6			
14		150	/	/	818			2 minutes, TOE = OK				1028	8.9			
15		"	/	/								1028	8.9			
16		100	/	/	819	✓				✓		1028	8.9			
17		"	/	/								1028	9.2			
18		50	/	/	820	✓		✓	✓			1028	11.4			
19		"	/	/						✓		1028	12.3			
20		10	/	/	821	✓		✓	✓			1028	12.3			
21		"	/	X												
22		20	/	/	822	✓		✓	✓			1028	12.5			
23		"	/	/						✓		1028	12.5			
24		5	X	/	823	✓		✓	✓			1028	11.8			

(3)

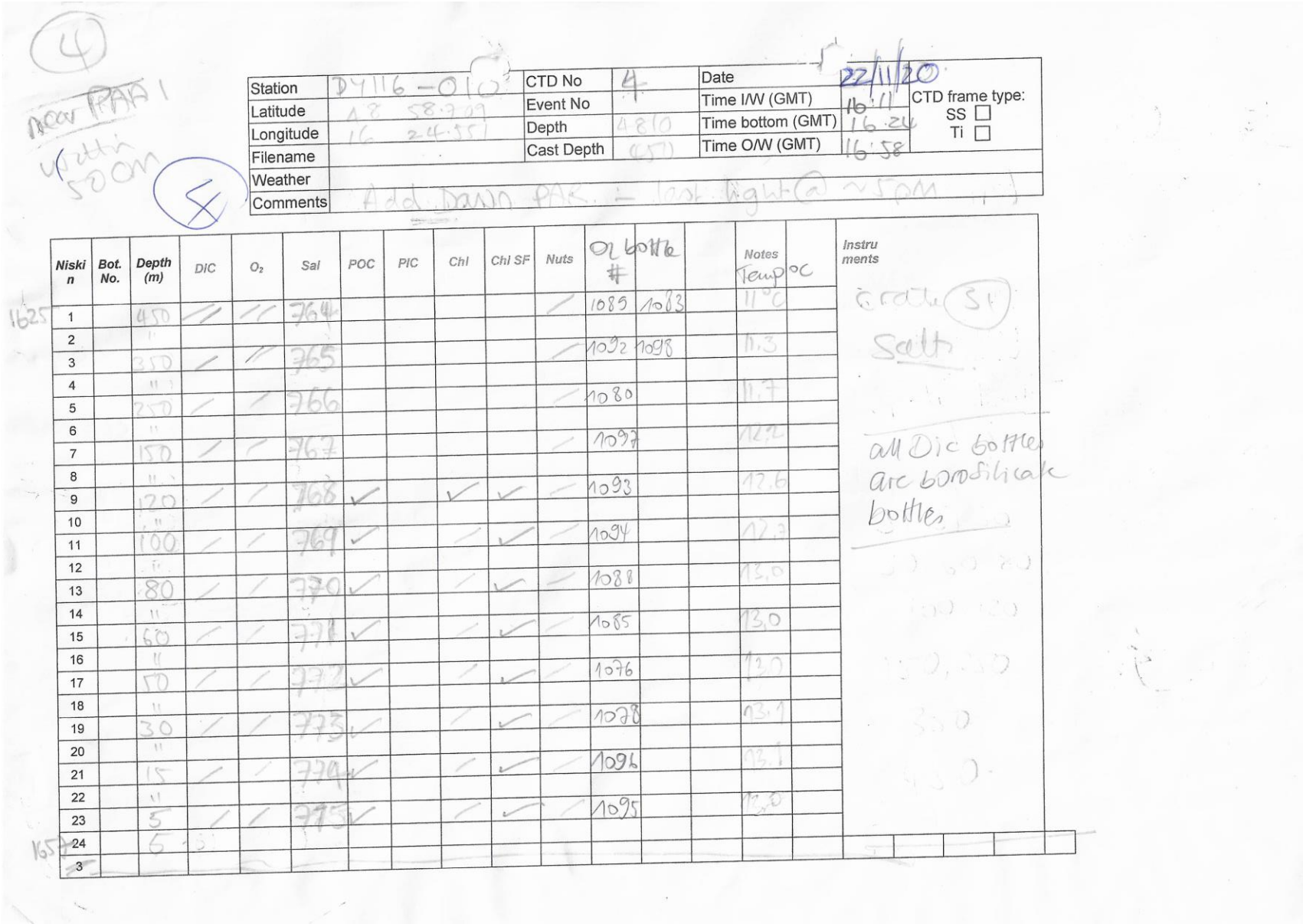
DY116

CTD. 3

Station	DY116 -005	CTD No	(3)	Date	20/11/20
Latitude	49 00.012	Event No		Time I/W (GMT)	0850
Longitude	16 29.988	Depth	4810	Time bottom (GMT)	1012
Filename		Cast Depth	4700	Time O/W (GMT)	1253
Weather	Sunrise + light swell				
Comments	Post PAP3 Neat (Cal). Remove bottle (7)				

CTD frame type: SS ☐ Ti ☐

Niskin n	Bot. No.	Depth (m)	DIC	O₂	Sal	POC	PIC	Chl	Chl SF	Nuts		O₂ N°	T °C	Notes		Instruments
1		4700	//	//	824					✓	1089	1083	6.2			
2	1030	4000	//	//						✓	74	1084	6.3			PAP3: (POST) 9469.
3		3500	/	/	825					✓		1092	6.1			
4		3000	/							✓		1098	6.2			
5		[illegible]	/		826					✓		1080	[illegible]			
6		[illegible]	/							✓		1015	6.[illegible]			
7								missing for				SBE				→ (wrong interval)
8	1140	1500	/	/	227					✓		1097	7.[illegible]			
9		1500	/	/						X		1093	[illegible]			
10		1000	/		[illegible]					✓		1082	[illegible]			
11		1000								X		1094	9.2			(3) long stops @10mins.
12	1205	[illegible]	/	/	229					✓		1090	9.[illegible]			
13		[illegible]	/							X		1088	[illegible]			
14		800	/	/	230					✓		1079	9.7			
15		800	/	/						X		1085	9.8			
16		500	/	/	231	✓				X		1087	11.1			
17		[illegible]	/							✓		1076	11.1			(20) - MF
18		300	/	/	[illegible]	✓		✓		✓		1091	11.[illegible]			
19		130	/	/		✓		✓		✓		1078	[illegible]			
20		75	→		232			→ misfire			→	1079				
21		75	/	/	833	✓		✓		✓		1086	13.0			
22		30	/	/	834	✓		M		✓		1096	13.1			
23		30	X			✓		✓		X		1095	13.[illegible]			→ no DIC
24	1248	5	/	/	835	✓		✓		✓		1081	[illegible]			

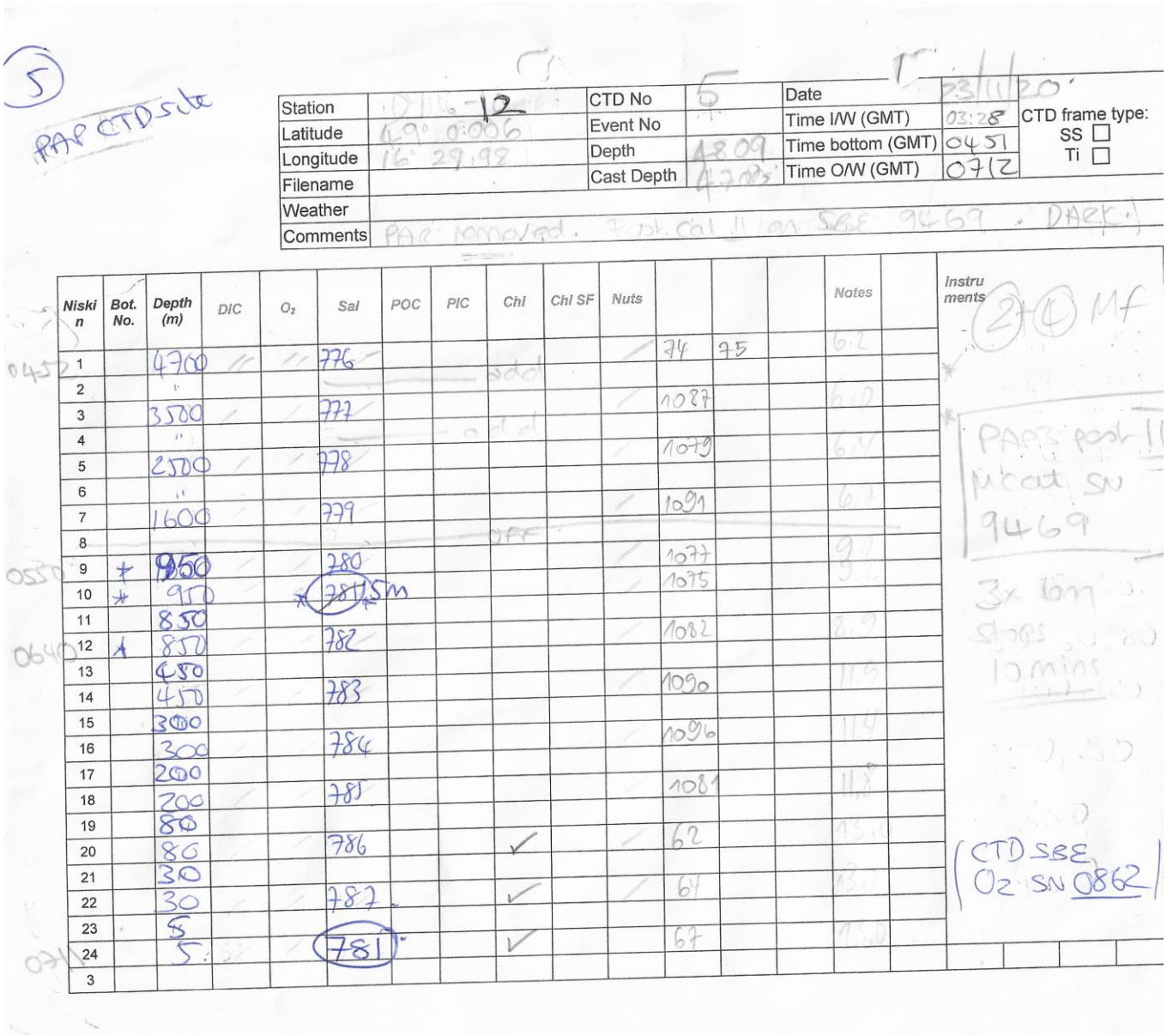


Station	D4116-010	CTD No	4	Date	22/11/20
Latitude	43 58.799	Event No		Time I/W (GMT)	16'11
Longitude	16 24.351	Depth	4810	Time bottom (GMT)	16'24
Filename		Cast Depth	(4571)	Time O/W (GMT)	16'58
Weather					
Comments	Add Dawn PAR. + last light @ ~50m				

CTD frame type: SS ☐ Ti ☐

Niskin	Bot. No.	Depth (m)	DIC	O_2	Sal	POC	PIC	Chl	Chl SF	Nuts	O2 bottle #			Notes Temp °C	Instruments
1		450	/	/	764					/	1085	1083		11°C	Grade (S1) South
2		"									1092	1098		11.3	
3		350	/	/	765					/					
4		"									1080			11.7	
5		250	/	/	766					/					
6		"									1097			12.2	
7		150	/	/	767					/					
8		"									1093			12.6	
9		120	/	/	768	✓		✓	✓	/					
10		"									1094			12.3	
11		100	/	/	769	✓		/	✓	/					
12		"									1088			13.0	
13		80	/	/	770	✓		/	✓	/					
14		"									1085			13.0	
15		60	/	/	771	✓		/	✓	/					
16		"									1076			13.0	
17		50	/	/	772	✓		/	✓	/					
18		"									1078			13.1	
19		30	/	/	773	✓		/	✓	/					
20		"									1096			13.1	
21		15	/	/	774	✓		/	✓	/					
22		"									1095			13.0	
23		5	/	/	775	✓		/	✓	/					
24		6													
3															

All Dic bottles are borosilicate bottles



5

PAP CTD site

Station	12	CTD No	5	Date	23/11/20	CTD frame type:	
Latitude	49° 0.006	Event No		Time I/W (GMT)	03:28	SS ☐	
Longitude	16° 29.98	Depth	4809	Time bottom (GMT)	0451	Ti ☐	
Filename		Cast Depth	4703	Time O/W (GMT)	0712		
Weather							
Comments	PAR removed. Itoh cal II on SBE 9469. DARK						

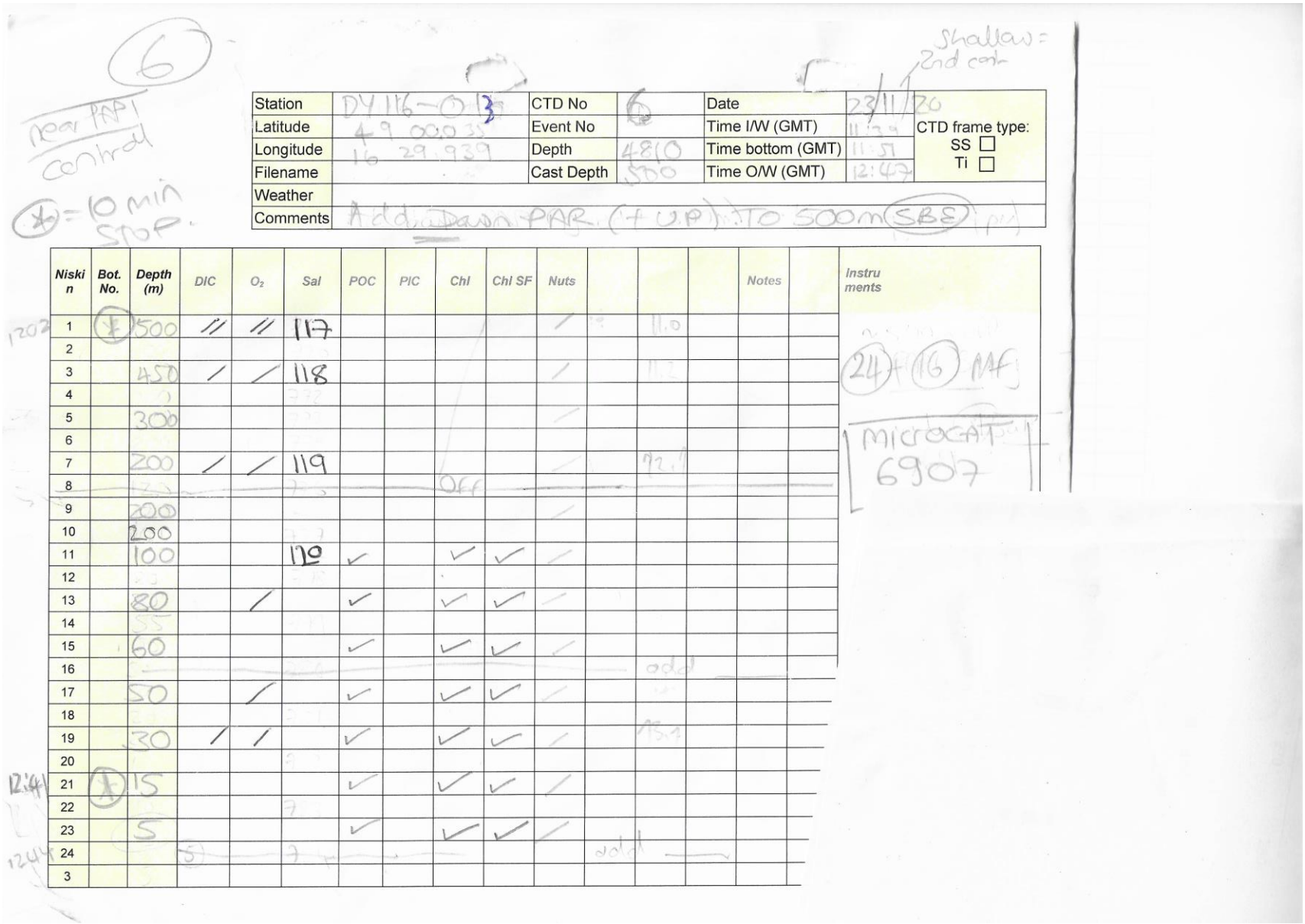
Niskin	Bot. No.	Depth (m)	DIC	O_2	Sal	POC	PIC	Chl	Chl SF	Nuts				Notes		Instruments
1		4700			776						74	75		6.2		
2		"														
3		3500			777						1087			6.10		
4		"														
5		2500			778						1079			6.4		
6		"														
7		1600			779						1091			6.2		
8																
9	*	950			780						1077			9.2		
10	*	950			781.5m						1075					
11		850														
12	*	850			782						1082			8.9		
13		450												11.5		
14		450			783						1090					
15		300												11.9		
16		300			784						1096					
17		200												11.8		
18		200			785						1081					
19		80												11.5		
20		80			786			✓			62					
21		30												11.5		
22		30			787			✓			61					
23		5												11.4		
24		5			781			✓			67					
3																

Instruments: 24 CTD MF

PAR: pool II, µcat SN 9469

3x 10m stops 10 mins

CTD SBE O_2 SN 0862



6

near PAP1 control

Shallow = 2nd cast

Station	DY116-01 3	CTD No	6	Date	23/11/20	CTD frame type: SS ☐ Ti ☐	
Latitude	49 00.03	Event No		Time I/W (GMT)	11:39		
Longitude	16 29.939	Depth	4810	Time bottom (GMT)	11:57		
Filename		Cast Depth	500	Time O/W (GMT)	12:47		
Weather							
Comments	Add Dawn PAR (+UP) TO 500m (SBE)						

(*) = 10 min stop.

Niskin	Bot. No.	Depth (m)	DIC	O_2	Sal	POC	PIC	Chl	Chl SF	Nuts				Notes		Instruments
1	(*)	500	//	//	117					/		11.0				
2																
3		450	/	/	118					/						
4																
5		300								/						
6																
7		200	/	/	119					/						
8								Off								
9		200								/						
10		200														
11		100			120	✓		✓	✓	/						
12																
13		80		/		✓		✓	✓	/						
14																
15		60				✓		✓	✓	/						
16												add				
17		50		/		✓		✓	✓	/						
18																
19		30	/	/		✓		✓	✓	/						
20																
21	(*)	15				✓		✓	✓	/						
22																
23		5				✓		✓	✓	/						
24												void				
3																

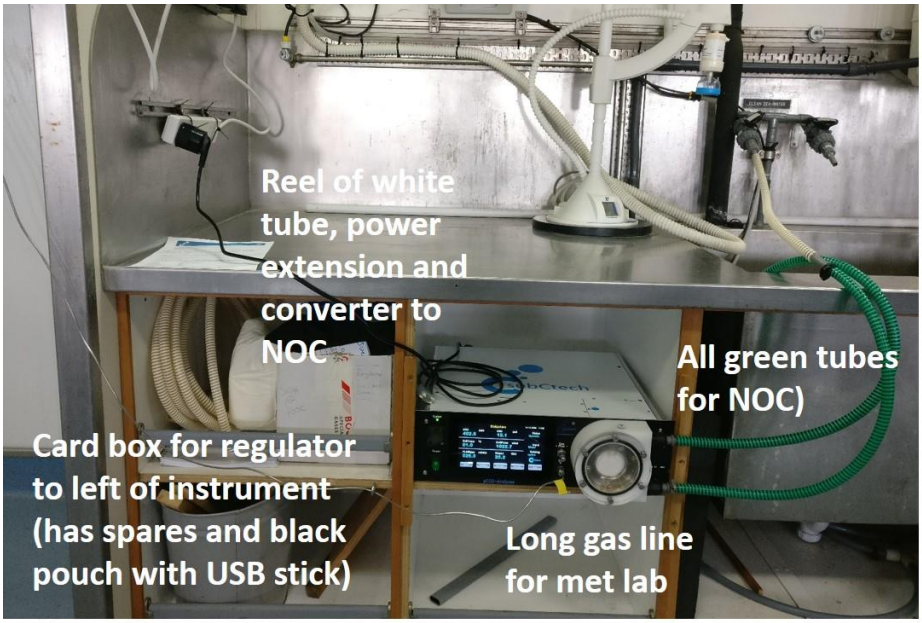
(24) (16) MF

MICROCAT 6907

9. Underway sampling and CO_2 measurements

Anita Flohr, Sue Hartman

On DY116 a SubCtech Flow-through pCO_2 Analyzer (OceanPack™ Family) was connected to the underway seawater supply in the deck lab, measuring underway pCO_2. The system uses a combination of membrane equilibration and Licor gas measurements. It is designed to be small and light enough to work on round-the-world sailing vessels (using dive bottle gas standards). The SubCtech system was used until recently on the Plymouth-Roscoff ferry, operated by Yann Bozec and Stefan Raimund. Stefan set up the instrument in Roscoff just prior to DY116 and is planned to also run on the following RAPID cruise. This work was disseminated on a blog on our website (noc.ac.uk/pap) and SubCtech was also in one of our @PAP_observatory Dy116 tweets.



SubCtech installed in the deck lab

Methods

Measurement cycle and calibration

The system can be used with a range of gases to make data of SOCAT quality. During DY116, one reference gas was used, an artificial air, calibrated CO_2 gas standard (plus regulator), provided by Ute Schuster (Exeter University) (for return at end of RAPID). The measurement cycle was set to perform a calibration once a day involving a zero CO_2 measurement and measurement of the reference gas (BOC, 422 ppm). On 11/11/2020 the reference gas value was set at 400 ppm and changed to the correct value of 422 ppm on 20/11/2020 at 10:40. Initially the system was programmed to run on a 24hr cycle of: 2hr operate, 5 min zero calibration, 5 min ref gas 1, 21hr 50 min operate. On 20/11/2020 this schedule was changed to a 24hr cycle of: 10 min operate, 5 min zero calibration, 5 min ref gas 1, 23hr 40 min operate.

The data log interval was initially set to 20 sec. Changing the interval to 1 min averages does not work at the moment, thought to be caused by a software bug (personal communication with S. Raimund). On 16/11/2020 the data log was changed to 30 sec intervals.

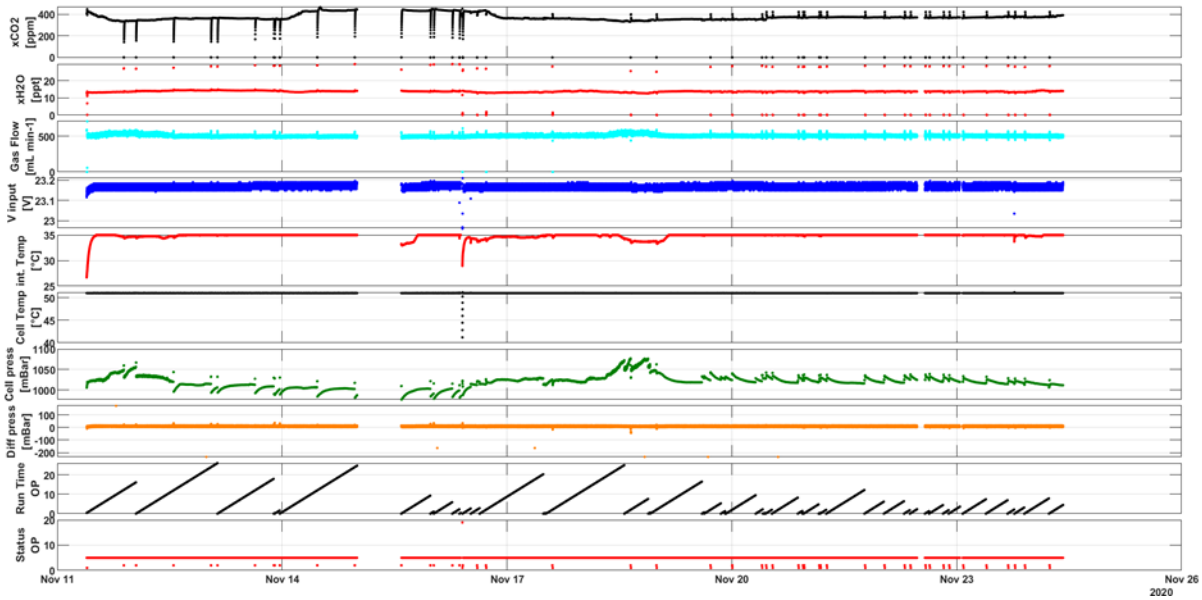
Merge with ship's underway data

The SubCtech system does not have an inbuilt sensor to measure and log the water temperature. The temperature of the analyser's water outflow was checked regularly using a handheld temperature probe (Fisher Scientific, Pt Thermometer, S/N: 140212361) and checked against the ship's TSG underway SST readings. The water temperature of the analyser's outflow agreed to ±0.01 °C with the ship's TSG readings.

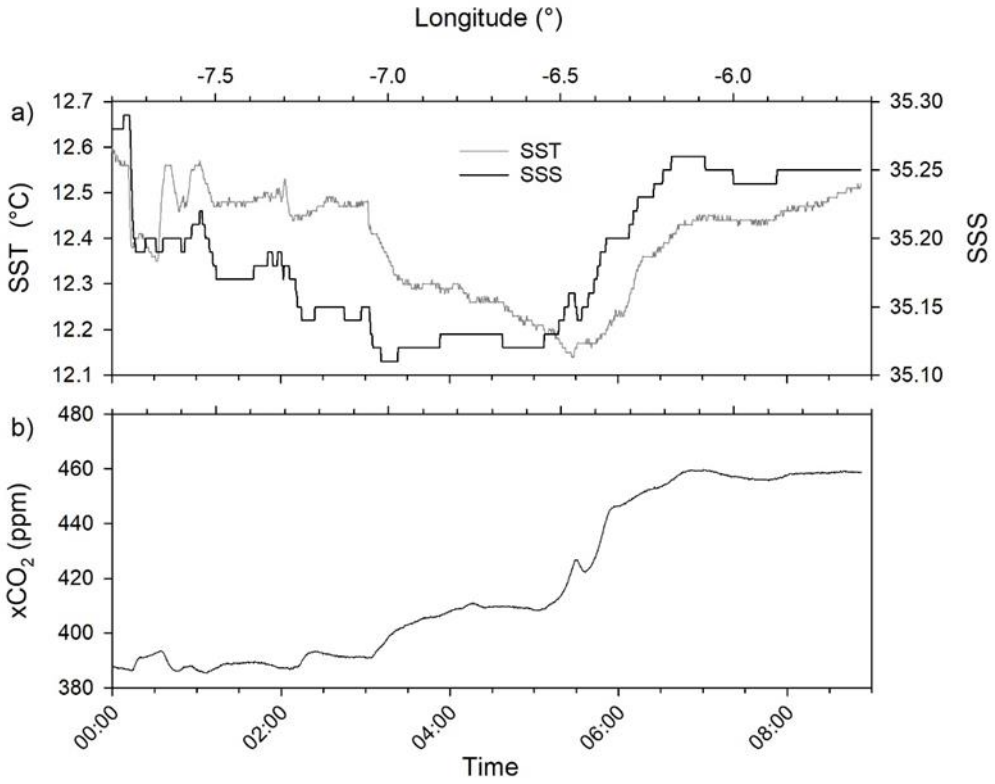
Stefan provided us with a data cable (to RS232) to record the outcoming data in real-time (baud rate is 19200), however we didn't use it on DY116. Data was copied frequently with the provided USB key (fat32 format). Matlab files (rar-container) were also provided for a quick data analysis; including a dataloader. Note: plot10 only works with GPS data. GPS and other ancillary data was provided from a 1min average of the data base (Grafana, downloaded by Anita – after initial instructions from Martin Bridger).

Issues:

We couldn't set it up to read at 1 or 2 min timings (to be compatible with the underway TSG data), it always wants more than zero seconds. We frequently had more than 2 gas readings a day which we thought may be due to an interruption in the power supply. This was consistent with the new files that were created (a few each day, followed by a 2 hour gas sample). A Europe to UK adapter (plus extension board) was used until 23rd November. Replacing these didn't stop the interference issues. However, a UPS (borrowed from engineers onboard, with thanks to Charlie) was used from 24th November and we hope that this will resolve the issues for the return transect to the UK and for RAPID.



Raw data output of the SubCtech covering the entire duration of the cruise.



Excerpt of underway raw data collected on 25th November on the transit from the PAP site to Southampton.

Scanned logs from the underway system are shown below:

DY116 Underway Sample Log start JDAY 316 at 0944

	date	time	lat	lon	tsg crate	salin	temp	sal	flu	air pres	DIC ID	Chl	depth	
shelf	11/11/2020	13:00	49 20.61	6 26.56	4	97	12.66	35.16	0.16	1003.43	#615 201111-13:00	-	-	1
	11/11/2020	15:40	49 14.19	6 48.34	4	98	12.81	35.14	0.16	1000.45	#586 201111-15:40	uway1	122	2
	11/11/2020	18:52	49 7.16	7 20.36	4	99	13.32	35.23	0.15	1006	#542 201111-~~2036~~ 18:52		129	3
	12/11/2020	08:57	48 37.94	9 53.09	4	100	13.61	35.49	0.11	1008.99	#549 201112-08:57	uway2	358	4
@WC	12/11/20	10:46	48 37.54	10 0.17	4	101	13.81	35.52	0.10	1009.20	~~#506~~ 201112-10:46	—	1578	5
CTD	12.11.20	15:30	48 18.72	10 9.11	4	102	13.9	35.53	0.125	1005.42	507 201112-15:30	—	3387	6
@WC	13.11.20	08:16	48 37.57	9 59.81	4	103	13.75	35.53	0.11	100877	547 201113-0816	— d		7
	13.11.20	15:53	48 42.22	9 47.57	4	104	13.6	35.5	0.11	1006.11	544 201113-15:53	UW3	d	8
→UK	14.11.20	07:30	49 44.76	5 38.02	4	105	12.81	35.23	0.09	999.76	520 201114-07:30	UW4	d	9
UK	14.11.20	11:13	50 3.28	5 0.27	4	106	13.17	35.16	0.1	997	541 201114-11:13	UW5	65m	10
UK	15.11.20	20:28	50 5.73	5 2.86	4	107	13.61	35.155	0.096	1000.13	539 201115-2028	—	50M	11
MV (4)	16.11.20	10:39	49 55.30	5 4.87	4	108	12.94	35.21	0.096	1013.89	289 201116-10:39	UW6	80M	12
	17/11/20	10:13	49 29.68	9 26.51	4	109	12.71	35.235	0.112	1013.45	545 201117-10:13	UW7	137m	13
	17.11.20	15:44	49 24.80	10 32.20	4	110	13.18	35.48	0.10	1008.52	537 201117-15.44	UW8	142.5	14
	18.11.20	0940	49 11.84	13 19.25	4	111	13.35	35.50	0.09	1015.88	538 201118-0940	—	4122	15
323	18/11/20	11:10	49 0.77	14 3.49	4	112	13.29	35.49	007	1017.35	504 201118-11:10	UW9	4480	16
@CTD 2	19/11/20	02:14	48 59.98	16 30.01	4	113	13.34	35.54	0.09	1032.45	536 201119-0214	UW10	4807	17

13/11/20 0842 – 0859

TSG cleaned: 18/11/20 By 13:59.

DY116 Underway Sample Log

Day 324

	date	time	lat	lon	tsg crate	salin	temp	sal	flu	air pres	DIC ID	Chl	depth
PAR3	19.11.20	17:29	48 51.39	16 24.33	4	114	13.33	35.56	0.098	1032.95	543 20111?-1729	uw11	?
PAR1	21.11.20	08:12	48 58.28	16 21.06	4	115	13.14	35.52	0.10	1022.38	802 201121-0812	uw12	?
CTD	23/11/20	05:36	49 0.08	16 29.98	4	116	13.15	35.53	0.10	108.25	142 201123-0536	—	4809m

10. Met Office Biogeochemistry Argo float

Andrew Gates

To increase collaboration on ocean biogeochemistry between Met Office and NOC at the PAP-SO, the Met Office provided a Bio-geochemical Argo float to take regular water column profiles while in the vicinity of the PAP site. The data generated will support the Met Office work on the Argo programme and will provide greater temporal resolution to NOC's monitoring at the observatory, at least while it remains near PAP. The delayed mode Argo float data can quality controlled against CTD casts done during DY116 and can help to validate data from the PAP-1 mooring. The float is a Navis BGCi F0660 with the WMO number 6903751. It carries the following sensors:

- SBE-41N CTD head,
- SBE-63 dissolved oxygen sensor,
- MCOMS three channel optical sensor (standard channels 1 bbp (700 nm), 1 chl, and 1 CDOM).

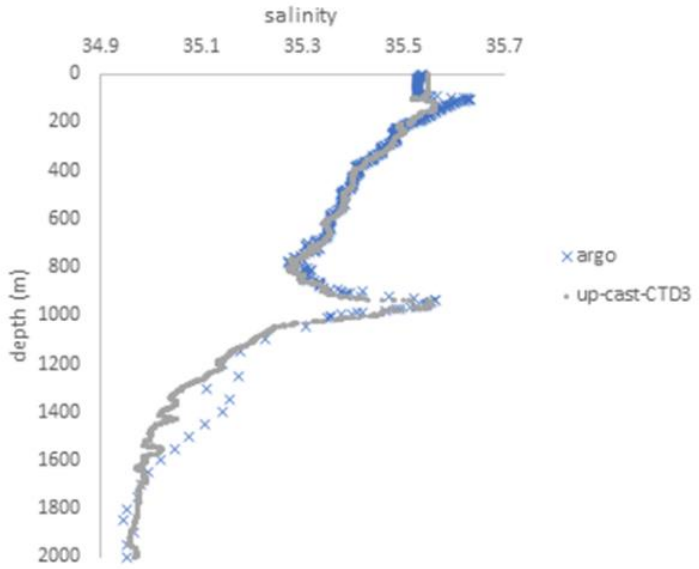
The float was provided in 'pressure-activation' mode to self-activate after sinking below 25 dbar. Deployment is simple and only required lowering the float gently into the water, releasing it while the ship is stationary. The float was programmed to sink on deployment, self-activate at 25dbar, rise to the surface for a short mission prelude transmission then descend to maximum depth (2,000 m) and profile from 2,000 m. The first profile was expected <15 hours after deployment. After that the float was programmed on a 5-day cycle while it was in the vicinity of the mooring to collect maximum data in the region. It will be switched to a standard 10-day cycle remotely once it has moved away.

The float was deployed Friday 20th November 2020 (below), 13:03 at 49 0.03 N, 016 30.10 W, 4837 m (DY116-006) just after a deep CTD profile (DY116-005) at the same location. The float was lowered into the water on a line from the starboard side of the stern of the ship. It lay horizontal in the water momentarily before turning vertical and slowly sinking.

Deployment of the Met Office biogeochemistry Argo float at PAP-SO (DY116-006)

At the time of the cruise there was a problem with the data. Met Office could see data on CLS MyData portal showing that the float had transmitted via Iridium following its deployment as expected. However, data were not available on the CLS RUDICs server. CLS advised that, although they were getting the messages, the float was calling 0014256432394 so the data were going to SeaBird and not the CLS RUDICS number (00881600005155). The solution was for Met Office to send an updated mission configuration file and for CLS to contact Sea Bird who will set the correct call parameters so the float will then call into the CLS RUDICS server that Met Office.

Once data communication issues were resolved the latest data from Navis BGCi F0660 can be viewed and downloaded from: https://fleetmonitoring.euro-argo.eu/float/6903751 an example early profile is shown alongside the CTD profile carried out just prior to deployment of the float (CTD - DY116-005).



Plot showing salinity from the first BGC Argo dive and data from CTD cast just prior to deployment

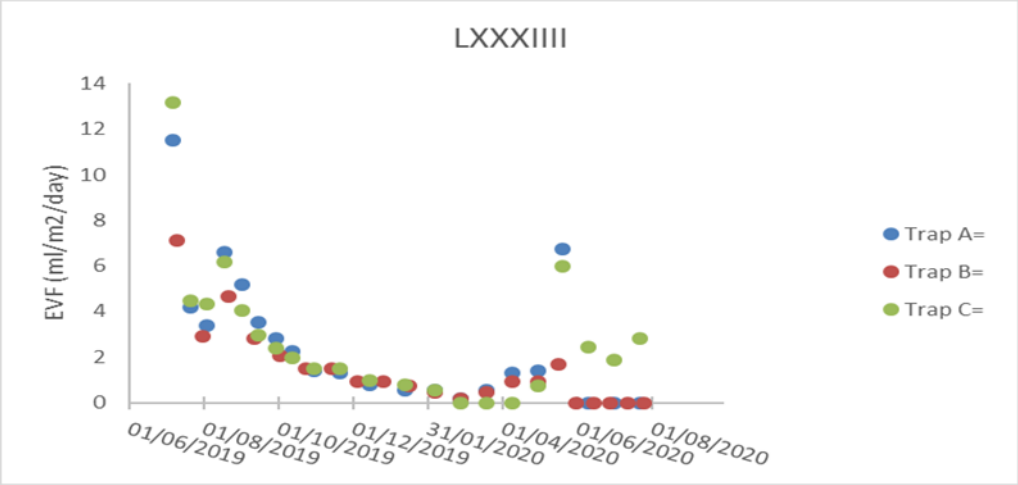
11. PAP3 - Sediment traps scientific report

Corinne Pebody

For details of the mooring see Section 6. On 19/11/2020 DY103-009, the PAP3 sediment trap mooring was released at 12:00, it surfaced at 13:15, was alongside RRS *Discovery* at 14:10 and all in by 16:00. The recovery included 3 traps, 2 Nortek current meters and 1 x microcat CTD and 1 x release, all apparently working well.

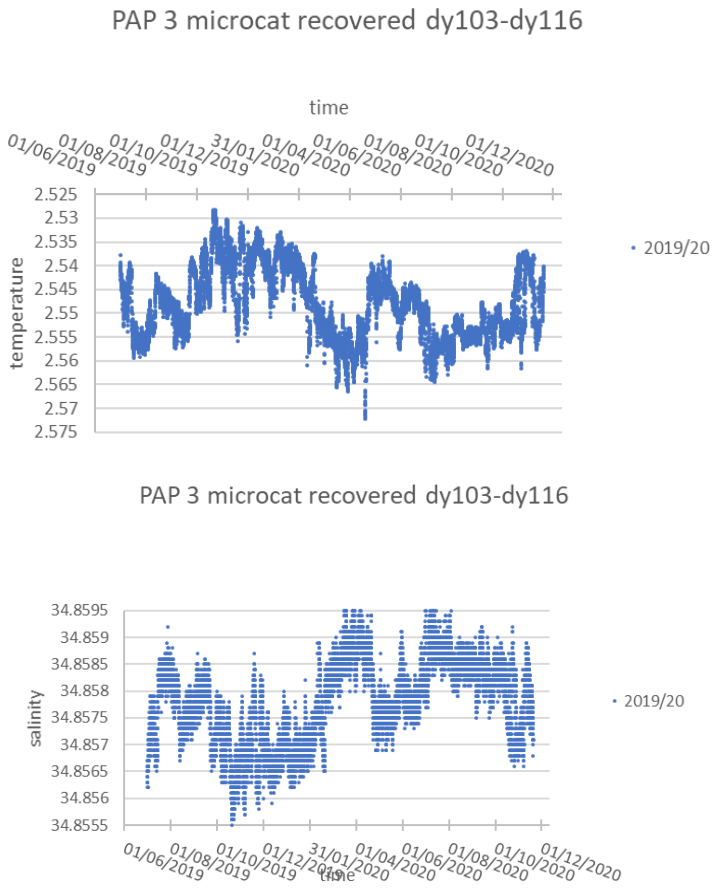
On recovery traps were photographed prior to removing bottles. EVF was calculated from recovered bottles. Bottles were photographed and the pH checked and recorded.

Images of bottles from the three sediment traps (upper = trap A at 3000 m, middle = trap B at 3050 m, Lower = trap C at 100 m above bottom)



EVF from the three sediment traps during the deployment duration

Data downloaded from the current meters at 3000 m and 100 mab show low current speeds and slightly lower still when running south. Microcat data shows that the cooler water tends to be fresher which suggests a northerly origin but when temperature overlaid over direction there doesn't seem to be a clear link. The microcat sbe s/n9469 was recovered and downloaded. Uncalibrated data are as below. The microcat was then calibrated on CTD 05 (DY116-012).



Temperature and salinity data from Microcat sensor on PAP-3 sediment trap mooring (DY103-009) at 100 m above the seabed

PAP3 Deployment (DY116-007)

Mooring deployment was started at 15:15 and the anchor was in by 17:34. Trap A (s/n 12432_06), Trap B (s/n 12283-01), Trap C (12432-02). Microcat at 80mab (s/n 12462) nb this was recovered from Whittard canyon, calibrated and redeployed. Norteks were at 3100 m and 100 mab 6178 and 8351.

Deployment of PAP3

12. Benthic systems - Bathysnap

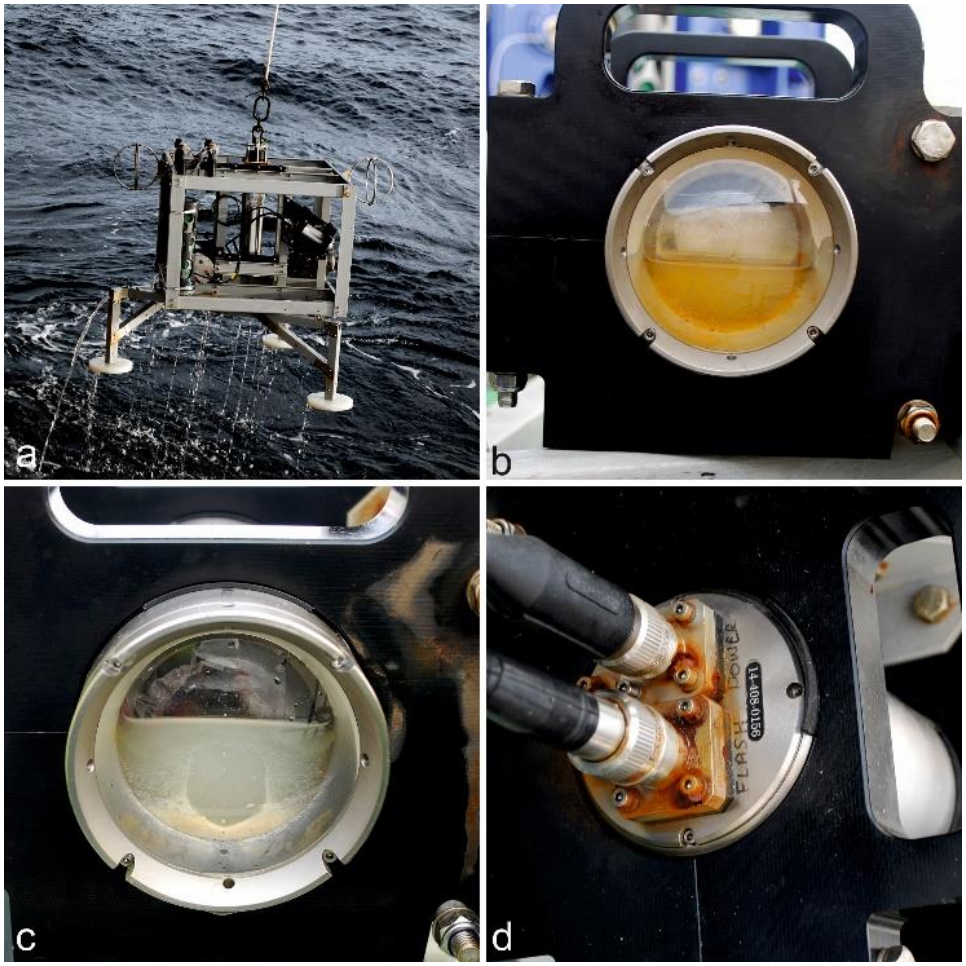
Andrew Gates

The *Bathysnap* time-lapse camera lander deployed as station DY103-038 in 2019 was recovered (Below, a). At 07:57 18 November 2020 the ship approached the *Bathysnap* location to range the release, 49° 0.202 N, 016° 26.961 W 4832 m water depth (uncorrected). The release could be heard but was not giving a range. The release code was entered at 08:01 and the mooring began to rise to the surface. At 08:09, (4616 m) it began to give ranges; 08:12 (4805 m), 08:54 (2823 m), 09:58 (420 m). At 10:04 the billings float was spotted from the bridge, to starboard of the ship at the surface, 49° 00.208 N, 016° 26.980 W. By 11:14 the *Bathysnap* lander was on board 49° 0.993 N, 16° 26.056 W and the ship ready to move to the next location.

On inspection of the *Bathysnap* system it was immediately clear that the camera and flash units had both flooded (below, b & c). The corrosion around the bulkhead connectors (below d) suggest that this is the likely source of water ingress. Inspection of the underwater cables suggested they appeared quite loose but the pins inside remained in good condition. The camera and flash were left on the *Bathysnap* frame for closer inspection at NOC to aid the development of the new system.

This *Bathysnap* system was refurbished after flooding during its first deployment at the LTER Observatory HAUSGARTEN. At that time it received a new frame and refurbished Kongsberg camera and flashgun. It was then deployed as station JC165-068 during RRS *James Cook* cruise 165, on 7 June 2018. On attempted recovery of that mooring on DY103 (06 July 2019) it did not rise when released. A Hybis rescue mission was required to locate and recover it (detailed in DY103 cruise report). The camera system was turned around on DY103 and deployed as the DY103-038 station recovered here.

The Bathysnap frame hosted two settlement experimetns and a larval trap for the LO^{3}Cated Project. Details of the samples taken from these experiments are in section 13.



a) Recovery of the Bathysnap time-lapse camera system, b) the flooded flash, c) the flooded camera and d) corrosion around the bulkhead connectors.

13. FixO^3 TNA project - LO^{3}CAted

Andrew Gates

Work on the **L**arval **O**ccurences in **O**pen **O**cean: **C**onnectivity **s**tudies in NE Atlantic and Mediterranean Sea (LO^{3}CAted) project continued at PAP this year. The nature of the cruise meant that it was only possible to carry out recovery of the settlement experiments and larval traps from the PAP3 and Bathysnap moorings this year. No further experiments were deployed.

Larval traps

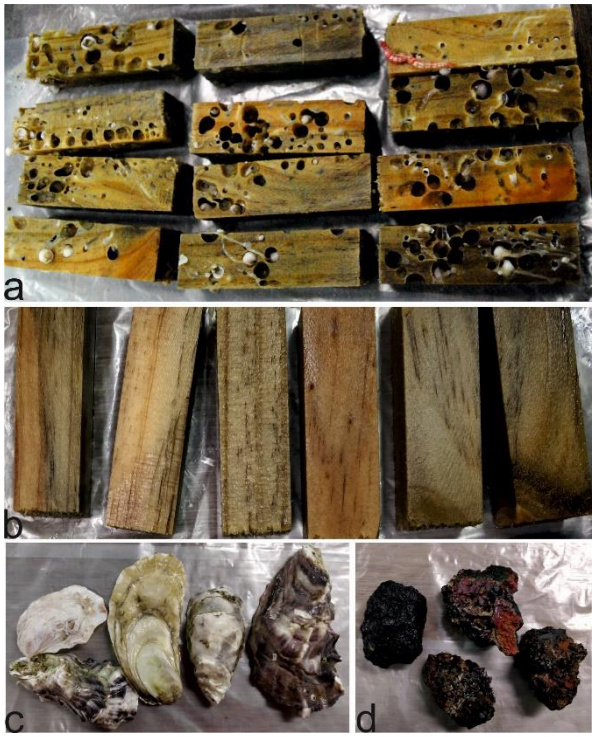
Bathysnap was recovered Thursday 19th November. Of the four larval trap tubes, only two of the plastic covers had released during the deployment. It appeared that the magnesium links had dissolved but two loops of elastic band were still holding the covers in place. The two traps that had not opened were discarded. The two remaining traps were transferred to new tubes in their preservation fluid and chilled. The samples looked to have retained a small amount of material including apparent phytodetritus particles.

PAP3 was also recovered on the same day. All four larval traps had functioned correctly on the trap at 3000 m on PAP3. Like Bathysnap, only 2 had functioned at 100 m above the seabed.

Settlement experiments

The settlement experiments were removed from Bathysnap when it had been recovered to surface. All substrates were immediately transferred to the controlled environment laboratory (5°C) before processing. The substrates were removed from the housing, photographed and preserved by freezing at -80 °C as soon as possible (within 1.5 hours). There was no obvious colonisation of the shell and clinker substrates but the wood had been colonised by wood-boring molluscs below (a).

The settlement experiments from the PAP3 mooring were treated in the same way as Bathysnap. There was no obvious evidence of colonisation of the substrates on experiments at 3000 m depth or 100 m above the seabed (below - b, c & d).



Contrast between a) near seabed samples (Bathysnap) and b) water column (3000 m sediment trap) from the LO³CAted experiments.

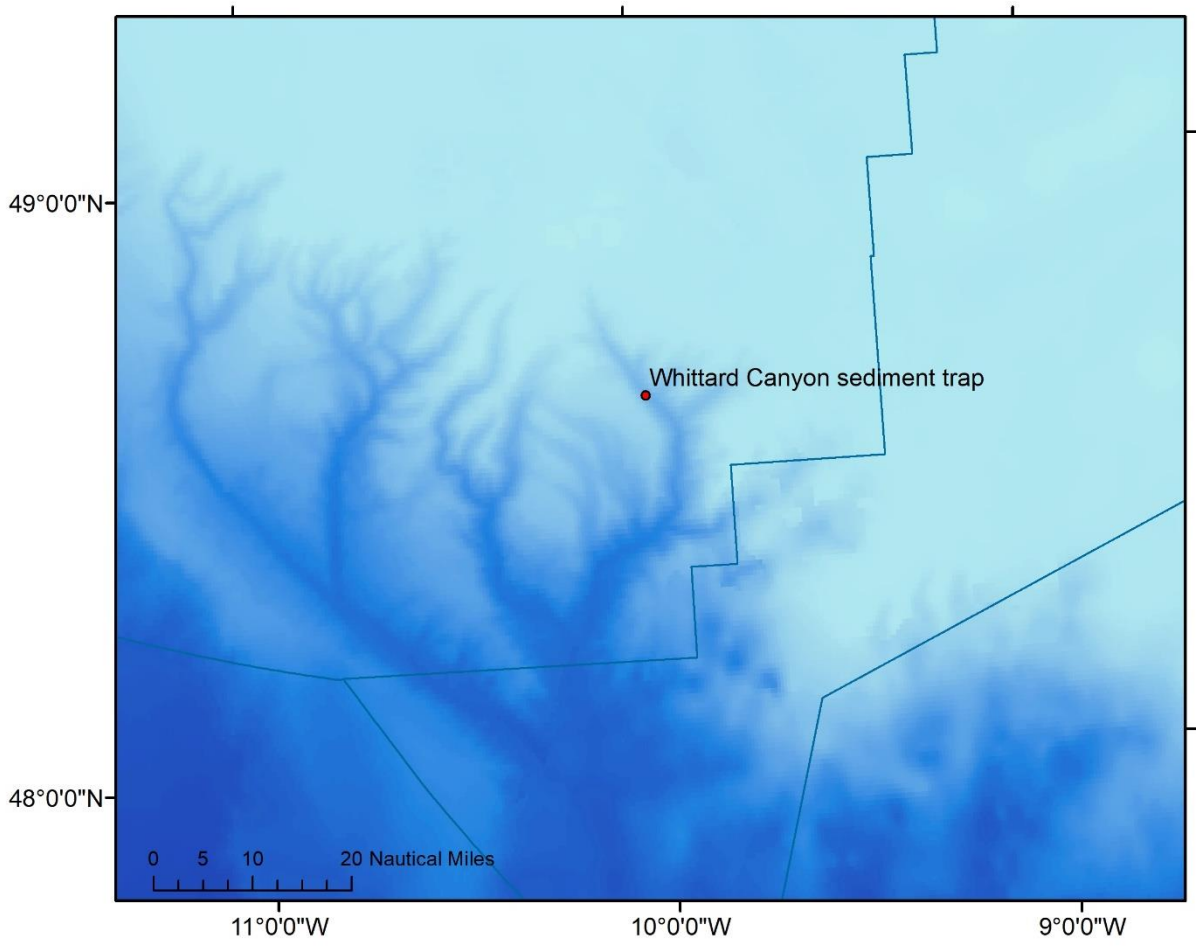
LO³CAted samples recovered from the PAP3 and Bathysnap moorings at PAP

Mooring	**Depth (m)**	**Frame**	**Substrate**	**Preservation**
PAP3 - 3000m	3000	2	Shell	2 x bags at -80°C
			Wood	2 x bags at -80°C
			Wood (2)	2 x bags at -80°C
		X	Clinker	2 x bags at -80°C
			Wood	2 x bags at -80°C
			Shell	2 x bags at -80°C
PAP3 - 100mab	4750	5	Shell	2 x bags at -80°C
			Clinker	2 x bags at -80°C
			Wood	2 x bags at -80°C
		6	Shell	2 x bags at -80°C
			Clinker	2 x bags at -80°C
			Wood	2 x bags at -80°C
Bathysnap	4850	1	Wood	2 x bags at -80°C
			Shell	2 x bags at -80°C
			Shell (2)	2 x bags at -80°C
		6	Wood	2 x bags at -80°C
			Shell	2 x bags at -80°C
			Clinker	2 x bags at -80°C

14. Whittard Canyon sediment traps

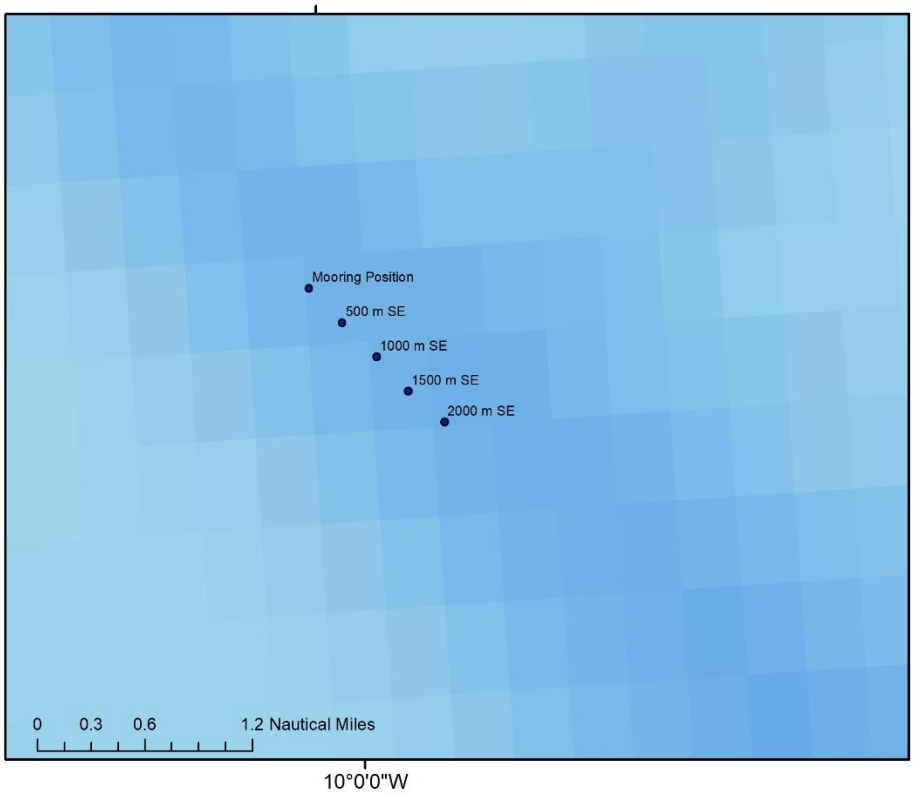
Science report – for mooring details see mooring report

The Whittard Canyon sediment trap and ADCP mooring (WCM) deployed on DY103 (DY103-041) was recovered on 12/11/2020 during DY116.



Location of the Whittard Canyon sediment trap mooring in the eastern branch of the canyon system

The mooring was approached from south east of the deployment location, travelling up canyon in case there had been any down-canyon movement since it was deployed. The mooring was ranged every 500 m from 2000 m south east:



Location of the WCM and the locations from which it was ranged prior to recovery.

At 0944, 48° 36.78 N 009° 59.35 W, the WCM was ranged and then released. The mooring was spotted from the bridge at 1020, alongside 11:00 and on deck by 11:35. Second ADCP was not floating with buoyancy spheres (possibly because of quantity of material in the sediment trap).

On recovery trap was spilling water, evidence that it was not on open hole as per programming. Bottle was removed to allow water out, after some was wasted, the rest was collected in three buckets. It was evident that the first bottle was full, but there was evidence of some material in other bottles too. The downloaded log suggested that all 22 events had happened on time and all finished on 22/09/20 as programmed. So the sediment either ended on bottle 1 or on open hole and somehow forced the trap round to bottle 1 again. The possibility of the bottles being put on in reverse was investigated and found not so because bottle 18 being under the topping up hole (bottle 17+1). The ADCP and microcat data will give more information on the timing and scale of the event, but the trap appears to have collected sediment in a major sedimentation event.

Inspection of the sediment trap from the WCM, filled with sediment on recovery to deck

Sediment trap bottles removed from WCM and shown in sequence in the laboratory

Mooring deployed - DY116-002

The WCM mooring was deployed on 13/11/2020. The top float was deployed at 10:45, weight in at 12:05. The trap was deployed to sample at 18 day frequency as per deployment record below.

```
Event   1 of  22 = 12/01/2020 12:00:00
 Event   2 of  22 = 12/19/2020 12:00:00
 Event   3 of  22 = 01/06/2021 12:00:00
 Event   4 of  22 = 01/24/2021 12:00:00
 Event   5 of  22 = 02/11/2021 12:00:00
 Event   6 of  22 = 03/01/2021 12:00:00
 Event   7 of  22 = 03/19/2021 12:00:00
 Event   8 of  22 = 04/06/2021 12:00:00
 Event   9 of  22 = 04/24/2021 12:00:00
 Event  10 of  22 = 05/12/2021 12:00:00
 Event  11 of  22 = 05/30/2021 12:00:00
 Event  12 of  22 = 06/17/2021 12:00:00
 Event  13 of  22 = 07/05/2021 12:00:00
 Event  14 of  22 = 07/23/2021 12:00:00
 Event  15 of  22 = 08/10/2021 12:00:00
 Event  16 of  22 = 08/28/2021 12:00:00
 Press any key to continue.
 Event  17 of  22 = 09/15/2021 12:00:00
 Event  18 of  22 = 10/03/2021 12:00:00
 Event  19 of  22 = 10/21/2021 12:00:00
 Event  20 of  22 = 11/08/2021 12:00:00
 Event  21 of  22 = 11/26/2021 12:00:00
 Event  22 of  22 = 12/14/2021 12:00:00
```

15. Acoustic mapping

Andrew Gates

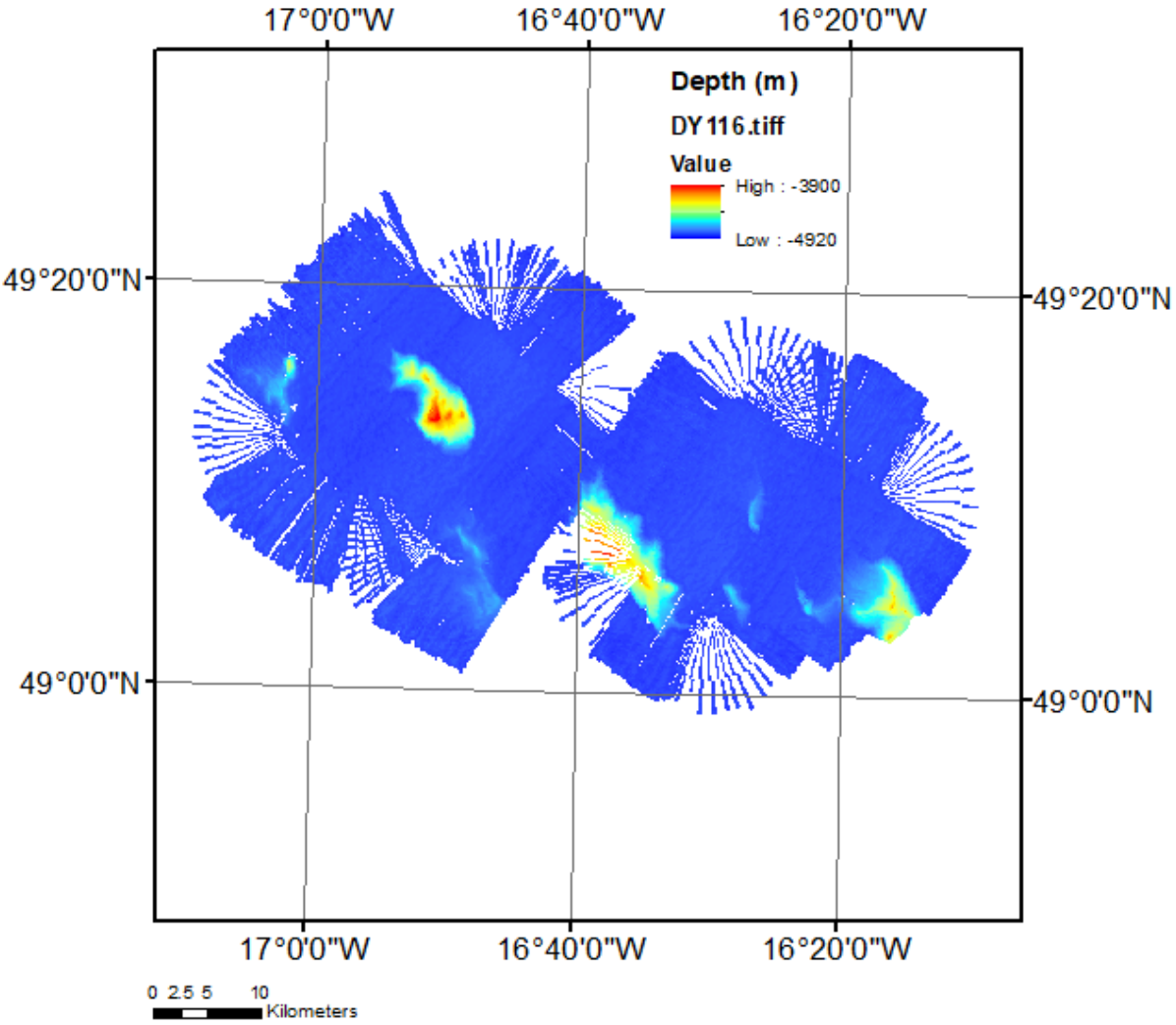
Shipboard Multibeam Systems: EM122 and EM710

The RRS Discovery has two Kongsberg multibeam echosounders, an EM122 (12kHz) and an EM710 (70kHz), mounted on the hull. The EM122 recorded throughout the cruise (unless turned off for mooring release or triangulation) but the EM710, a shallow water system, was only recorded where depths allowed along the transit. Once depths exceeded the system capabilities, the EM122 was the sole system.

At PAP, two opportunistic MBES surveys were conducted using the EM122, at 6 knots to collect data where there are gaps in the existing maps of the PAP area. The initial survey was conducted over an abyssal hill to the NW of the main PAP area and the second survey was carried out over a flat area of seabed to the north of the mooring area. A sound velocity profile from PAP CTD was used. No other settings were changed.

A 1 hour cetacean watch was performed before the systems were started, when no cetaceans were observed and the systems were started. Details are provided in Section 19. A sound velocity profile were taken from CTD casts and entered into each system. After the cruise Cat Wardell has processed the new PAP bathymetry data (see figure below).

Station number	**Multibeam Start**	**Purpose**	**Way point**	**Position**
DY116-004	19/11/2020 2114	Multibeam survey of abyssal hill NW of PAP.	WP1	49° 20.010 N 016° 51.820 W
			WP2	49° 12.822 N 017° 01.972 W
			WP3	49° 10.263 N 016° 55.853 W
			WP4	49° 17.320 N 016° 47.180 W
			WP5	49° 14.640 N 016° 42.750 W
			WP6	49° 08.072 N 016° 50.653 W
DY116-011	22/11/2020 19:04	Multibeam survey of flat area N of PAP central.	WP1	49° 2.885 N 016° 24.46 W
			WP2	49° 9.752 N 016° 17.207 W
			WP3	49° 11.879 N 016° 22.231 W
			WP4	49° 4.287 N 016° 29.287 W
			WP5	49° 6.664 N 016° 34. 683 W
			WP6	49° 13.661 N 016° 27.186 W



New PAP-SO area bathymetry collected on DY116

16. Meteorological Calibration (Met Cal)

Sue Hartman

Mags Yelland (ashore) requires information on the ship's met sensors due to high noise to signal ratio. On DY116 data were acquired close to PAP1, soon after deployment, for a comparison of met and wave data from the ship and the PAP1 mooring. There was an additional aim to understand the distortion (acceleration/deceleration) of the air flow to the anemometer on the foremast. This distortion biases the measured wind speed, and the bias depends on (a) the angle of the ship to the wind and b) the speed of the ship relative to the wind speed. This can be addressed by completing circles with the ship. It is important that the circles were not around the buoy itself since this would interfere with the wind speed measurement on the buoy when the ship is upwind of it.

The Met Cal was done by the bridge overnight on the 21st November (20:46 until 00:36 on the 22nd November) and assigned a single station number (DY116-009). The wave radar was switched on 21st November and the underway data associated with the Met Cal data was downloaded by Martin Bridger. **Data file is \\dynas1\Public\DY116\Met Cal - ship pirouettes\Underway_data DY116-009. Wamos data will be downloaded separately.**

The ship completed a number of circles at different speeds 'pirouettes'. These were done at 0, 4 and 8 knots as the weather conditions were favourable. The zero knot speed was the highest priority and the fastest feasible speed the second priority. The final timings and speeds are in the table:

Ship speed (knot)	Start time (21st Nov)	End time
0	20:46	21:47
4	22:24	23:25
8	23:34	00:36 (22nd Nov)

Some notes on Met Cal requirements:

- The 0 knot circle, can be completed using DP by putting a marker on the position of the ship's anemometer on the bow, and rotating the ship about the anemometer.
- A steady rate of change of heading is preferred (e.g. better than stepped changes)
- For the circles at 4 or 8 knots, a steady ship speed preferred, as well as a steady change of heading, (realising the ship speed might vary a bit with the wind and waves).
- The size of the circle/spiral does not matter.
- Good wind speed data from the met buoy acts as a reference, it is best if the ship is not upwind of the buoy when doing the circles.
- A full range of relative wind directions at a steady rate of change of heading (and ship speed if possible) - a spiral is fine

17. Processing samples recovered on DY120

Andrew Gates

Settlement experiments deployed at Darwin Mounds on DY108 were recovered on OSNAP cruise DY120 (before DY116 - cruise numbers were not sequential because of the Covid reschedule). The samples were left on board after DY120 for DY116 scientists to process according to these protocols:

Proposed assessment of DY108-048 colonisation hard hats.

Main objectives are:

- Obtain high quality images of the hard hats to study the distribution of the various taxa
- locate and collect all individuals of any coral species that may have settled on the hard hat
- Preserve them for identification and genetics

Secondary/optional objectives:

- List all the species/morphotypes present on the hard hats
- Obtain samples of representative individuals of these other groups, particularly barnacles, goose barnacles and annelids
- When possible, have several specimens of each preserved (also for genetics)
- Get some information on the relative abundance of each species/morphotypes

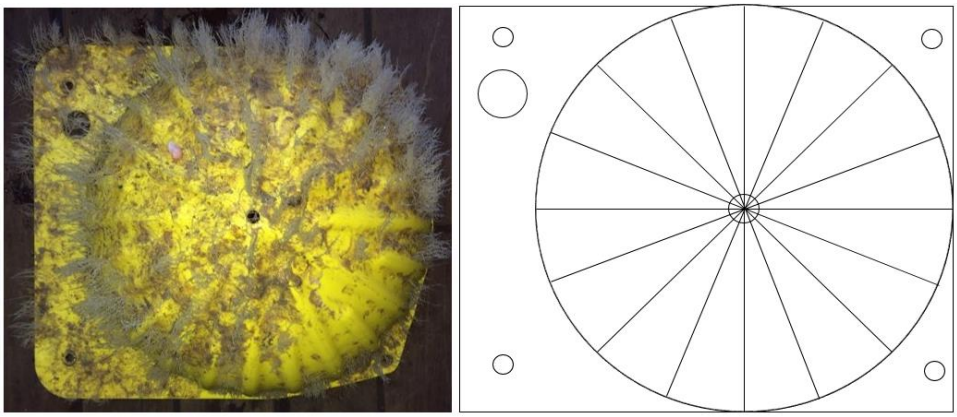


Diagram is orientated as the photos with both bolt holes to the right and hole for the rope in the downright corner.

Taking samples off the hard hats

1) Before scraping anything off, take photos.
    a. Ideally, take enough photos from all angles so that a 3D virtual model of the hard hat can be recreated. However, priority must be given to limiting the time the hard hats are exposed so they remain frozen.
    b. Include both the inside and outside of the hard hats as their surfaces may have different properties and harbour different communities
    c. Add a ruler/scale to the photos if possible
    d. While scanning the surface (preferably with a head-mounted binocular), if any individual polyp is spotted, a close-up photo must be taken
    e. Report their position on the hard hats (diagrams below)
    f. Specify if they sit on a ridge or a trough
2) Pick off each individual with tweezers while wearing latex gloves.
    a. Coral polyps are likely to be small. One individual per tube/pot seems achievable. Preserve them (fully) in tube/pot without any added preservative.

b. Name the samples as DY108-048_4/11mab_hat1/2_inside/Outside_sampleNumber numbered in order they are taken off (report samples in tables below diagram)
c. Place samples in -80 freezers

3) On return, contact Tammy Horton about space in -80 freezer. If space confirmed, arrange handover and transfer to shore-side freezer – if not, arrange to stay on board as a temporary measure.

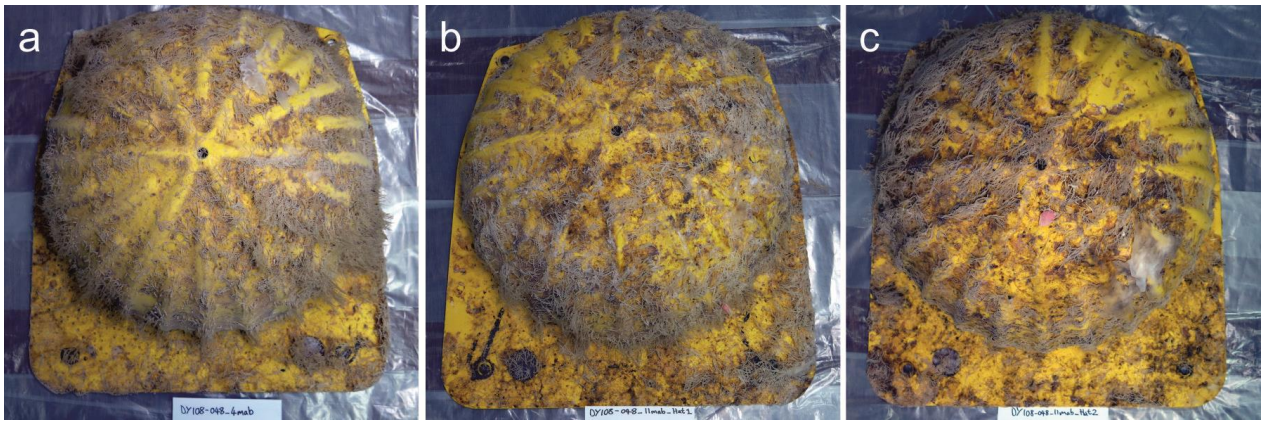
Optional objectives:

- Provide list of morphotypes present on each hat
- Pick a few individuals of groups of interest with the same protocol as the corals
- If possible, estimate density of abundant taxa like hydroids or provide close-up photos that can permit such quantification

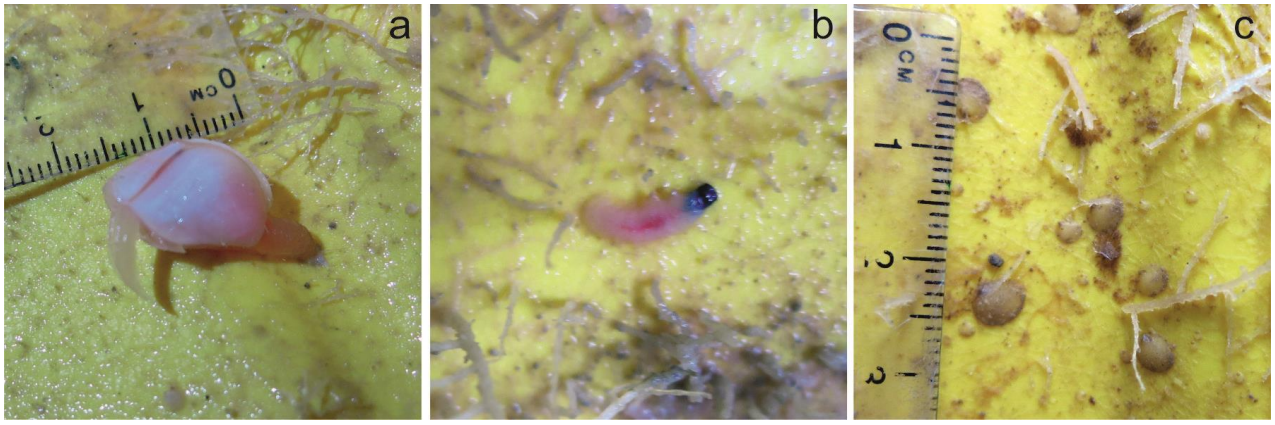
The following specimens were picked during DY116. Hard hats were cleaned at the end of the cruise:

Vial#	Sample	Diagram position	Tentative ID	Preservation (-80C)	First photo (IMG_XXXX.jpg)	Ridge/ Trough
1	DY108-048_4mab_Hat1_outside_1	1	saddle oyster	2 ml vial	8558	T
2	DY108-048_4mab_Hat1_outside_2	2	selection of molluscs	5 ml vial	8565	T
3	DY108-048_4mab_Hat1_outside_3	3	saddle oyster	2 ml vial	8568	T
4	DY108-048_4mab_Hat1_outside_4	4	encrusting	25 ml vial	8570	T
5	DY108-048_4mab_Hat1_inside_5	5	pink cnidarian	2 ml vial	8583	T
6	DY108-048_4mab_Hat1_inside_6	6	pink cnidarian	2 ml vial	8583	T
7	DY108-048_4mab_Hat1_inside_7	7	pink cnidarian	2 ml vial	8583	T
8	DY108-048_4mab_Hat1_inside_8	8	pink cnidarian	2 ml vial	8586	R
9	DY108-048_4mab_Hat1_inside_9	9	pink cnidarian	2 ml vial	8690	T
10	DY108-048_11mab_Hat1_outside_10	10	Stalked barnacle	25 ml vial	8626	T
11	DY108-048_11mab_Hat1_outside_11	11	Stalked barnacle	25 ml vial	8631	edge
12	DY108-048_11mab_Hat1_outside_12	12	pink cnidarian	2 ml vial	8637	T
13	DY108-048_11mab_Hat1_outside_13	13	polychaete	2 ml vial	8639	edge
14	DY108-048_11mab_Hat1_outside_14	14	pink cnidarian	2 ml vial	8652	T
15	DY108-048_11mab_Hat1_outside_15	15	representative hydroid	25 ml vial	8657	R
16	DY108-048_11mab_Hat1_inside_16	16	polychaete	2 ml vial	8663	T
17	DY108-048_11mab_Hat1_inside_17	17	polychaete	2 ml vial	8672	T
18	DY108-048_11mab_Hat1_inside_18	18	unknown	2 ml vial	8676	T
19	DY108-048_11mab_Hat1_inside_19	19	pink cnidarian	2 ml vial	8681	T
20	DY108-048_11mab_Hat1_inside_20	20	barnacle	2 ml vial	n/a	n/a - fallen off
21	DY108-048_11mab_Hat1_inside_21	n/a	nudibranch?	2 ml vial	8684	in hydroid
22	DY108-048_11mab_Hat1_inside_22	22	bivalve (*Pecten*-like shell wing)	2 ml vial	8689	R
23	DY108-048_11mab_Hat1_inside_23	n/a	bivalve (*Pecten*-like shell wing)	2 ml vial	n/a	edge
24	DY108-048_11mab_Hat1_inside_24	24	saddle oyster	2 ml vial	n/a	n/a
25	DY108-048_11mab_Hat2_outside_25	25	Stalked barnacle	25 ml vial	8736	R
26	DY108-048_11mab_Hat2_outside_26	n/a	unknown	2 ml vial	8739	n/a fallen off

27	DY108-048_11mab_Hat2_outside_27	27	polychaete (scaleworm?)	2 ml vial	8742	R
28	DY108-048_11mab_Hat2_outside_28	28	pink cnidarian x 3	2 ml vial	8746	T
29	DY108-048_11mab_Hat2_outside_29	29	polychaete (scaleworm?)	2 ml vial	8755	T
30	DY108-048_11mab_Hat2_outside_30	30	representative hydroid	25 ml vial	8760	R
31	DY108-048_11mab_Hat2_outside_31	31	pink cnidarian	2 ml vial	8763	T
32	DY108-048_11mab_Hat2_outside_32	32	pink cnidarian	2 ml vial	n/a	R
33	DY108-048_11mab_Hat2_outside_33	33	barnacle	2 ml vial	8768	T
34	DY108-048_11mab_Hat2_outside_34	34	bivalve	2 ml vial	8773	R
35	DY108-048_11mab_Hat2_inside_35	35	Stalked barnacle	25 ml vial	8778	T
36	DY108-048_11mab_Hat2_inside_36	36	polychaete (scaleworm?)	2 ml vial	8788	T
37	DY108-048_11mab_Hat2_inside_37	37	Hydroid (different morphology)	25 ml vial	8792	R
38	DY108-048_11mab_Hat2_inside_38	n/a	bivalve	2 ml vial	n/a	
39	DY108-048_11mab_Hat2_inside_39	39	pink cnidarian	2 ml vial	n/a	T
40	DY108-048_11mab_Hat2_inside_40	40	pink cnidarian	2 ml vial	n/a	T
41	DY108-048_11mab_Hat2_inside_41	41	polychaete	2 ml vial	n/a	T



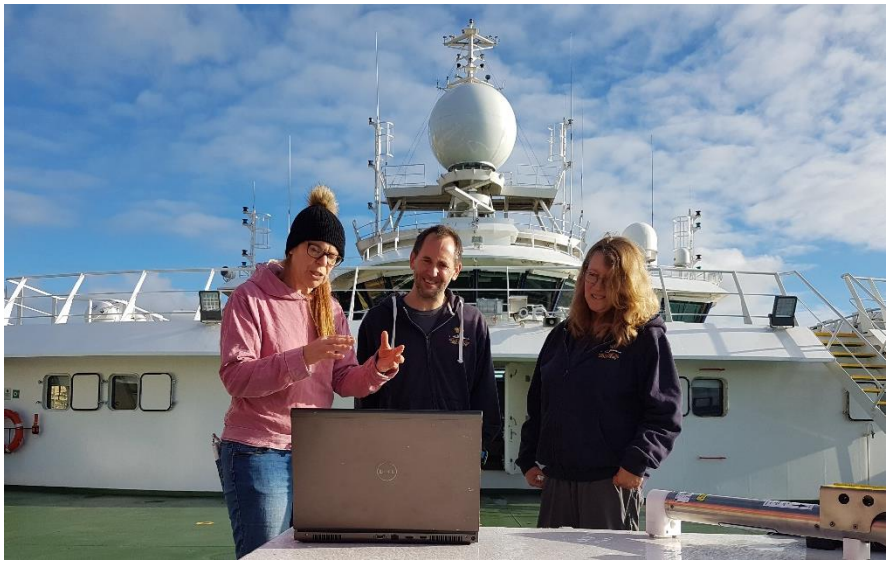
Settlement experiments ('hard hats') on removal from -80°C freezers on RRS Discovery a) 4 m above bottom, b) 11 m above bottom Hat 1, c) 11 m above bottom Hat 2



Example specimens removed from settlement experiments: a) Barnacle, IMG_8777, b) polychaete, IMG_8665, c) bivalves, IMG_8560

18. Public engagement

Several public engagement activities took place during DY116. Before departure the science team participated in a live link up with Lanes End School, Cowes, IOW, coordniated by Nick Rundle. Materials were provided to the school before the cruise and a Q&A session was held on board *Discovery* before departing for PAP. The session ended as *Discovery* pulled away from the quayside at NOC. Engagement continued throughout the cruise via blogs and social media.



Online Q&A session from the foredeck of RRS Discovery with Lanes End School, Cowes, IOW.

Articles were written for the NOC website about the cruise (https://noc.ac.uk/news/rrs-discovery-sails-porcupine-abyssal-plain) and the international coordination of the recovery of the drifting PAP-1 buoy.https://noc.ac.uk/news/noc-ocean-observatory-torn-lose-hurricane-epsilon-safely-recovered-fs-maria-s-merian

Articles were also written by ERICs for which PAP-SO is a node/regional facility: EMSO - http://emso.eu/2020/11/19/rrs-discovery-sails-to-the-porcupine-abyssal-plain/ and ICOS -

https://otc.icos-cp.eu/node/189

Social media (Twitter) was used to disseminate more information about the cruise, with good engagement across several accounts: @PAP_observatory, @CLASS_UKRI, @EMSOeu and individual scientists on board.

A cruise blog was maintained (https://papobservatory.wordpress.com/category/2020-cruise-dy116/)

Discovery Sails to the Porcupine Abyssal Plain 	Sue Hartman Corinne Pebody Andrew Gates
Team CO2 on DY116 	Sue Hartman Anita Flohr
Sediment Traps and pilot whales at PAP-SO 	Corinne Pebody
Upgrade to the PAP Observatory 	Andrew Gates
Meet the Galley Team on RRS Discovery DY116 	Anita Flohr

19. Marine Mammal Observation report

The following report was submitted to JNCC detailing the outcomes of the MMO observations:

Marine Mammal Observation Report – Scientific cruise DY116

Dr Anita Flohr, National Oceanography Centre, Southampton

This report summarises the relevant project details and mitigation measures for research cruise DY116 on board RRS Discovery.

Reference	Cruise DY116 (SME 17/392)
Operator	National Oceanography Centre, European Way, Southampton, SO14 3ZH, United Kingdom
Project details	The scientific cruise DY116 on RRS Discovery from 05.-30.11.2020 to the Northeast Atlantic Ocean was a continuation of a long-term time-series of observations at the Porcupine Abyssal Plain Sustained Observatory (PAP-SO)
Cruise PI	Dr Andrew Gates, National Oceanography Centre, Southampton, Email: arg3@noc.ac.uk; Tel: +44 (0)23 8059 6363
MMO	Dr Anita Flohr, National Oceanography Centre, Southampton, Email: aflohr@noc.ac.uk; Tel: +44 (0)2380 599346 JNCC MMO training attended: 12th February 2019 Non-dedicated MMO during cruise DY116 Martin Bridger, National Oceanography Centre, Southampton, Email: mart@noc.ac.uk, Non-trained MMO during cruise DY116 Corinne Pebody, National Oceanography Centre, Southampton, Email: corinne@noc.ac.uk, Non-trained MMO during cruise DY116
Mitigation	At-sea mitigation measures: 1. At water depth is >200 m, 60 minutes of observation focusing on the mitigation zone (500 m from the acoustic source) should be undertaken. 2. If marine mammals are observed during the search, start-up should be delayed at least 20 minutes from the time of the last detection within the mitigation zone, or the vessel manoeuvred away. 3. A soft-start (as defined in Appendix 1) should be enacted if the equipment allows.

	4. Any observations of marine mammals should be recorded on the forms provided by JNCC – an MMO is only necessary before and during the start-up of equipment, and not for the whole time it is running. Post-sea requirements: 1. Provide feedback to MEA regarding what mitigation measures were taken.
Sources	Multibeam Echosounder (Kongsberg, 12 kHz at up to -50 db) 2 x ADCP (RDI Teledyne, at 75 and 150 kHz with a dynamic range of 80 db)
Summary	Guidelines were met, i.e. a trained non-dedicated JNCC MMO assisted by non-trained MMO carried out search of mitigation zone for 60 minutes before use of active acoustics in water depths >200 m. Only at one occasion, marine mammals (pilot whales) were sighted prior to the start of a multibeam survey. The ship maneuvered away and visual MMO watch out was carried out for 30 mins until it got dark. No marine mammals were observed during this time. More details are documented in the attached MMO recording form (Annex 2).
Annex	Annex 1: copy of license (pdf) Annex 2: MMO recording form (excel) Annex 3: MEMP_DY116 Annex 4: pictures of long-finned pilot whales (courtesy of Andrew Gates)

Date 29/01/2021

Note: Annex 1 – 4 not included in Cruise Report

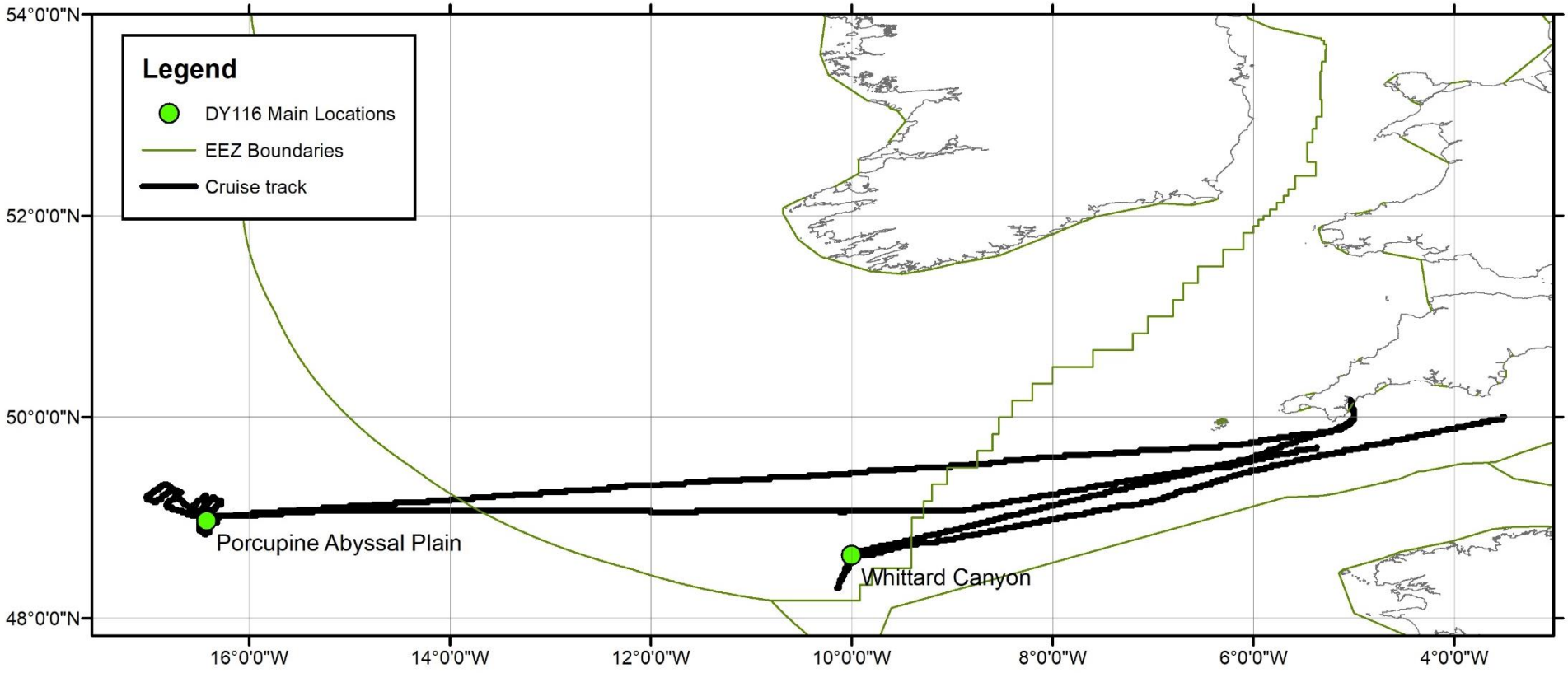
20. Acknowledgements

We acknowledge the additional support from NMF to ensure the cruise could take place safely under difficult circumstances with the Covid-19 pandemic. We thank all the crew of the RRS *Discovery* and the NMF technicians who enabled us to meet our scientific objectives. The catering was exceptional this year and we were well looked after.

We are grateful to the captain, crew and scientists of the FS *Maria S. Merian* for their assistance in the recovery of the PAP-1 buoy after it went adrift before our cruise.

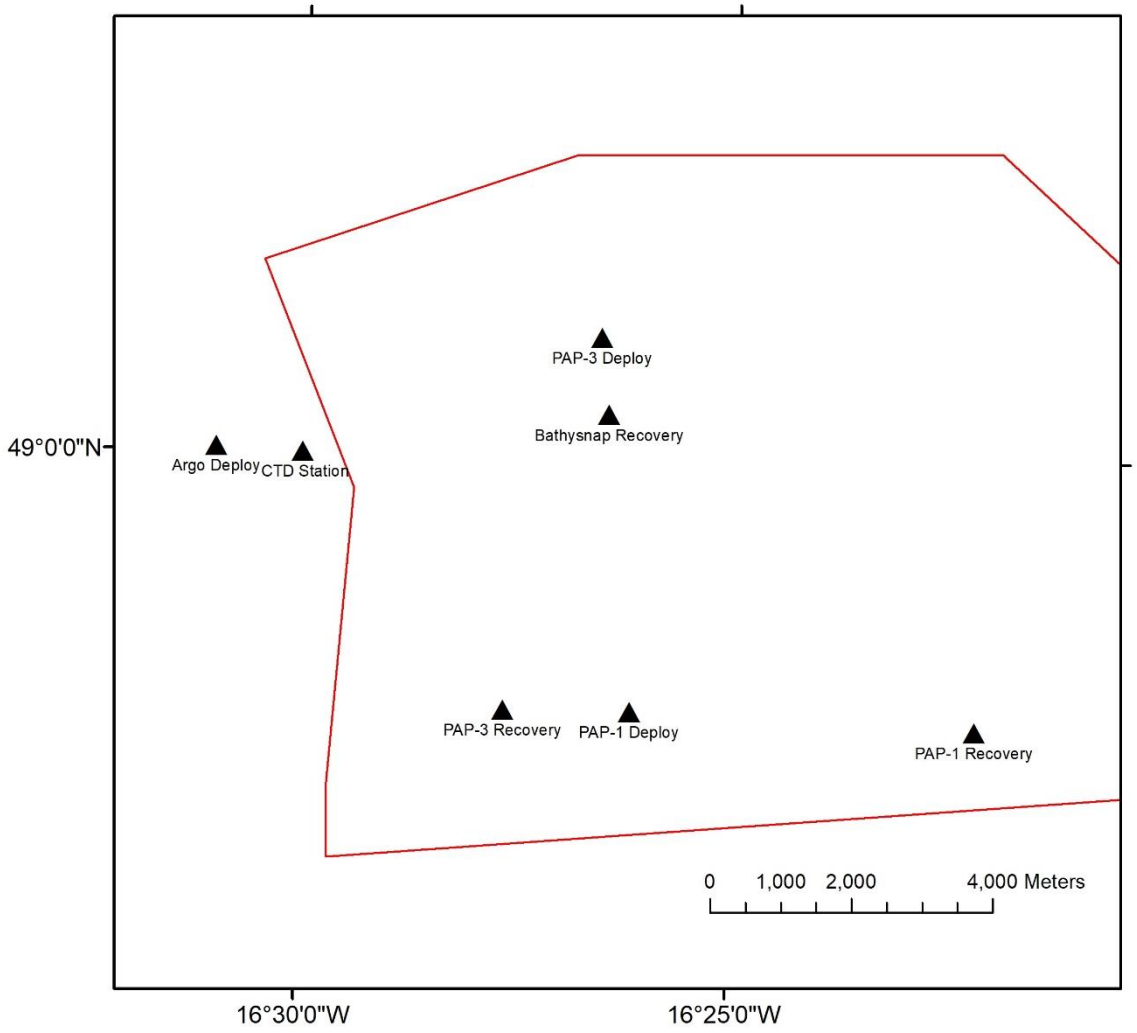
This cruise was a contribution to the Climate Linked Atlantic Section Science (CLASS) project supported by the UK Natural Environment Research Council (grant number NE/R015953/1).

21. General cruise track chart



General track chart for RRS Discovery Cruise 116

22. PAP Observatory operations



Location of PAP Observatory operations during DY116

23. Station list

The following tabulation provides basic metadata for all operations during RRS *Discovery* cruise 103. ***In the case of benthic operations, please refer to the tabulation of benthic station data provided in the body of this cruise report for the full metadata that should be used / reported in any subsequent work (reports / publications).***

Station number – formed of deployment cruise and station number; please use as unique identifier.

Event number – please use / interpret with great caution, these do not represent unique identifiers and may be employed in an *ad hoc* manner.

Date - date on which the deployment was initiated made (note that recovery may be on a later date).

Latitude / Longitude – Nominal sample position, please interpret appropriately to the particular instrument operation. All positions are given in degrees and decimal minutes based on the WGS84 datum.

Sounding – full depth of the water column (i.e. not necessarily the depth of sample / data collection) provided in uncorrected metres (ucm) based on a uniform assumption of sound velocity as 1500 ms^{-1}.

Time - time or times given relate to entry into water, first arrival at or near the seafloor, recovery to deck as appropriate to the particular instrument operation. All times given are UTC.

Gear type	**Brief description**
ARGO	Met Office Biogeochemistry Argo float
BSNAP	OBE Bathysnap time-lapse camera system mooring
CTD	NMF conductivity temperate and depth instrument, with water bottle rosette
MBES	Multibeam Echosounder
METCAL	Calibration of ship's meteorological sensors against PAP1 data
PAP1	MetOffice / NMF ODAS buoy and *in situ* sensor frame mooring
PAP3	NMF sediment trap string mooring
WCM	Whittard Canyon Mooring

Station	Gear	Date	Time	Latitude (N)		Longitude (W)		z (m)	Sounding (m)	Comment 1
JC165-058	PAP1	04/06/2018	09:07	48	57.936	016	22.143	4836	4844	Deployed JC165. All sensors recorded
		22/11/2020	14:25	48	57.492	016	20.788			End time = subsurface buoy on deck
DY103-009	PAP3	29/06/2019	10:40	48	58.05	016	27.624	4842	4842	Trap 84.
		19/11/2020	15:50	48	55.936	016	28.005			Recovered samples look good
DY103-028	PAP1	03/07/2019	14:43	48	57.936	016	22.143	0	4845	Surface buoy recovered by Merian.
		23/11/2020	15:15	48	57.51	016	21.46			End = Sensor frame on deck
DY103-039	BSNAP	06/07/2019	15:10	49	0.214	016	26.615	4840	4840	Deployed with Located traps
		19/11/2020	11:14	49	0.317	016	26.447		4830	Camera and flash flooded
DY103-041	WCM	08/07/2019	06:22	48	37.569	010	0.224	1577	1577	2 x ADCP, MicorCAT and Sed. Trap
		12/11/2020	11:35	48	37.713	010	1.024	1560		Trap & bottle 1 full of sediment. Some fouling, samples taken, -80
DY116-001	CTD	12/11/2020	15:51	48	10.722	010	9.117	900	3389	Release fired, electrical fault, bottle didn't fire
		12/11/2020	18:20	48	10.722	010	9.117			
DY116-002	WCM	13/11/2020	12:05	48	37.574	010	0.252	1577	1577	MicroCAT took a hit on deployment (surface postion)
DY116-003	CTD	19/11/2020	02:21	48	59.984	016	30.018	4700	4807	Release PAP3 fired, Microcat SN 12462 (post W.C, pre PAP3)
		19/11/2020	06:25	48	59.984	016	30.018	4700		
DY116-004	MBES	19/11/2020	21:14	49	20.299	016	50.686	4844	4844	just ahead of WP1. Line count 0231
DY116-005	CTD	20/11/2020	08:50	49	0.012	016	29.988	4700	4810	post PAP3 microCATS (deploy settings)
		20/11/2020	12:53	49	0.012	016	29.988			
DY116-006	ARGO	20/11/2020	13:03	49	0.032	016	30.1		4837	Just after CTD for comparison
DY116-007	PAP3	20/11/2020	17:34	49	0.905	016	26.542		4835	long tow
DY116-008	PAP1	21/11/2020	18:04	48	58.057	016	26.149	4838	4838	Systems operational. RTD except temp and sal. Time = anchor release
DY116-009	METCAL	21/11/2020	20:46	48	57.006	016	25.0044			0, 4 & 8 knt circles - calibration of ships met instruments with PAP-1 data
		22/11/2020	00:36	48	53.01	016	26.0046			
DY116-010	CTD	22/11/2020	16:11	48	58.709	016	24.551	450	4810	add PAR
		22/11/2020	16:58	48	58.709	016	24.551			
DY116-011	MBES	22/11/2020	19:04	49	2.869	016	24.422	4832	4832	
DY116-012	CTD	23/11/2020	03:28	49	0.0061	016	29.981	4700	4809	PAP3 post microcat SN 9469, 3x 10min stops
		23/11/2020	07:12	49	0.0061	016	29.981			
DY116-013	CTD	23/11/2020	11:39	49	0.035	016	29.939	500	4810	Add PAR, PAP1 post microcat 6907, 2x 10min stops
		23/11/2020	12:47	49	0.035	016	29.939			