SONNE-Berichte

Equatorial Pacific GEOTRACES

Cruise No. SO298

April 14 – June 2 2023

Guayaquil (Ecuador) – Townsville (Australia)

GEOTRACES GP11

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GEOMAR Helmholtz Centre for Ocean Research Kiel

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1 Cruise Summary

1.1 Summary in English

Research cruise SO298 with RV SONNE was sailed in the period April to June 2023 in the Equatorial Pacific Ocean (EPO) from Guayaquil (Ecuador) to Townsville (Australia), with a focus on trace element biogeochemistry and chemical oceanography but also including physical and biological oceanographic components. The research topic of the cruise was to determine in detail the distributions, sources and sinks of trace elements and their isotopes (TEIs) in the water column along a zonal section in one of the biogeochemically least studied ocean regions on earth. We aimed to investigate the biogeochemical cycling of TEIs, and their interactions with surface ocean productivity and the carbon and nitrogen cycles (incl. N_2 fixation), given that some TEIs act as micronutrients. The findings will have global significance for understanding the chemical environment in which ecosystems operate. The supply pathways of TEIs to the EPO from ocean boundaries including the atmosphere (dust and rain), continents (mainly Asian rivers), sediments (on continental shelves/slopes of the Indonesian Island Arcs), and ocean crust (hydrothermalism) were investigated. The TEI transport within water masses was determined with a focus on the equatorial eastward flow of Asian shelf derived TEIs in the Equatorial Undercurrent and the deep inflow of Southern Ocean waters in the western EPO. The TEI transport assessment along the cruise track will allow a more reliable use of particular TEIs as paleo circulation proxies. The cruise is officially part of the GEOTRACES program.

1.2 Zusammenfassung

Die Forschungsfahrt SO298 mit FS SONNE wurde im Zeitraum von April bis Juni 2023 im äquatorialen Pazifik (EPO) von Guayaquil (Ecuador) nach Townsville (Australien) durchgeführt, wobei der Schwerpunkt auf der Biogeochemie von Spurenelementen und der chemischen Ozeanographie lag, aber auch physikalische und biologische ozeanographische Komponenten einbezogen wurden. Das Forschungsthema der Fahrt war die detaillierte Bestimmung der Verteilungen, Quellen und Senken von Spurenelementen und ihren Isotopen (TEIs) in der Wassersäule entlang eines zonalen Abschnitts in einer der biogeochemisch am wenigsten untersuchten Ozeanregionen der Erde. Unser Ziel war es, den biogeochemischen Kreislauf der TEIs und ihre Wechselwirkungen mit der Produktivität des Oberflächenozeans und dem Kohlenstoff- und Stickstoffkreislauf (einschließlich N_2-Fixierung) zu untersuchen, da einige TEIs als Mikronährstoffe wirken. Die Ergebnisse werden von globaler Bedeutung für das Verständnis des chemischen Umfelds sein, in dem Ökosysteme funktionieren. Untersucht wurden die Zufuhrwege von TEIs in das EPO von den Ozeangrenzen, einschließlich der Atmosphäre (Staub und Regen), den Kontinenten (hauptsächlich asiatische Flüsse), den Sedimenten (auf den Kontinentalschelfen/an den Hängen des indonesischen Inselbogens) und der Ozeankruste (Hydrothermalismus). Der TEI-Transport innerhalb der Wassermassen wurde bestimmt, wobei der Schwerpunkt auf dem äquatorialen ostwärts gerichteten Fluss der vom asiatischen Schelf stammenden TEIs im äquatorialen Unterstrom lag, aber auch auf dem tiefen Einstrom von Wasser aus dem Südlichen Ozean in das westliche EPO. Die Bewertung des TEI-Transports entlang der Fahrtroute wird auch eine zuverlässigere Verwendung bestimmter TEIs als Proxies für die Paläozirkulation ermöglichen. Die Fahrt ist offiziell Teil des internationalen GEOTRACES-Programms.

2 Participants

2.1 Principal Investigators

Name	Institution
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Frank, Martin, Prof. Dr.	GEOMAR
Koschinsky, Andrea, Prof. Dr.	Constructor University

2.2 Scientific Party

Name	Discipline	Institute
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Steiner, Zvi, Dr.	Mar. Biogeochem/ Co-Chief Scientist	GEOMAR
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Battermann, Paul	Chemical Oceanography	GEOMAR
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Gammanpila, Anjala	Biological Oceanography	GEOMAR
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Norbisrath, Mona, Dr.	Chemical Oceanography	GEOMAR
Wang, Yu, Dr.	Biological Oceanography	GEOMAR
Wittmers, Fabian,	Biological Oceanography	GEOMAR
Guo, Jiaying	Biological Oceanography	Uni. of Tasmania
Nicolas, Angele	Chemical Oceanography	GEOMAR

Ajmar, Marco	Chemical Oceanography.	GEOMAR

2.3 Participating Institutions

GEOMAR	Helmholtz-Zentrum für Ozeanforschung Kiel
Constructor	Constructor University Bremen
Tasmania	University of Tasmania, Australia
Zhejiang	Zhejiang University China
PTB	Physikalisch-Technische Bundesanstalt, Germany

3. Research Program

3.1 Description of the Work Area

The Equatorial Pacific Ocean (EPO) plays a central role in the global overturning circulation, with upper ocean waters flowing into the Indian Ocean as the Indonesian Through Flow (ITF) and onwards to the North Atlantic, and deep waters flowing into and out of the Southern Ocean. In the EPO the zonal flows however dominate the meridional flows, except at the western boundary. Along our cruise track, the westward wind-driven surface flow is the South Equatorial Current (SEC), with the eastward flowing Equatorial Under Current (EUC) just beneath the SEC. The meridional deep water circulation in our study region is evidenced by major water masses (Antarctic Intermediate Water (AAIW), Lower Circumpolar Deep Water (LCDW), Upper Circumpolar Deep Water (UCDW), and Pacific Deep Water (PDW) (Talley et al., 2011)), at least two of which play crucial roles in micronutrient supply to the Pacific and Southern Ocean surface waters. Despite this importance, biogeochemistry of trace elements and their isotopes (TEIs) in the EPO is strongly understudied compared to other ocean regions whilst it represents an ideal area to assess the cycling, inputs, and exchange of TEIs and to study their transport within surface, undercurrents, intermediate, and deep water masses.

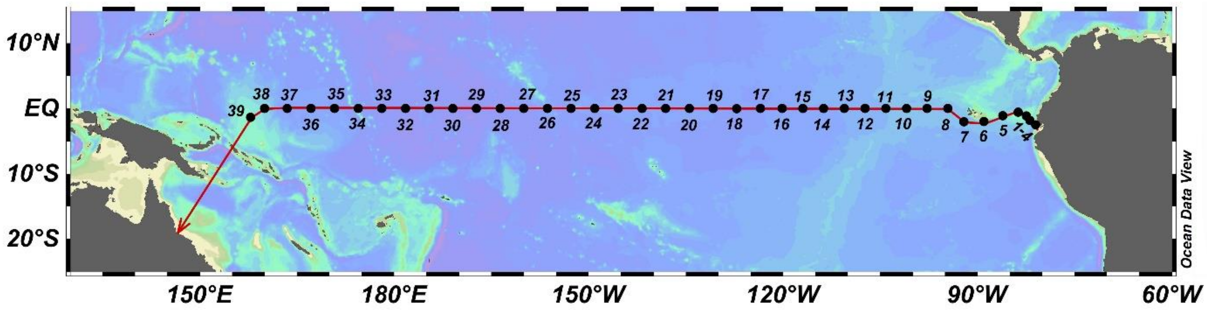


Fig. 3.1 Cruise track (red line) for SO298 with station locations (black circles).

3.2 Aims of the Cruise

The main **scientific aim** of the cruise was to establish the distributions of TEIs, quantify their sources from the four major ocean boundaries (rivers, atmosphere, exchange with sediments, ocean crust), and determine their biogeochemical cycling and relationships to large scale ocean circulation along a cruise track in the EPO.

We have the following **major goals** that we wanted to achieve for the cruise:

- Obj 1. Determine the distribution, as well as the physical and chemical speciation of TEIs, including micronutrients (such as Cd, Co, Cu, Fe, Mn, Mo, Ni, V, Zn, Cr), non-biologically essential elements (such as Al, Pb, Hg, Ti, Zr, Hf, Nb, U, W and REEs) and a range of isotope systems (including Pa/Th, Ra, Nd, Ba, Si, Pb, Fe, Cd) in high resolution full-depth profiles and along a continuous surface water section.

• Obj 2. Quantify the fluxes of these TEIs and micronutrients to the ocean from the four ocean boundaries: atmosphere, continent, ocean crust and sediments and assess the role of physical and chemical speciation of TEIs for their fluxes from the different sources.

• Obj 3. Assess, using chemical tracers and physical oceanography, the mixing and advection of the TEIs away from their sources into the ocean interior, and upwards into the surface ocean.

• Obj 4. Explore the relationship between macro- and micro-nutrient concentrations and fluxes, ocean productivity, particle and zooplankton distribution, metagenomic markers of particle export, nutrient utilization and limitation, diazotrophy, and nitrogen/carbon cycles.

3.3 Agenda of the Cruise

The cruise was conducted along a zonal section from Ecuador to Australia, which is an ideal section to assess the cycling of micronutrients in general, and in the EPO in particular. The section features important hydrothermal inputs to deep waters and pronounced contrasts in surface ocean productivity. The **major questions** that were addressed on the cruise:

1. The EPO surface waters exhibits a transition from high nitrate low chlorophyll (HNLC) waters with probable iron (Fe) limitation in the east to oligotrophic conditions with low concentrations of nitrate and micronutrients (Fe, cobalt (Co), zinc (Zn)) in the west. What are the proximally limiting or co-limiting (micro)nutrients for surface ocean productivity along cruise track, and how do N_2 fixation rates and diazotrophic communities change?
2. The sources, sinks, and internal cycling of TEIs in the EPO are poorly understood despite the importance of this region for the global cycling of nutrients and carbon. Which processes control the fluxes, supplies and cycling of TEIs?
3. Seafloor spreading centres along the East Pacific Rise (EPR) are well-known, but the region near Papua New Guinea in the Western EPO also features hydrothermal activity and provide deep water Fe inputs. Are there notable hydrothermal Fe fluxes in the western EPO, and can we determine the length scales of the Fe plumes?
4. Are the Central American and Papua New Guinean shelf and slope systems important sources of Fe and other TEIs to the Pacific Ocean along our ocean section?
5. The zonal current systems form a prominent feature of the EPO. The EUC is the dominant zonal current with respect to volume transport along the equator, transferring TEI-rich waters from the west EPO shelves eastwards along the equator, and supplying micronutrients following upwelling to surface waters in the EPO and Peruvian coastal regions. How large is the EUC TEI transport?
6. Intermediate and deep water masses in the Pacific upwell in the tropical Pacific, and therefore supply micronutrients to the EPO. The Fe/N ratios in these waters are likely below those required by phytoplankton communities in surface waters, but in terms of the total Fe supply to the surface ocean, these waters make a contribution to setting surface productivity.
7. Enhanced productivity in the EPO facilitates particle export from the surface to deeper ocean. Can we observe a zonal variation in carbon export and nutrient utilisation (Si, Ba isotopes) related to upwelling strength and supplied (micro)nutrients?
8. How does large scale ocean circulation affect the TEI distributions in surface and subsurface

EPO water masses? Is the advection of intermediate depth water masses from the Southern Ocean reflected by their TEI distributions (including Nd isotopes, Rare Earth Elements (REEs))?

On cruise SO298, we have adhered to all 'Measures to Conduct Responsible Marine Research'. We have carried out our research activities in the frame of the OSPAR Code of Conduct for Responsible Marine Research in the Deep Seas and High Seas of the OSPAR Maritime Area. Water samples were collected using a CTD rosette configuration with Niskin bottles attached. The impact on the marine environment was hence negligible. There were no collections of benthic or zoological samples. No explosive or noise intensive measurements were conducted. All chemicals used onboard were be returned to home laboratories. In case we worked in the EEZ of a state, then all the additional measures prescribed measures were adhered to.

4 Narrative of the Cruise

April 10-14, 2023- Scientists and technicians travelled from their home laboratories to Ecuador (Guayaquil) to join RV SONNE. A group of GEOMAR scientists and technicians had travelled already on April 10 and 11 to arrive earlier in Guayaquil to unload containers and set up the equipment for the cruise. Unfortunately, the port of Guayaquil was not able to handle containers for the SONNE before the evening of April 12. Also, all the airfreight was delivered late (April 13 and 14). All the cruise participants of SO298 were transferred to the vessel by bus in the morning of April 13. A total of 7 containers for SO298 were loaded plus the catering supplies containers for the cruise and also 6 containers for the GEOMAR ROV team (for cruise SO299). The GEOMAR trace metal clean winch container with a cable guiding deck block was installed, as was our clean container for sample filtration. The CTD sensors, UVP, nitrate sensor, LADCP and other instruments were installed on the GEOMAR stainless steel CTD frame. The cruise participants installed their laboratories. We departed Guayaquil in the evening of April 14 with calm sea conditions in the coastal waters off Ecuador.

April 14, 2023- The cruise started sampling surface waters from our trace metal clean tow fish for trace elements and biological variables at the first station in the coastal waters of Ecuador. This sampling activity using the tow fish continued until we reached the waters of Papua New Guinea (May 27). The surface waters were sampled for nitrogen fixation, nutrients and trace elements to establish the rates of nitrogen fixation, types of diazotrophs present (using nifH gene analysis), and the chemical environment of the diazotrophs. Nutrients and trace elements were sampled typically every 3 hours when steaming, and also upon arrival or departure at stations. The tow fish was taken out of the water for inspection only once or twice.

The ship's ADCP, multibeam and TSG (underway T, S system) were functioning (until May 27) whilst the vessel was sailing. In addition, we sampled aerosols (until May 27). The aerosol collector was placed on the top deck of the SONNE and filters changed every 72 h.

We have deployed 2 different CTDs (titanium GEOMAR CTD, stainless steel GEOMAR CTD) and also a set of 7 *in situ* pumps. The titanium GEOMAR CTD was operated by a dedicated winch system with a Kevlar cable (Fig. 5.1a), thereby preventing contamination of the samples during the sample collection. The deployments of the CTDs have been successful. The GEOMAR stainless steel CTD did not function at station 1, but was fixed successfully and functioned fine afterwards. The deployment of the *in situ* pumps was also very successful and greatly contributed to the success of the cruise.

At each station, we sampled the full water column with the titanium GEOMAR CTD (Ti-CTD) for contamination prone variables, and using the stainless steel GEOMAR CTD (SS-CTD) for less contamination prone variables, including isotopes like Nd and Th. An additional SS-CTD (BIO-CTD) was deployed every other day to about 300 m depth for collection of biological variables. Biological rate experiments of nitrogen fixation were conducted using water from the BIO-CTD (and tow fish). Phytoplankton resource limitation experiments were conducted in the ship-board laboratory and in incubation tanks on the aft deck.

We sampled a total of 39 stations on SO298, and 12 were so-called superstations. At the superstations, we deployed an additional SS-CTD for the collection of additional waters for isotope measurements. In addition, at the superstations we deployed 7 in situ pumps on the stainless steel wire of the SS-CTD. The pumps and SS-CTD deployment occurred simultaneously. The stainless steel wire of the SONNE was clean and released few particles. The freshwater rinsing system of the cable on the SONNE facilitated a clean CTD wire.

The *in-situ* pumps were used to collect particles for geochemical and biological investigations. Particulate Th isotopes (Th 234) obtained from the filters of the *in-situ* pumps will be analysed. In addition, a Mn cartridge was placed on the *in-situ* pumps, which allowed for the collection of long-lived Ra samples. We also sampled the Niskins from the SS-CTD for helium isotopes which we will use as a tracer of the hydrothermal fluid inputs to the ocean.

The first station on April 15, 2023 was conducted in coastal waters of Ecuador with a depth of just 110 m. The GEOMAR Ti CTD with OTE Niskin bottles worked well, but the SS CTD GEOMAR CTD had problems with the Niskin bottle release mechanisms (carousel). The carousel was exchanged for the unit from the SONNE CTD and all worked well for the next 38 stations. The occupation of the first station was finished within about 1 hour.

The next 4 stations moved from the slope to the deep ocean, and were conducted in waters with depths of less than 2600 m, and therefore took only a few hours to complete. Also, the distance between the stations was relatively short with only a few hours steaming between stations, increasing to 12 hours by station 6. Therefore, the sampling and sample processing teams were very busy during the first days. After station 6, the steaming times between stations ranged between 19 and 22 hours, and the depths were about 3000 m or more, which allowed good time for sample handling and sleep between stations. We had permission to sample in EEZ waters of Ecuador, but not in waters of the Ecuadorian National Park of the Galapagos Islands and the National Park of Hermandad. Therefore, we sailed south of the Galapagos, and reached the equator at station 8.

We sailed in international waters until the waters of Kiribati. Station distances were 3 to 4 degrees (longitude) along the cruise track. The region along the equator where our cruise track passed over the East Pacific Rise did not have any reported vent systems. We therefore did not attempt to sample specifically over a vent region, but kept our standard station distance. Sailing west from the East Pacific Rise, we kept our sampling stations at a 3 or 4 degrees distance along 0°0S. Station occupation along the equator continued until station 38 (May 26), following which we sailed southwest towards the waters of Papua New Guinea. We occupied station 39 in international waters at a short distance of about 10 miles from the EEZ of Papua New Guinea. Station 39 was a superstation, and we also conducted an additional BIO-CTD. As we did not have a formal signed permission to work in waters of Papua New Guinea, we stopped all the ship-based recording instruments, took the tow fish out of the water and stopped station occupation until the official issue of the research permits. In the end the permit did not arrive, and station 39 was our last station and we arrived in Townsville (Australia) on June 2. During the transit through the Coral

Sea towards Australia we packed up and loaded our containers.

The cruise took place during a transition period of La Nina to El Nino. We already noticed this in the Ecuadorian region where surface waters were up to 2°C warmer than the previous year. Also, further to the west on the equator, the surface ocean temperatures were higher than in 2022. Along the equator we anticipated an east to west current which would move the ship along. However, we instead faced a west to east current of 2 to nearly 4 knots which impeded the ship's speed. Thanks to careful engine and speed management, we were able to make excellent progress along the cruise track. The west to east surface current weakened to the west of 170°W. The surface current was in fact the Equatorial Undercurrent which had shoaled, providing nutrient-rich waters to the surface ocean, with enhanced pCO_2. We assume that the shallow EUC was caused by the transition to El Nino. The weather in the study area has been kind and we have not lost any station time as a result of poor weather.

5 Preliminary Results

5.1 SS-CTD System, Oxygen Measurements, and Calibration

(R. Czeschel, C. McKellar, M. Müller)

5.1.1 SS-CTD-Rosette System

During SO298 a total of 70 CTD-profiles and 1517 water samples were collected with the SS-CTD-Rosette-system (owned by Physical Oceanography Group at GEOMAR). The rosette system was installed in a Seabird Rosette System frame for 24 bottles. All casts were made with 22 bottles installed. Depth profiles up to a maximum pressure of 5494 dbar were performed. For the majority of stations, the full water column was sampled. Data acquisition was done using Seabird Seasave software version 7.26.7. Preprocessing was done with SBE Data Processing 7.26.7.

At the first ship station the data acquisition could not be started due to communication problems with the water carousel. After we replaced the water carousel with a spare one from the SONNE the CTD system worked fine throughout the cruise. Therefore, the first CTD profile was collected at ship station #2. It was determined that all regular sensors (P, T, S, O) as well as the Chl-fluorescence and turbidity sensor FLNTU manufactured by Wetlabs recorded data with sufficient accuracy and no errors were detected. These sensors provided high quality reliable data throughout the cruise. A full-depth PAR sensor was attached to the CTD and delivered good measurements throughout the cruise.

The exact configuration of the CTD system can be found in Table 5.1. Additionally, two self-recording LADCPs, a self-recording, self-powered UVP5, a self-recording nutrient sensor (OPUS, TRIOS), and a self-recording, self-powered PISCO (camera system) were attached to the water sampler. They are described separately in this cruise report.

Processed preliminary CTD data, 5-dbar binned, was sent in near real time to the Coriolis Data Centre in Brest, France, (via email: codata@ifremer.fr) for integration in the databases to be used for operational oceanography applications and the WMO supported GTS/TESAC system.

Table 5.1 Summary of CTD system SBE #9 configuration used during SO298.

	CTD system SBE#9
Pressure sensor	# 410
T primary	# 5806
T secondary	# 5807
C primary	# 3300
C secondary	# 4062
O2 primary	SBE 43 # 631
O2 secondary	SBE 43 # 2600
PAR Sensor	# 70714
Altimeter	# 42299

5.1.2 CTD-conductivity Calibration

Overall, 155 calibration points were obtained by sampling for salinity. Salinity samples were taken by the CTD watch in ‘Flensburger’ bottles, which proved to be ideal for storing salt samples over a long time. In order to calibrate the conductivity sensors of the CTD system, the conductivity of 155 water samples will be measured at GEOMAR. Therefore, we cannot give further information on salinity and pressure downcast calibration for the CTD system used during SO298.

5.1.3 Oxygen Calibration

The CTD oxygen downcast for CTD systems is calibrated by using the best 66% of the joint data pairs between downcast CTD sensor value and Winkler-titrated oxygen (Section 5.1.3). For the calibration a correction polynomial depending on pressure, temperature, oxygen and the product of pressure and oxygen was fitted (Table 5.2). A total of 300 oxygen samples were

Table 5.2 Downcast oxygen summary of calibration information for the CTD system used during SO298.

	Oxygen Sensor #613	Oxygen Sensor #2600
Sensor pair	primary	secondary
RMS misfit after calibration - oxygen	0.3986	0.40942
Polynomial coefficients - oxygen	Offset: 3.1056 P1: 0.00094713 T1: -0.054443 O1: 0.034471 P*O: 9.2679e-6	Offset: 1.7155 P1: 0.00066537 T1: 0.030056 O1: 0.020819 P*O: 1.0336e-5

taken. In the end, 166 different oxygen data points were used as several duplicates and triplicates were taken (see chapter oxygen), which resulted in an RMS-misfit for the downcast of 0.52076 µmol kg^{-1} for the primary SBE43 and 0.43803 µmol kg^{-1} for the secondary SBE43. The upcast calibration even surpassed these very good values with an RMS-misfit of 0.49209 µmol kg^{-1} for the primary SBE43 and 0.48091 µmol kg^{-1} for the secondary SBE43.

5.1.4 Thermosalinograph

(C. McKellar)

Underway measurements of sea surface temperature (SST) and sea surface salinity (SSS) were continuously done by the ship's dual thermosalinograph (TSG). One inlet is located at the portside (TSG A) while the other thermosalinograph's inlet is at the starboard side (TSG B). The parallel system worked well throughout SO298, except for data gaps in the starboard salinity data due to a failure in the software of TSG B from 16 May to 22 May 2023 in the period between 7:35 h to 18:33 h UTC. No scientific measurements in the EEZs of Papua New Guinea and Australia were conducted. SSS and SST measured by the TSG system will be calibrated with CTD measurements at 5 m as soon as the salinity of CTD system is calibrated.

5.2 Current Observations

5.2.1 Vessel Mounted ADCP

(R. Czeschel)

Underway current measurements of the upper ocean were performed continuously throughout the entire cruise (except in the territorial waters of Papua New Guinea and Australia) using two Vessel Mounted Acoustic Doppler Current Profilers (VMADCPs): a 75kHz RDI Ocean Surveyor (OS75) and a 38kHz RDI Ocean Surveyor (OS38) both mounted in the ship's hull. Measurements started at the first CTD station at 2.5°S, 81°W on 15 April 2023, 11:43 UTC. We stopped the record of both VMADCPs at boundary of the EEZ of Papua New Guinea at 1.35°S, 157.86°E on 26 May 2023, 22:33 UTC.

The OS75 and the OS38 are aligned to zero degrees (relative to the ship's center line). Both instruments ran in narrowband mode. The OS75 instrument was configured with 100 bins of 8 m and a blanking distance of 4 m, pinging 24 times per minute and reaching a range of 700 m to 800 m. The OS38 used 55 bins of 32 m and a blanking distance of 16 m, pinging 19 times per minute and reaching a range between 1200 m and 1500 m. During the entire cruise, the SEAPATH navigation data was of high quality. No interference was detected with the 12kHz echosounder EM122 that delivered high quality bathymetry data.

Post processing of the data was carried out separately for each instrument. The applied mean misalignment angles and amplitude factors with the associated standard deviation are summarized in Table 5.3.

Table 5.3 Vessel mounted ADCP calibration

OS	Mode	Misalignment angle ± std	Amplitude factor ± std
75	NB	-0.1260° ± 0.3962°	0.9979 ± 0.0094
38	NB	-0.2504° ± 0.4410°	1.0012 ± 0.0095

5.2.2 Lowered ADCP

(R. Czeschel, M. Müller)

During the whole cruise the CTD/Rosette system was equipped with a lowered ADCP setup based on two Teledyne RDI ADCPs. The setup consisted of an upward looking and a downward looking

300-kHz instrument. These two instruments were mounted inside the CTD rosette with especially manufactured frames protecting the instruments and allowing zero obstruction of the acoustic beams. The LADCP system worked without trouble with SN #11461 as downward-looking master instrument and #11436 as upward-looking slave during the whole cruise. During the cruise, we used a software, which controlled the start, stop, download, and erase of the cycles of the two LADCP systems (ladcp_tool_1.9.3 developed at GEOMAR).

A newly developed energy supply system that draws energy for the ADCPs from the CTD system using rechargeable capacitor (10.000uF / 100V) worked well throughout the cruise. The start as well as the download signal for the LADCP system was conducted via Bluetooth.

The first profile of the LADCP was performed on ship station #2 due to problems with the CTD at ship station #1 (see section 5.1.1). On the first shallow cast at ship station #2 the LADCP system could not be started due to transmission problems of the start signal via Bluetooth. The distance between the LADCP instruments and the Bluetooth transmitter was then reduced by installing the transmitter at a tension belt that was stretched in the hangar next to the CTD to minimize communication problems. On the second cast at ship station #2 the communication with the LADCPs via Bluetooth worked well until the end of the cruise.

Data processing took place during the cruise using the GEOMAR LADCP processing software V10.22, which includes both shear and inversion methods to derive an absolute velocity profile. As additional data are necessary for the processing, the corresponding pre-processed CTD files were used containing pressure, temperature and salinity profiles as well as time and navigation data.

The instruments of Teledyne RDI instruments delivered very good deep-ocean velocity profiles when processed in conjunction with the observations of the VMADCP and when coming close enough to the seafloor to obtain TRDI bottom track data.

5.3 Sample Collection and *In-situ* Measurements With Trace Metal Clean CTD/Rosette and Tow-fish sampler

(K. Gosnell, E. O´Sullivan, D. Jasinski, Y. Guo, N.D. Singh, Z. Steiner, J. Guo, A. Imig, A. Nicholas, P. Tselykh, N. van Horsten, A. Hollister, Florian Evers and Elisabeth Bauer)

5.3.1 Seawater Collection and I*n-situ* Measurements With Ti-CTD

The GEOMAR Ti rosette frame was equipped with 24 trace metal clean 12 L Niskin bottles (Ocean Test Equipment) was used for the collection of trace metal clean seawater samples. The Ti-CTD was equipped with two conductivity sensors, two temperature sensors, a pressure sensor, two oxygen sensors, a turbidity meter, an altimeter (Seabird Electronics) and a WET Labs C-Star transmissometer. The Ti-CTD was attached and operated using a conducting plastic-coated Kevlar wire and deployed over the starboard side of the ship using a trace metal clean LEBUS winch system. The Ti-CTD was typically lowered to 10-20 m above sea floor, as indicated by the altimeter, and the 24 Niskin bottles closed during the up-cast, typically at a wire speed of 0.3 m/s. There was one Ti-CTD cast per station during the cruise. Following an electrical problem during the down-cast in station 36, the system was rebooted and the down-cast resumed from 1000 m and saved as a separate file, hence there are 40 CTD files for the cruise’s 39 stations. As soon as the TM-clean rosette was recovered and secured on deck, all 24 Niskin bottles were quickly unloaded and hand carried into the trace metal clean sampling container where sampling was to occur. Clean vinyl gloves were placed on all Niskin bottle taps in order to minimize contamination risk during movement, and then removed once bottles were in the van.

The oxygen sensors were calibrated using bottles titrated using the Winkler method (see section 5.9). Samples were also collected for post-cruise calibration of the salinity data.

5.3.2 Surface Seawater Samples

Surface water samples were collected every three hours using a trace metal clean tow fish during transit, and on approach to each station. Standard surface water sampling included collection for analyses of trace metals, nutrients, aluminium and major elements. Additional parameters were sampled on approach to stations to complement the Ti-CTD samples with a surface ocean sample. Information regarding sampling locations and salinity was obtained from the ship's underway system based on the time of sample collection (Table 12.2).

5.3.3 Clean Lab Unfiltered Seawater Sampling

In the clean lab, unfiltered samples were always collected first from the Niskins. The first samples were for dissolved oxygen, which were obtained from ~6 different depths, including at least one triplicate per station. Dissolved oxygen samples were taken without any bubbles using a silicon tubing into a 100 mL glass bottle. The overflowing glass bottle was handed outside the sampling van for chemical treatment for Winkler analysis. This was quickly followed by salinity samples

Fig. 5.1a Left: Winch with Kevlar conducting wire. Right: Deployment of titanium CTD frame. Photo E. Achterberg (left) and C. Rohleder (right).

(300 mL) from other selected depths (both GEOMAR). Next, the bubble-free, unfiltered samples were collected for Hg speciation. Three different samples were collected for Hg; dissolved gaseous Hg sample from approximately every other depth (150 mL); methyl-Hg from every depth (150 mL), and total Hg from every depth (60 mL). These samples were collected from approximately every other station (see section 5.13 for further detail).

At 4 stations additional unfiltered samples (~2 L) were collected at 3 depths for sequential filtration for trace metals (Constructor University). Unfiltered samples (1 L) were also collected for Pb isotopes from approximately 7 depths per profile at each superstation (MPI Mainz). All samples collected were first triple rinsed with the targeted sample water prior to being filled.

5.3.4 Clean Lab Filtered Seawater Sampling

Filtered samples were collected by passing seawater through a 0.8/0.2 µm filter cartridge (AcroPak 500, Pall). Sampling bottles were all triple rinsed with filtered target water prior to final sampling. Dissolved aluminum (125 mL), nutrients (10 mL), and dissolved trace metals (125 mL) were collected from every station and every depth of the transect (all GEOMAR; 39 stations). Dissolved cation samples were aliquoted out of the dissolved trace metal samples proceeding acidification. Approximately 185-190 µL were pipetted into 15 mL of 0.12 M HCl in acid cleaned 15 mL centrifuge tubes (GEOMAR).

Additional filtered samples aliquots were also collected for dissolved trace metals (100 mL), high-field strength elements (HFSE; 100 mL), organic ligands (125 mL and 250 mL), and V speciation (100 mL) at ~every third station (Constructor University) (see section 5.11 for further detail). At approximately every 4 stations an additional >6 L filtered water was collected for sequential filtration, as well as for V isotopes (2 L) (Constructor University). About 1 L or 4 L (for depths < ~75m) of sample was collected from every superstation depth for Fe isotopes (University of Florida and GEOMAR). At superstations, samples for cadmium isotopes (1 or 2 L) were also collected from approximately 21-23 depths. Additionally, filtered subsamples were collected for the analysis of the soluble fraction of trace metals from 12 depths of each superstation. These samples were initially collected in 125 mL bottles, and then the water was further filtered through 0.02 µm filters (25 mm, Anapore, Whatmann) via a peristaltic pump under the laminar flow bench inside the clean lab container.

All LDPE bottles used to collect respective trace metal clean samples were cleaned prior to the cruise in accordance with GEOTRACES cleaning approval. Further information on this is provided in the GEOTRACES cookbook (https://www.geotraces.org/methods-cookbook/.)

5.3.5 Particulate Filter samples

After AcroPak sample filtering was finished, the Niskin bottles were connected to pressurized nitrogen gas lines (~0.5 bar; 99.999% Alphagaz™ 1) for collection particulate trace metals (>0.2 µm). Each Niskin bottle had its own gas line and tubing setup which could be manually opened or closed as needed. For superstations, particulate matter was sampled at every depth, while 12 filter depths were sampled for particulate material at normal stations. For these samples, an acid-cleaned and MilliQ rinsed polyethersulfone (PES) filter (25 mm, Pall) was placed in an acid-cleaned Swinnex filter holder, then directly attached to the Niskin bottle tap. After securely clamping the closed bottles (via custom made adjustable Teflon clamps), to ensure that bottles were secure under pressure, the taps were opened up and water was allowed to filter out. A 2 L volumetric pitcher was placed below each filter to collect and record how much water volume passed through each filter. Water volumes were variable depending on the depths and region, however typically 2-7 L would pass through each filter. After collection the filter was gently removed via teflon tweezers, folded like a little taco, and placed in a small clean bag, then stored in the freezer prior to shipment back to GEOMAR.

5.4 In-situ Pump Deployment for Biological Carbon Pump Assessment

(J. Guo)

Sinking of particulate organic matter (POM) links carbon dioxide (CO_2) fixed through photosynthesis by phytoplankton in the surface ocean with carbon storage in the ocean interior. This pathway has been conceptualized as the biological carbon pump (BCP), and represents a key carbon sequestration mechanism. However, the bioavailability and bacterial transformation of POM, which are key determinants of BCP efficiency, remain poorly understood. Biomarkers (e.g., amino acids and amino sugars) provide powerful tools for insight into the bioavailability and transformations of POM.

5.4.1 Sampling

Particles were collected using *in-situ* pumps. We had 6 Challenger Oceanics Pumps from NOC Southampton, and 1 KISP pump from GEOMAR. The Challenger pumps had both a 51 and 1 µm filter (293 mm), whilst the KISP pump only 1 µm filters (293 mm). The Challenger pumps were also fitted with cartridges for Ra sampling (see below). Two size fractions (1 and 51 µm) were obtained by PET meshes at each depth (SEFAR PETEX 07-1/2 and PETEX 07-51/33). After retrieving pumps back on-board, half of the particles on the mesh were rinsed to the beakers and then divided into 6 parts (bulk POM, amino acids, amino sugars, nitrogen isotopes, BSi, Th-234) and 4 parts (bulk POM, amino acids, amino sugars, nitrogen isotope) with a Folsom splitter for 51 µm and 1 µm, respectively. The partitioned seawater for bulk POM, nitrogen (N) isotope, amino acids (AA) and amino sugars (AS) were filtered onto GF/F filters and then stored at -20°C. Samples for Th-234 were filtered onto QMA filters. Samples for BSi were filtered onto Track Etch membranes and dried on board. Samples for PIC-$\delta^{13}C$, Fluorine (F) (or Hg), Barium (Ba) isotope, Silicon (Si) isotope, Metagenomics, Rare Earth Element (REE), Synchrotron and Microscopy were obtained by cutting a piece of mesh. PIC-$\delta^{13}C$, F (or Hg), Ba isotope, Si isotope and Metagenomics samples accounted for 1/12 of the total pumped seawater volume, respectively. REE accounted for 1/24 of the total particles. The *in-situ* pumps were deployed at 12 stations (each station 7 depths). In total, 151 bulk POM (51 µm: 70; 1 µm: 81), 151 AA (51 µm: 70; 1 µm: 81), 151 AS (51 µm: 70; 1 µm: 81), 70 Th_{234} (51 µm: 70), 70 BSi (51 µm: 70), 140 N isotope (51 µm: 65; 1 µm: 75), 151 PIC-$\delta^{13}C$ (51 µm: 70; 1 µm: 81), 73 F (51 µm: 34; 1 µm: 39), 77 Hg (51 µm: 36; 1 µm: 41), 151 Ba isotope (51 µm: 70; 1 µm: 81), 151 Si isotope (51 µm: 70; 1 µm: 81), 151 Metagenomics (51 µm: 70; 1 µm: 81), 104 REE (51 µm: 48; 1 µm: 56), 140 Synchrotron (51 µm: 65; 1 µm: 75) and 151 Microscopy (51 µm: 70; 1 µm: 81) samples were collected.

5.4.2 Sample Analysis

Samples for POC, PN and bulk $\delta^{13}C$ and $\delta^{15}N$ determination will be fumigated with hydrochloric acid (HCl) to remove inorganic carbonate followed by oven-drying at 60°C for 24 h, and analyzed using a Flash EA IsoLink CN elemental analyzer coupled with a MAT 253 plus IRMS (Thermo Fisher Scientific, Germany).

Pretreatment of AS samples will follow the method of Zhu et al. (2014). Briefly, GF/F filters or ground sediments were hydrolyzed using 6 M HCl at 105°C for 8 h. The hydrolysates will be then neutralized with 6 M potassium hydroxide (KOH) to a pH ~6.8 and centrifuged immediately. The supernatant will be taken through solid phase extraction (SPE) cartridges to remove salts, and then eluted with methanol and dichloromethane. The eluent containing AS will be concentrated under nitrogen and then redissolved in Milli-Q water for concentration and stable carbon isotope analysis. Individual AS concentrations will be quantified using an ion chromatograph (IC, Dionex

ICS-5000+ SP) coupled with an electrochemical detector.

Concentrations of D- and L-amino acids will be hydrolyzed using 6 M hydrochloric acid and then separated as *o*-phthaldialdehyde derivatives using a Thermo Fisher Scientific U3000 ultrahigh performance liquid chromatography (UPLC) system equipped with a Poroshell 120 EC-C18 column (4.6×100 mm, 2.7 μm particles). Further details of amino acid hydrolysis and chromatographic separation are provided by Shen et al. (2017).

5.5 Assessment of Carbon Export Using ^{234}Th, ^{230}Th, and ^{238}U

(X.G. Chen)

Thorium isotopes, ^{234}Th (half-life 24.1 d) and ^{230}Th (half-life 75400 yr) are radioactive decay daughters of dissolved ^{238}U and ^{234}U in seawater. Unlike their parent isotopes, Th isotopes are highly particle reactive. Therefore, Th isotopes have been extensively used as tracers to calculate particle fluxes (e.g., POC export), water mass mixing, advection, etc.

Samples for dissolved ^{234}Th, ^{230}Th, and ^{238}U were collected at all superstations (Stations 3, 7, 11, 15, 18, 21, 25, 28, 30, 34, 37, and 39) from the SS CTD. Most samples were collected at depths down to 600 m to quantify particle fluxes. Two deep (depths > 1000 m) water samples were additionally collected at each superstation to set the background levels of Th isotopes.

Thorium-234 samples (about 4 L) were collected without filtration and were subsequently acidified to pH < 1.5 using 6.5 mL concentrated nitric acid. The pH values after acidification fell in a range between 1.17 – 1.48. Then, 100 μL of particle flux internal standard was added to each sample. After > 8 h of stabilization, the pH values were raised to 8.2 – 8.5 using ~ 9.5 mL concentrated ammonium solution. Subsequently, 50 μL $KMnO_4$ solution and 50 μL $MnCl_2$ solution were sequentially added to co-precipitate ^{234}Th with MnO_2 particles. After > 8 h of precipitation, the precipitate was filtered onto 25 mm QMA filter with a pore size of 2.2 μm. The filter was rinsed with pH 9 MilliQ water and dried at 60°C overnight. The sample bottles were cleaned with 100 mL rinse solution (HNO_3/H_2O_2 solution) and rinsed three times with MilliQ water.

Particulate ^{234}Th samples were taken from filters in *in-situ* pumps that were deployed at each superstation with depths down to 600 m. Material from the PET filters were transferred onto QMA filters (see section 5.4). Particulate ^{234}Th QMA filters were dried at 60°C overnight. After drying, each particulate and dissolved ^{234}Th filter was mounted with plastic film and aluminium foil onto the sample holder. All ^{234}Th samples will be analyzed for beta activity using Risø low-level beta GM multicounter until the measurement uncertainties < 3%. The beta activity will be measured after 6 months for baseline radioactivity correction. The dissolved ^{234}Th filters will be digested after beta counter analyses to determine the recovery rates of Th.

For every dissolved ^{234}Th sample, 12–14 mL dissolved ^{238}U sample was correspondingly collected by filtering seawater through a Fisherbrand syringe filter (pore size 0.45 μm). Dissolved ^{238}U samples were acidified by adding 50 μL concentrated HCl and stored at room temperature.

Thorium-230 samples were collected by passing seawater through 0.8/0.2 μm filter cartridge (AcroPak 500, Pall). The weights of the samples were measured by a balance onboard. Subsequently, the ^{230}Th samples were acidified by addition of 2 mL concentrated HCl per kg. Several ^{230}Th samples were collected from the Ti-CTD by passing seawater through the 0.8/0.2 μm filter cartridge. For stations 11–39, surface water samples were collected for Th-U from a towed fish, with procedures identical to above.

Table 5.4 Sample list for dissolved ^{234}Th, ^{238}U, ^{230}Th, and particulate ^{234}Th

Station	**Dissolved $^{234}Th/^{238}U$**	**Particulate ^{234}Th**	**Dissolved ^{230}Th**
	Sampling Depth (m)		
3	1250, 1000, 600, 400, 299, 204, 120, 90, 70, 38, 25, 15, 5	40, 120, 200, 400, 600	1250, 1000, 600, 299, 204, 120, 70, 15
7	2000, 800, 600, 401, 300, 201, 118, 100, 70, 50, 40, 15, 5	40, 70, 120, 200, 400, 600	1500, 800, 600, 401, 300, 118, 70, 40, 15, 5
11	2100, 800, 600, 500, 300, 200, 150, 120, 80, 40, 20, FISH	40, 80, 200, 370, 600	2300, 800, 600, 500, 250, 200, 80, 40, 20, FISH
15	2100, 800, 600, 500, 370, 200, 150, 120, 80, 60, 40, 20, FISH	40, 80, 120, 200, 370, 600	2200, 800, 600, 500, 370, 270, 200, 90, 80, 40, 20, 5
18	2100, 800, 600, 450, 360, 200, 120, 80, 60, 40, 20, FISH	40, 80, 120, 200, 370, 600	800, 600, 450, 360, 270, 200, 100, 80, 40, 20, 5
21	1250, 600, 470, 355, 200, 110, 94, 75, 55, 40, 20, 10, FISH	55, 90, 115, 200, 355, 600	1900, 600, 355, 200, 94, 75, 55, 40, 20, FISH
25	600, 460, 350, 200, 175, 130, 70, 50, 35, 20, FISH	50, 90, 130, 200, 350, 600	1800, 600, 460, 350, 200, 175, 130, 70, 50, 35, 5
28	1400, 600, 420, 350, 200, 150, 143, 100, 65, 50, 20, FISH	50, 100, 135, 200, 350, 600	1800, 600, 350, 200, 150, 143, 100, 65, 50, 5
30	1400, 600, 410, 370, 200, 170, 129, 100, 75, 60, 45, 20, FISH	45, 100, 125, 200, 370, 600	1800, 600, 370, 200, 170, 129, 100, 60, 45, 5
34	2100, 600, 420, 340, 260, 200, 150, 100, 80, 60, 45, 20, FISH	60, 100, 160, 200, 420, 600	1800, 600, 340, 260, 200, 150, 100, 60, 45, FISH
37	1000, 630, 410, 340, 260, 200, 160, 100, 80, 60, 40, 20, FISH	60, 100, 175, 210, 410, 630	1800, 630, 260, 200, 160, 100, 80, 60, 40, FISH
39	1000, 600, 400, 320, 240, 150, 125, 100, 80, 60, 40, 20, FISH	70, 110, 160, 210, 410, 610	1000, 600, 400, 240, 184, 150, 125, 100, 80, 60, 40, FISH

5.6 Plankton Imaging With PISCO

(A. Theileis)

The PISCO is a prototype system for *in-situ* observations of zooplankton. It was developed at GEOMAR and was used on this cruise for the second time. PISCO was integrated in the SS-CTD rosette. Unfortunately, due to problems with the pressure strength of the optical windows, PISCO was just rated for 1000 m depth and not the originally planned 6000 m. Therefore, it was only possible to use it during the *in-situ* pump (ISP) stations, and BIO-CTD profiles. Furthermore, a leakage appeared on the first station, which could be fixed, but also on the last station a Microcontroller stopped working. So, in total PISCO was active during 27 CTD profiles. During the 27 profiles, 1,110,000 raw images were recorded. The camera itself works like a focused shadowgraph, consisting of a light tube and a camera tube, so it records the shadows of the objects. As a novelty, a high-speed tunable lens is applied, which makes it possible to focus through a very large sample volume (7.5 cm diameter x 50 cm length “depth-of-field”) during a single exposure of 16 µs duration. The optical setup is also optimal for recording transparent organisms, e.g., most gelatinous zooplankton. The system uses a 2560x2560 Monochrome Image Sensor, with a pixel resolution of 23 μm/pixel, achieving an effective maximum optical resolution of ~10.8 LP/mm. This makes it possible to identify and taxonomically classify organisms in the size range from ~300 µm up to several cm (limited by the size of the window) (Fig. 5.1). The camera takes 10 pictures per second, corresponding to a sample volume of ~20 liter per second during vertical profiles with 1m/s. Detailed analysis of the collected image data will be done back at GEOMAR. The aim is to provide data on zooplankton abundance and biomass, its taxonomic composition, and vertical distribution and variability for each of the 81 profiles. Data will also be quantitatively compared and combined with data from the UVP5. This will provide a holistic view of zooplankton communities and their role in the pelagic food web and particle fluxes along the equatorial Pacific Ocean.

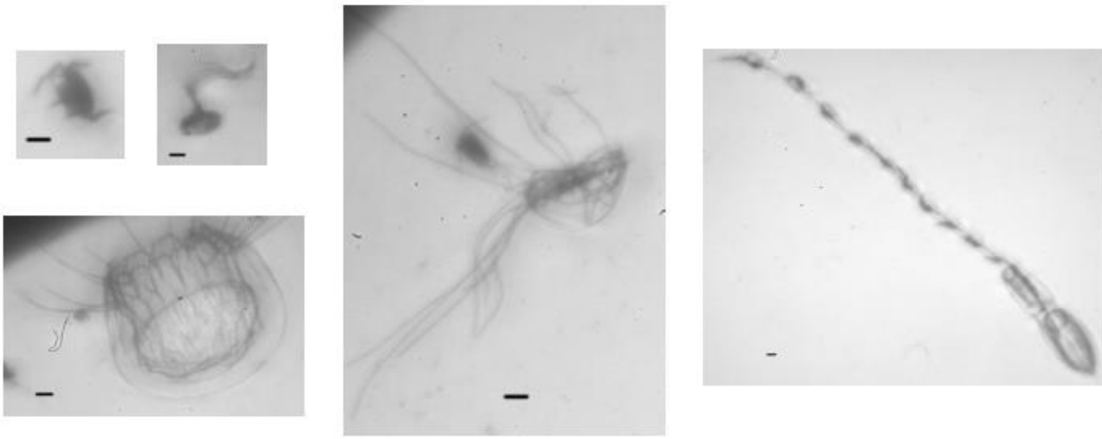


Fig. 5.1b Different zooplankton species captured with PISCO during SO298.

5.7 Underwater Vision Profiler

(A. Theileis)

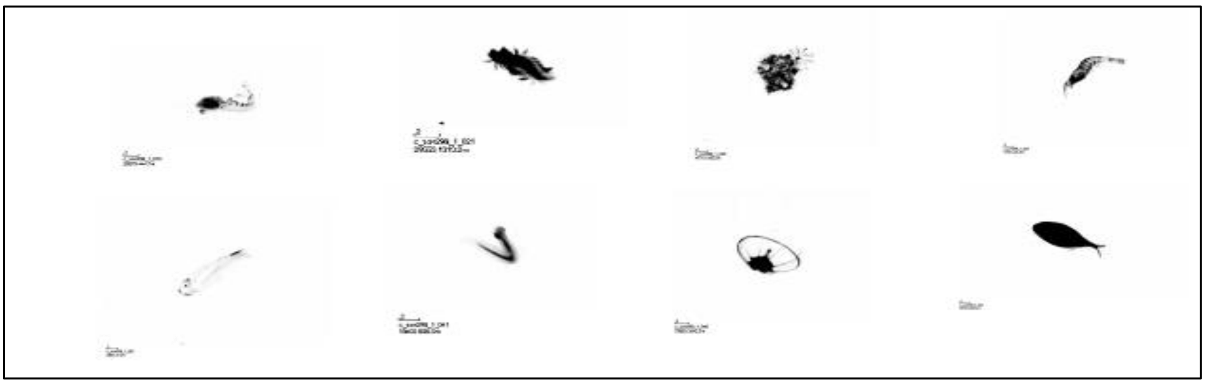


Fig. 5.2 Different zooplankton species captured with UVP5 during SO298.

During all SS-CTD casts, an Underwater Vision Profiler 5 HD (UVP5 HD; serial number 205) was operated on the CTD rosette. The instrument consists of one down-facing HD camera in a 6000-dbar pressure-proof case and two red LED lights which illuminate a 1.24 L-water volume.

During the downcast, the UVP5 takes 20 pictures per second of the illuminated field. For each picture, the number and size of particles are counted and stored for later data analysis. Furthermore, images of particles with a size > 500 µm are saved as a separate “Vignettes” - small cut-outs of the original picture – which allow for later, computer-assisted identification of these particles and their grouping into different particle, phyto- and zooplankton classes.

Since the UVP5 was integrated in the CTD rosette and interfaced with the CTD sensors, fine-scale vertical distribution of particles and major planktonic groups can be related to environmental data. In total 70 UVP5 profiles could be obtained. At each station with a water depth < 6000 m a full-depth profile was obtained. Further, computer-assisted analysis of the approximately 700000 images taken with the UVP5 will be done in the home laboratory in order to reveal fine-scale distribution patterns of particles and zooplankton.

5.8 Nutrient Analysis

(T. von Keitz, A. Mutzberg)

The distribution of nutrients in seawater is a key for understanding the biogeochemical processes, and their signatures allow the differentiation between the various water masses in the ocean. In addition, they are used to identify leaking bottles due to their well-defined and oceanographically consistent distributions.

Every Niskin bottle fired from every single cast depth was sampled for nutrient analysis onboard. The seawater was collected in 15 mL polypropylene sample vials. Containers and caps were rinsed three times with the water of the sample before the actual sampling. Samples were placed immediately in the fridge after collection (4°C in darkness) in case they could not be immediately analyzed.

Analysis of macro nutrients was undertaken onboard by segmented flow injection analysis using a QUAATRO39 (Seal Analytical) auto-analyzer including a XY2-autosampler unit. For nano molar nutrient samples, a modified detector set up with 1000 mm flow cells has been used. The system set-up included 4 channels for nitrate + nitrite (TON), silicate, nitrite, and phosphate. The analytical methods followed during the cruise correspond to those described by QuAAtro Applications: Method No. Q-068-05 Rev. 11 for TON, Q-066-05 Rev. 5 for Silicate, Q-070-05 Rev. 6 for Nitrite and Q-064-05 Rev. 8 for Phosphate.

A total of ~2480 samples were collected using: (1) all Ti-CTD casts, (2) stainless steel BIO-CTD casts in depths between ~5 and 300 m, and (3) GEOMAR SS-CTD-casts, and measured for macro-molar nutrients on-board. Additionally, ~275 samples, collected by all GEOMAR SS-CTD casts, were measured for dissolved organic nitrogen and phosphorous (DON / DOP) after digestion onboard (using Oxisolv).

About 250 towfish samples from oceanic surface with expected concentration values lower than ~100 nM for mainly nitrate + nitrite were stored as nano-molar nutrient samples from the GEOMAR SS-CTD casts at -20°C to be subsequently analyzed onboard with the macro set up and modified nano set up QUAATRO39 (Seal Analytical) auto-analyzer.

About 180 bio-assay-experiment samples were stored like the nano-molar nutrient samples from the incubator experiments at -20°C and analyzed onboard with the macro set up and modified nano set up QUAATRO39 (Seal Analytical) auto-analyzer.

Certified Reference Material for Nutrients in Seawater (RMNS) was used for every run in order to: (1) guarantee repeatability and reproducibility between analytical runs and (2) validate the data set in terms of compatibility within the scientific community. Nutrient analysis was validated with KANSO CRM, Lot-No. CO, CL for macro molar Nutrients and BY for nano molar nutrient concentrations.

5.9 Oxygen Winkler Titrations for CTD Sensor Calibrations

(T. von Keitz)

Oxygen sensors attached to the CTD rosette frames measured oxygen concentrations for the different CTD casts. In total 638 oxygen samples were collected from different depths of the water column to calibrate these sensors. There were two different CTD types: the SS-CTD and Ti-CTD. For each CTD type per station 10 samples were taken (with minor changes if the water budget was not enough). For *in-situ* pump stations, the 10 samples for the stainless steel CTD were split onto the deep and the shallow cast. The samples were collected bubble free and as soon as possible after the CTD was on deck. The decision for the sampled depths were made during the down cast. Five different depths were chosen following the same pattern: the highest and lowest depths, the oxygen minimum zone and depths that showed no or the weakest possible gradient. For the trace metal clean CTD, the samples were taken inside the clean lab and fixed with the reagents outside of the clean lab to prevent contamination of the other parameters that get sampled in the clean lab. From station 6 to 18 oxygen samples were taken as duplicates. From station 19 onwards, six different depths were chosen with two triplicates and 4 discrete samples to be able to verify how stable the taken sample values are. Oxygen concentration samples were analysed during the cruise using the Winkler (1888) Method.

Table 12.5 shows the oxygen samples taken, including station numbers and casts and the results of the Winkler titration.

5.10 Bio-optics Measurements on RV SONNE

(T.B. Robinson)

Ocean Colour Remote Sensing: Automated continuous above-water hyperspectral radiometric quantities were recorded along the whole cruise track of SO298. Two identical radiometer setups were installed. Each with one TriOS RAMSES-ACC hyperspectral cosine irradiance meter to measure incoming solar irradiance Es (λ), and two TriOS RAMSES-ARC hyperspectral radiance meters to measure total sea surface leaving radiance Lsfc (θsfc, Φ, λ) and sky-leaving radiance Lsky (θsky, Φ, λ). Initially, the radiometers were installed using a custom-made frame at the bow of RV SONNE. However, they were moved on 20.04.2023 to the top of the mast at the front of RV SONNE to remove issues of ship and mast shadowing (Fig. 3). Hyperspectral measurements were collected at 5-minute intervals over a spectral range of λ = 320–950 nm. Remote sensing reflectance (Rrs) and water leaving radiance (Lw) can be calculated from the radiometric measurements via the following equation and will be used to investigate changes in fluorescence line height (normalized to Chl *a*) along the cruise track. Preliminary Lw results are shown in Fig. 5.4; however, all data still require quality control checks.

$$R_{rs} = \frac{L_w}{E_s} = L_{sfc} - \frac{\rho_{air-sea} * L_{sky}}{E_s}$$

Preliminary measurements of photosynthetically active radiation (PAR) and Chlorophyll *a* based on the Rrs data have been obtained (Fig. 5.5) and will be compared to ship measurements. The two sets of radiometers (1 ACC and 2 ARC each) were placed at opposing relative azimuth angles (45° and 315°) in order to ensure that at least one set would always have minimal effect from a solar azimuth angles <90°. In addition to the application of sun glint correction, data will be optimized for each timepoint so that the sensor set with the least effect from solar azimuth angles is used. Data processing will be completed as proposed in literature (Garaba and Zielinski, 2013) and after quality control, datasets will be made open-access via PANGAEA.

Fig. 5.3 TriOS hyperspectral radiometers and irradiance meters on top of the mast at the bow of RV SONNE during the cruise SO298.

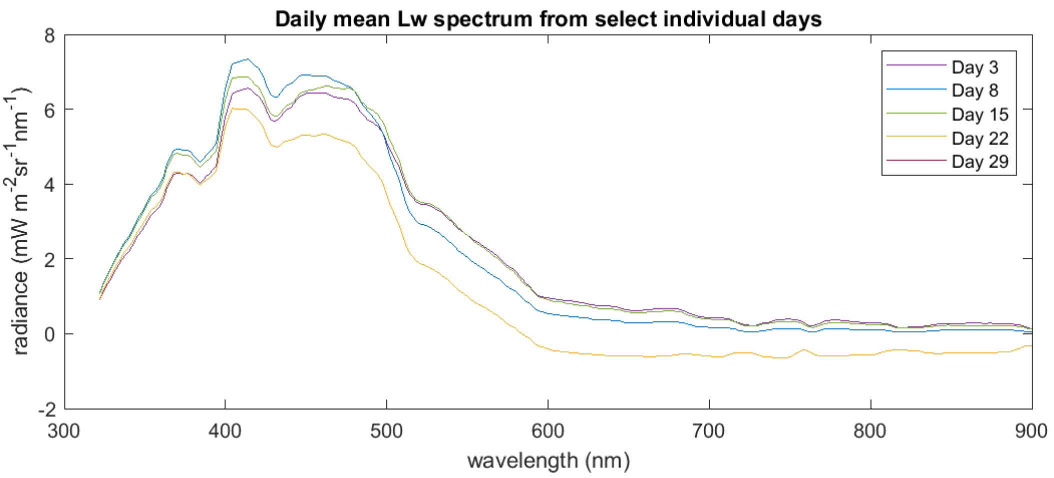


Fig 5.4 Daily mean radiance values for water leaving radiance (Lw) for five separate days. Dates were chosen based on general spacing along the cruise track and are given here to show the general wave spectrum observed in the study area.

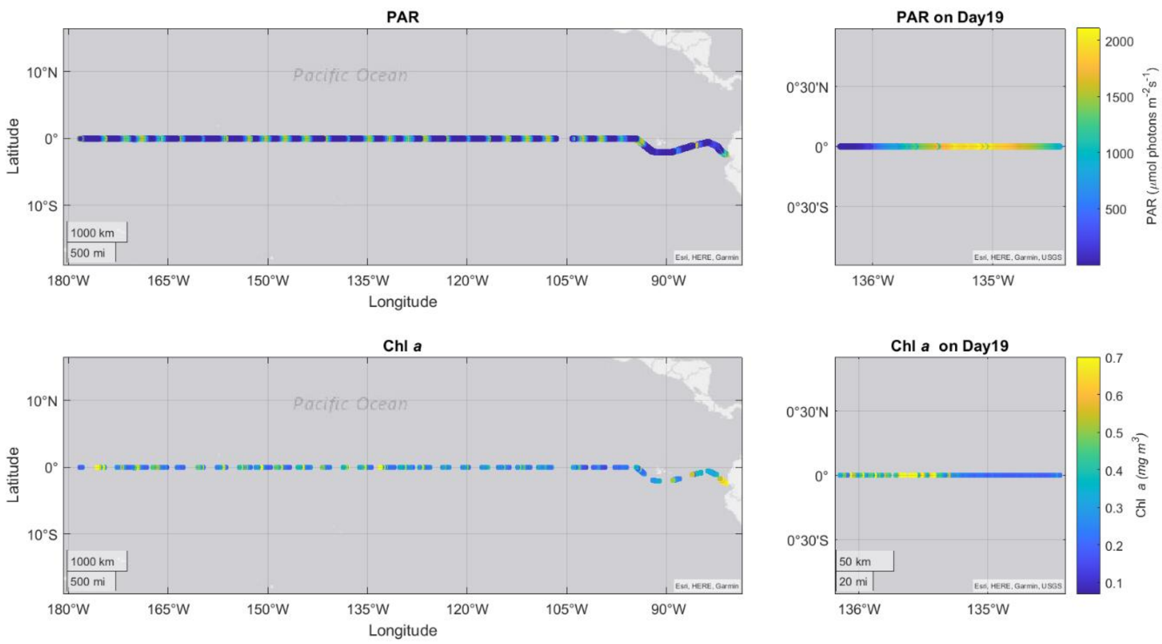


Fig. 5.5 Photosynthetically active radiation (PAR) and chlorophyll *a* (Chl *a*) concentrations derived from the TriOS sensors along the cruise track (left) and a single example day (right).

5.11 Investigation of oxyanion and high field strength elements (HFSE), Chromium (Cr) and Vanadium (V) redox speciation, V isotopes and organic metal-binding ligands in different size fractions

(A. Hollister, N. Van Horsten, P, Tselykh)

5.11.1 Parameters

Oxyanion elements such as molybdenum and uranium were chosen as representatives for commonly known conservative metals for this investigation. Chromium and V on the other hand, represent redox-sensitive trace metals in the marine environment, with the OMZ an important area of interest for their study. In addition to redox speciation, the isotopic composition of V has the potential to provide information on changes in ocean oxygen content, acting as a paleo-proxy in tracing marine oxygenation changes. High field strength elements (HFSEs) (Zr, Hf, Nb, Ta) are particle reactive and are expected to be elevated in the OMZ off the coast of Ecuador, as well as areas influenced by continental inputs. Finally, many bioactive trace metals in seawater are extensively organically complexed, which aids in their stabilization and solubilisation.

5.11.2 Sampling Procedure

Sampling was done with the trace metal clean Ti-frame CTD, and Niskin bottles were immediately transferred to a clean-lab container, where they were filtered through a 0.2 µm AcroPak (Pall) filter. Subsamples for oxyanions, HFSEs, redox speciation of Cr and V, V isotopes, and metal binding ligands were collected and transferred to the chemical lab for processing. To determine the different size fractions according to the area of investigation, three 2 L samples of unfiltered seawater were collected from the surface layer, OMZ and deep waters for sequential filtration (0.8 µm, 0.2 µm, 0.015 µm and particles), at seven selected stations. At four of these stations one ~6 L sample was collected in the OMZ on which ultrafiltration was done using a 10 kDa membrane (approx. 3 nm). The ultrafiltration stations were chosen to correspond to the western upwelling region, the transitional zone to the open ocean, the open ocean oligotrophic region, and the western region towards Papua New Guinea. Additionally, we collected surface water samples from the Tow-fish at most stations. The methods for sequential and ultrafiltration are described in detail in the SO289 cruise report. In total, 1485 samples were collected at 24 stations (see Table 12.6).

5.11.3 Sample Storage

All sample containers were acid cleaned prior to the cruise following the GEOTRACES cleaning protocol (GTU) or the JUB-TM protocol (SO289 cruise report). Samples for oxyanion, HFSE and V isotopes were acidified to pH 1.7 with ultrapure HCl (1.5 ml/L). Samples for Cr and V redox speciation and ligands, as well as filter membranes from sequential filtration were frozen on board to −20 °C and transported frozen to Bremen for analysis.

5.12 Sampling and Onboard Analysis of Dissolved Aluminium

(N.D. Singh, D. Jasinski)

5.12.1 Introduction

A high abundance of aluminium (Al) in continentally derived mineral aerosols and short residence timescales (generally, few weeks to 5 years, Orians and Bruland, 1986) of dissolved Al (dAl) in the surface waters render surface ocean dAl distribution sensitive to atmospheric mineral dust deposition, particularly in the open ocean regions (Grand et al., 2015; Measures and Vink, 2000). Other important external sources of dAl to the ocean include suspended sediments from continental shelf/slope and the seafloor, and riverine discharge of lithogenic sediments and freshwater (Middag et al., 2015; Singh et al., 2020, 2022). In regional length scales, dissolved Al distributions have been observed to trace the mixing of water masses, carrying the dAl-rich signatures of their source regions (of high dust input) and/or that acquired along the advective pathways via interaction with Al-rich sediments over the continental shelf/slope and abyssal plain (Measures and Edmond, 1988).

Along the SO298 cruise transect, the dAl distribution will be useful to track the external supply of trace metals from lithogenic material input at different interfaces (atmosphere, continental margins and seafloor) of the EPO. Furthermore, dAl distribution along the advective pathway of

EUC will be crucial to understand the transport and scavenging of trace metals supplied from the continental sources of the western equatorial Pacific to the central and eastern Pacific.

5.12.2 Sampling and Analysis

Dissolved Al concentrations were analyzed onboard in samples (filtered and acidified to pH < 2) taken from all the Ti-CTD casts and underway tow-fish sampling system (Table 12.2). A modified analytical method of Ren et al. (2001), based on the fluorometric detection of aluminium-lumogallion complex, was followed. The use of Triton-X, o-phenanthroline, and Be solution was avoided to reduce the overall procedural blank. A Carey Eclipse fluorimeter was used to measure the fluorescence signal of the complex. During each batch of analysis, the analytical system was calibrated by running eight external standards (ranging from 0 to 15 nM), prepared by spiking low-Al deep seawater with different proportions of ~100 nM stock standard solution. Analysis of an internal reference sample (collected from the deep waters of station 2), and estimation of blank contributions from the manifold and the reagent addition were done for every batch. The manifold blank was assessed by the counts of acidified seawater sample (the one used for standard preparation) without reagents. The reagent blank was assessed using two series of calibration lines with 1x and 2x volume of reagent, respectively. The reagent blank was calculated as the difference in the intercepts of two series of the calibration lines. Blank contribution from the seawater matrix will be accessed in the laboratory on-shore by analyzing Al-free, column cleaned seawater.

5.12.3 Preliminary Results

Generally, dAl concentrations were observed to be relatively low and uniform in the open surface waters (ca. 2.5–3.5 nM, Fig. 5.6A). Enrichments in surface dAl concentrations were observed towards South America (~5–20 nM) and continents in the western equatorial Pacific (~4–10 nM), indicating increasing dAl input from the continental sources. Prominent

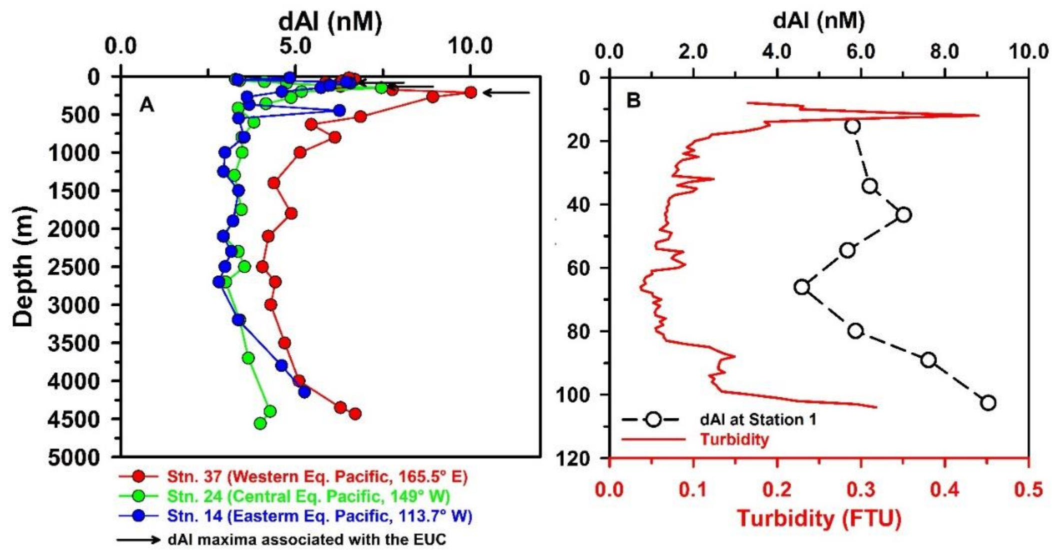


Fig. 5.6 **(A)** Examples of dAl vertical profiles observed in the western, central and eastern equatorial Pacific Ocean. **(B)** Vertical dAl profiles of dAl and turbidity at station 1. Note the correlated increase in dAl and turbidity levels close to the shelf.

dAl input from the South American continental shelf was observed (Fig. 5.6B) correlated with increase in turbidity, indicating re-suspension of shelf sediments. Throughout the transect, dAl maxima associated with the EUC was observed with, generally, increasing strength towards the western equatorial Pacific (Fig. 5.6A). At most of stations, dAl showed an increase close to the seafloor (Fig. 5.6A) suggesting Al release from re-suspended bottom sediments and/or Al-rich pore waters.

5.13 Mercury Collection and Analysis for the Equatorial Pacific

(K. Gosnell and M. Ajmar)

5.13.1 Project Overview

Mercury (Hg) is delivered to surface oceans through atmospheric deposition, while deep waters concentrations tend to increase via remineralization. Most atmospheric Hg results from anthropogenic sources (i.e., coal fired power plants and cement manufacturing), while volcanos and hydrothermal vents contribute natural atmospheric and deep-water sources. There have been recent measurements for Hg south of the equatorial Pacific (Bowman et al., 2016), however equatorial Pacific waters have not been assessed since >3 decades. It is possible that increased anthropogenic inputs have impacted or could ultimately influence Hg levels within this region. Measuring Hg biogeochemistry during the SO298 cruise in high resolution depth profiles of total Hg (HgT), methylmercury (MeHg) and dissolved gaseous mercury (DGM) will provide a timely assessment of Hg speciation and cycling within the EPO. This data is essential to complete a circulation link for current global evaluations as well to the update and revise models and other investigations completed throughout the overall Pacific and beyond.

5.13.2 Mercury Sampling

Unfiltered seawater was collected directly from the Niskin bottle spigot for Hg speciation samples. Each sample was filled with ~5% of the water volume and triple rinsed. Bottles were filled until slightly overflowing, with care taken to limit the amount of bubbles in the water. Caps were attached tightly and bottles were placed in separate boxes for transport and lab analysis. Three bottles were used to collect samples for the 3 different Hg speciation measurements. Dissolved Gaseous Mercury (DGM) was always collected first into a 125 mL PET bottle from 12 alternating depths of each profile. This was followed by a methyl Hg (MeHg) sample into separate 125 mL PET bottles, and total Hg (HgT) sample into an acid-cleaned 60 mL Teflon (PFA/FEP) bottle. The MeHg and HgT samples were collected from every depth. The HgT sample bottles were used repetitively throughout the cruise for collection and analysis, while DGM and MeHg bottles were always fresh. Complete mercury profiles were collected from approximately every other station. However, there were recovery issues with the DGM samples during the first couple weeks of the cruise, thus DGM results are only available after that period.

Rainwater was collected using a trace metal clean funnel and sampling setup whenever a rain event with sufficient water volume transpired. There were several rain events at the beginning and end of the cruise, however nearly no rain collected in the middle of the transect. Rainwater aliquots were subsampled unfiltered (after triple rinsing) into acid cleaned Teflon bottles for analysis of HgT.

Approximately every other superstation was sampled for particulate Hg (pHg) at specific target depths (e.g., surface, 50-60 m, max chl., OMZ, within plume). Cutouts of QMA filters of ~ 25 mm were collected at all superstations, frozen, and saved for THg analysis at GEOMAR.

5.13.3 At-Sea Analytical Work and Sample Processing

All ship-board analysis was completed on a Brooks Rand Model-III instrument that was modified for streamlined and mobile 'on-line' analysis (US EPA method 1631; Heimburger et al., 2015). The Hg was quantified by Cold Vapor Automatic Fluorescence Spectrometry (CVAFS) via a lamp and quartz cuvette (US EPA method 1631). Argon gas flow was set to 1 Bar, and was additionally regulated into the instrument using an AALBORG mass Flow Controller set to 32 mL/min. The Model-III sensitivity PMT was set to 900 V. Gold traps were replaced when the sensitivity dropped significantly (<90%), which was typically after 5-7 days of continuous use.

5.13.3.1 Methylmercury (MeHg)

Upon reception, the MeHg samples were acidified using concentrated HCl (620 µL) and placed in a plastic bag, then put in a box for storage. Methylmercury analysis will be completed using isotope dilution (Monperrus et al., 2005) via an ICPMS in the laboratory at MIO (Marseille) within the next 8 months. In total 21 profiles were collected for MeHg.

5.13.3.2 Total Hg (HgT)

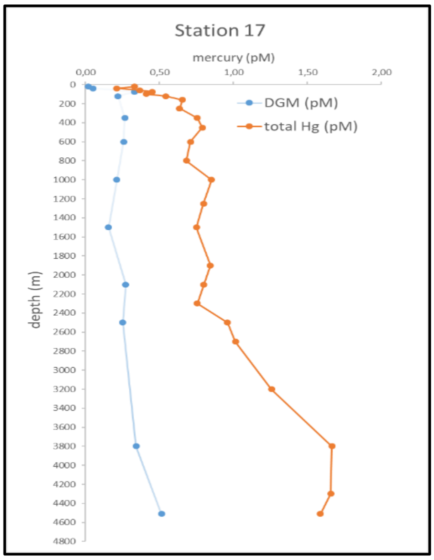
The analytical reagents bromine monochloride (BrCl) and stannous chloride ($SnCl_2$) were prepared at the beginning of the cruise following US EPA Method 1631. To start the analytical day ~30-40 mL of BrCl treated seawater was added to the sparging tube, followed by 1 drop of $SnCl_2$ (~30 µL), and the plunger cap was quickly and tightly sealed. Water was repetitively sparged until blank levels were consistent for ~3 peaks. Each HgT run would be sparged for 240 sec. Every day a working standard curve was created by pipetting increasing concentrations of NIST and ERM-400 reference seawater Hg standard into the purged water of the sparging tube until satisfactory ($r^2 = 0.99$).

The BrCl was added directly into each HgT sample bottle (1 drop; ~30 µL) at minimum 0.5 hour before analysis. For analysis; approximately 30 mL of the sample was poured into the sparging tube and 1 drop of $SnCl_2$ was added just before tightening. Sample peak area was recorded and quantified after ending each run. Purged water was poured into a measuring tube after analysis had ended in order to record sample volume. Duplicate analyses were completed for HgT on a minimum of 8 samples per station by analyzing the remaining sample volume. A 200 µL Hg ERM-400 reference standard was analyzed every ~6 samples and at the end of the analysis to track potential drift. Total Hg analysis was completed on 21 profiles for the cruise.

5.13.3.3 Dissolved Gaseous Mercury (DGM)

DGM is volatile and mobile, and rapidly escapes from collected samples. Accordingly, DGM samples were always analyzed first and as soon as possible. As DGM samples provoke quicker Au trap deterioration, and require more time, approximately 12 depths (out of 24) were analyzed for DGM per station.

For DGM analysis a standard curve was first completed as described for HgT measurements. The introduction setup and settings were then switched and adjusted for DGM analysis by attaching a bottle cap and sparging bulb directly to the first valve loop. DGM samples were measured as collected using no chemical treatment. Adequate head space was formed in each sample by quickly pouring out water immediately before attaching it to the sparging cap for



analysis. Water was typically adjusted until sample volume met 100 mL. Each sample was then attached directly to the online sparging cap for analysis. DGM samples were sparged for 752 s (~12.5 min) with Ar. DGM sample analysis was bracketed by standard measurements of 200 µL Hg (ERM) to assess potential drift during the run. Every DGM sample was acidified with concentrated HCl (400 µL) after analysis and placed in a plastic bag, then storage box until future MeHg analysis could be completed via isotope dilution (Heimburger et al., 2015; Monperrus et al., 2005) at MIO. A total of 16 profiles were completed for DGM samples during the cruise.

Fig. 5.7 Station 17. Total mercury (THg; orange) and dissolved gaseous mercury (DGM; blue).

5.13.4 Preliminary Results Overview

The HgT profiles were relatively consistent throughout the transect, displaying low surface HgT, a subsurface minimum typically coinciding with the chlorophyll maximum, then gradual increase in concentrations with depth (Fig. 5.7). DGM was typically also lowest in surface waters before increasing with depth (Figure 1). Average deep-water values for HgT ranged up to >1 pM, while deep water DGM was lower at 0.5 pM.

5.14 Neodymium Isotopes and Rare Earth Element Concentrations

(B. Liguori, L. Franzen, M. Frank)

The ratio of radiogenic neodymium (Nd) isotope 143Nd over stable 144Nd (143Nd/144Nd, i.e., the Nd isotopic composition "Nd IC") and the rare earth element (REE) concentrations are useful tracers of the provenance of terrestrial material (e.g., dust, ice-rafted debris), as well as water masses and trace element cycling in the ocean (e.g., Piepgras and Jacobsen, 1988; Lacan and Jeandel, 2004; Pahnke et al., 2012). The isotopic signatures in continental rocks vary as a function of the type and age of the rocks, which release these signatures during weathering and transfer them to seawater via riverine and dust inputs, but also via exchange with shelf sediments (Frank, 2002). Water masses, therefore, acquire their radiogenic Nd isotope signatures through weathering of rocks with characteristic isotopic compositions. The Nd residence time is between 400 and 2000 y and allows the tracing of deep-water mixing from different sources using their isotopic values. Because seawater Nd isotope signatures are preserved in marine archives such as sediments, Nd isotopes have also gained attention as proxies of past ocean circulation changes (e.g., Frank, 2002; Goldstein and Hemming, 2003). However, the distribution of trace elements and their isotopes in the equatorial Pacific and the processes affecting them are not fully understood.

During cruise SO298, our primary goal was to obtain water samples to investigate the EUC influence throughout the EPO, as well as water mass mixing in general. Besides water mass mixing, we will also investigate the influence of boundary exchange on the dissolved Nd isotope compositions at the margins, including dissolved and particulate riverine inputs, shelf exchange off South America, and Papua New Guinea and smaller islands, as well as dust input from Australia.

For the radiogenic Nd isotope measurements, a total of 134 samples were taken covering the entire cruise track. Samples from the full water column were collected with 10 L Niskin bottles attached to the SS-CTD rosette. On the surface, seawater samples were taken from the fish pump (trace-metal clean) right before or after the station. The samples were then treated in the onboard laboratory strictly following recommended GEOTRACES protocols. Each 20 L sample was filtered through a nitro-cellulose acetate filter (0.45 µm pore diameter) into an acid-cleaned LDPE cubitainer (20 L) with a peristaltic pump within 2 h after sample collection, and subsequently acidified with 1 mL/L concentrated, distilled HCl. For determination of Nd concentrations, REE concentrations, silicon isotope, and barium isotope measurements, 1-2 L aliquots from each filtered sample were collected in acid-cleaned 1 or 2 L PE-bottles and acidified. To each large-volume sample, 25 µL/L $FeCl_3$ solution (~200 mg Fe/mL) was added and the sample was left to equilibrate for 24 h. Ammonia solution (25%, Merck Suprapur®) was then added to raise the pH from about 2 to 7.8-8.2. After 48 h, the trace elements co-precipitated with the iron hydroxide precipitates settled to the bottom of the cubitainers and the supernatant was siphoned off. The precipitates were then transferred into 2 L PE-bottles, and were transported to the home laboratory at GEOMAR for further ion-chromatographic cleaning and measurement via MCICPMS.

5.15 Stable Silicon and Barium Isotopes

(B. Liguori, L. Franzen, M. Frank)

Besides nitrate and phosphate, diatoms require dissolved silicic acid (DSi) to build up their frustules (cell walls) made of biogenic silica, which makes dissolved Si an essential nutrient for diatoms growth. The silicon isotope composition (Si IC, here referred to as $\delta^{30}Si$) of DSi ($Si(OH)_4$) is a powerful tool to investigate the marine biogeochemical cycling of silicon (Si). It is primarily used to trace DSi utilization and diatom productivity in the surface waters (Reynolds et al., 2006). In the modern ocean, and due to its incorporation into diatom frustules, diatom $\delta^{30}Si$ can serve as a proxy for the reconstruction of DSi utilization in the past (e.g., De la Rocha et al., 1998; Pichevin et al., 2009; Ehlert et al., 2013). Its utility to trace water mass mixing has also been investigated throughout the global ocean (De Souza et al., 2012a; 2012b). At high southern latitudes, the uptake and associated isotope fractionation of Si by diatoms result in highly elevated $\delta^{30}Si$ values, which can be introduced into the ocean interior by the subduction of Subantarctic Mode Water (SAMW) and AAIW, whose northward spreading result in a strong isopycnal control on lower-thermocline and intermediate $\delta^{30}Si$ values at lower latitudes.

The stable isotope composition of barium ($\delta^{138/134}Ba$) is a novel tracer for biogeochemical cycling of barium (Ba) (Horner et al., 2015). It has also been tested to trace water mass mixing in the Atlantic (Bates et al., 2017). Distinct $\delta^{138/134}Ba$ signals in different deep-water endmembers facilitate the applicability of $\delta^{138/134}Ba$ to trace water mixing in the deep ocean, as well as to identify non-conservative behavior of Ba, revealing additional inputs or sinks of Ba during transport (Hsieh and Henderson, 2017).

During cruise SO298, we aim to apply $\delta^{30}Si$ to investigate Si utilization and diatom productivity in the euphotic zone and apply $\delta^{138}/^{134}$Ba to better understand organic matter degradation in the twilight zone, especially in the oxygen minimum zone. In the intermediate and deep waters, the utility of δ^{30}Si and $\delta^{138}/^{134}$Ba as a water mass tracer will be used.

In total, 134 water sample aliquots for stable Si and Ba isotopes were taken from the large volume samples for Nd isotopes, via nitro-cellulose acetate filter (0.45µm pore diameter) filtration. In addition, another set of 203 water samples for Si and Ba were collected via AcroPak filtration directly from the stainless steel CTD. All samples were transported to the home laboratory at GEOMAR for further pre-concentration, ion chromatographic cleaning and measurement via MC-ICPMS.

5.16 Major Elements Along Cruise Track of SO298

(E. Mary O'Sullivan, Z. Steiner)

We collected 921 samples for analyses of the major dissolved cations magnesium, calcium, strontium, lithium and potassium concentrations at 39 stations, including all superstations along the cruise track of SO298, by sub-sampling from samples collected for trace metal analysis. Furthermore, we also sub-sampled 247 surface water samples from a trace metal clean underway Tow-FISH between stations. A total of 1168 samples were therefore collected, as well as at least 50 acid blanks. The samples were diluted to a final salinity of 0.44‰ in 15 mL acid-cleaned centrifuge tubes with 0.12 M ultrapure HCl using our on-board MilliQ water purification system. The final dilution factor ranged from 78 to 82. The ratios of the major dissolved cations magnesium, calcium, strontium, lithium and potassium to sodium will be analysed at GEOMAR using a Varian-720 ICP-OES, using a sample-standard bracketing method (Steiner et al., 2020).

Samples for fluorine and bromine analysis were collected from the stainless steel CTD to avoid contact with fluorine contaminating Teflon within the trace-metal clean Niskin bottles and the tow-fish. 338 samples were collected for F in MilliQ-leached bottles and were not acidified. 79 Surface water samples for fluorine were taken from the ship's underway system every 1° closer to the eastern margin where productivity was high, and every 2-3° thereafter. 425 samples were collected in total. 16 underway samples for bromine were taken in duplicate 30 mL unwashed LDPE bottles from the Tow-FISH over the course of one day-night cycle, as well as 66 samples from 3 profiles from the SS-CTD in the vicinity of the eastern Pacific margin. High volume samples were collected on 1 and 51 µm PETEX filters using in-situ pumps for quantification of major element concentrations in particulate phases and for microscopical observations of the suspended phases. Fluorine and bromine concentrations will be analysed as their ratio to chlorinity using the spectrophotometric methods described by Kremling (1999).

5.17 Sample Collection for Metallomics

(A. Gammanpila)

To analyse trace element abundances in biomolecules (e.g., proteins), 2 L water samples have been collected into FlexBoys from the Niskin bottles of the shallow stainless steel CTD at 6 depths from 17 stations. Depths of sampling were selected depending on the light penetration levels after consultation of the sensor data of the CTD. Internal standard, H-Riboflavin was added to water sample at the final concentration of 160 pM. The water samples were filtered using Sterivex PVDF filters and Bond Elut ENV 500 mg columns by gravity. The filters and columns were cleaned with 15 mL of methanol, 15 mL of HCl (0.1 M) and 15 mL of MQ water before filtration. When the filtration was done, the excess water in the filters and columns were flushed with air using a syringe and the filters were frozen at −80°C and the columns at −20°C to be analysed via HPLC-SEC-ICPMS after the cruise. The FlexBoys were cleaned with MQ water and sampling water before filling at every station. A total of 102 samples were collected.

5.17.1 Sample Collection for Targeted Proteins

Four litre water samples from 1% light level and surface water from the Niskin bottles of the shallow SS-CTD from 17 stations were collected in ~4 L Nalgene LDPE bottles and filtered through 0.7 µm pore sized GFF filters using a filtration rig. The filter pads were placed in cryovials and flash frozen with liquid nitrogen and then stored in a -80°C freezer. We collected 34 samples.

5.17.2 Sample Collection for RNA Analysis

Four litre water samples from 1% light level and surface were collected in Nalgene LDPE bottles from the Niskin bottles of the Bio-CTD from 17 stations. The water samples were filtered through Sterivex PVDF filters using a peristaltic pump, stopped the filtering in 30 min and recorded the filtered volume. Excess water in the filter was removed and then one end was sealed with parafilm. About 2 mL of RNA-later was added to the filter, sealed the other end with parafilm and stored in the fridge for 12 h. After 12 h, filters were taken out from the fridge and the RNA-later was removed using a syringe, sealed both ends with parafilm and stored in -80°C freezer. A total of 34 samples were collected.

5.17.3 Fe Enrichment Experiments

A total of 12, 48 h on-deck Fe enrichment experiments were carried out in 4 L trace metal clean polycarbonate bottles. Four litre of seawater was collected using the trace metal clean towed fish. Bottled seawater was spiked with 400 µL of Fe standard to make the final concentration of 2 nM. Control samples received no additions. All experiments were carried out in triplicate. Sample collection and Fe addition were conducted inside a trace metal clean bubble in a lab. A total of 6 bottles was placed in on-deck incubator tanks which were connected to the ship's underway flow-through system to continuously maintain temperatures that were same as the sea surface water temperature. Incubators were screened with Blue Lagoon filters which maintained an irradiance at ~30% of that of the surface of the ocean. During the daytime, bottles inside the incubator were rotated and we changed their positions every few hours. After 48 h incubation, experiments were taken down and all bottles were carried back to the lab. For the measurement of Chlorophyll-a concentrations, 100 mL of water sample was taken, and the remaining water sample was divided into 1.3 L portions for filtering to obtain samples metallomics, targeted protein and RNA as described above. A total of 72 samples was collected for Chlorophyll-a, metallomics, targeted protein and RNA.

The polycarbonate incubation bottles were cleaned with 10% HCl and rinsed 3 times with MQ water and sampling water prior to each experiment.

Onboard measurement of Chlorophyll-a concentrations: 100 mL samples were filtered onto Fisher MF300 glass fibre filters. The filters were placed in 10 mL of 90% acetone for 12-24 hours in a −20 °C freezer in the dark to extract Chlorophyll-a. The Chlorophyll-a concentrations were then measured using a Turner Designs trilogy fluorometer.

5.18 Radium Isotopes

(P. Battermann)

Radium isotopes are produced by the decay of particle-bound thorium isotopes in sediments and are soluble in seawater. As they present a large range of half-lives, they can be applied to study the age of water masses, shelf-ocean mixing processes, ocean circulation, and as traces of element inputs into the oceans. Radium-226 has a half-life of 1600 years, low particle reactivity, and is principally produced by the decay of ^{230}Th in marine sediments, which makes this isotope a suitable tracer of water masses. Radium-228, with a shorter half-life of 5.7 years, is a suitable tool to study coastal and open ocean processes and can be used as tracers of shelf sediment and river water inputs into the oceans. The decrease in its activity from its source can be used together with its relatively short half-life to constrain flux rates. Thus, ^{228}Ra can be coupled with trace elements to identify their sources and quantify their fluxes to offshore regions. During the SO298 cruise, sampling and analysis of the short-lived Ra isotopes (^{223}Ra and ^{224}Ra) were not performed.

Approximately 1000 L of surface seawater were collected from 3 m depth from the ship's seawater intake and filtered through MnO_2-impregnated acrylic fiber (Mn-fibers) at a flow rate <1 L/min to quantitatively extract Ra isotopes. Surface samples were collected from all the stations.

In addition, 6 *in-situ* pumps (Challenger Oceanic, NOC) were used to collect depth profiles of dissolved Ra isotopes at every superstation deployed between 40 to 600 m. The in-situ pumps were equipped with a filter to collect suspended particles; the filtrate then passed through MnO_2-coated polypropylene filter cartridges (Mn-cartridges) to extract the Ra isotopes (Henderson et al., 2013). The Mn-fibers and cartridges were rinsed with radium-free fresh water and excess moisture was removed using compressed air. Small-volume samples (1 L) were also collected from the CTD cast for high-resolution ^{226}Ra depth profiles at stations Table 12.10. The chosen depths from the CTD casts also included the corresponding *in-situ* pump depths for determining the radium extraction efficiency of the Mn-cartridges. Following collection from the CTD, samples were acidified with 1 mL of sub-boiled nitric acid, double-bagged, and stored at room temperature. Radium-226 concentrations from the 1 L seawater samples will be determined by mass spectrometry at GEOMAR.

5.19 Sampling and Analysis of Ammonium

(A. Imig)

Samples for ammonium analysis were taken from Niskin bottles deployed on the SS-CTD. At all stations, samples were taken with varying resolution depending on depths which were sampled with the SS-CTD. During the cruise transect in Ecuadorian waters, samples were taken up to depths of 600 m. It was expected that near to the coast, upwelling of nutrients took place leading to ammonium rich waters also at greater depths. Whereas in the deep open ocean depths, oligotrophic regimes were expected and sampling depths were adjusted to shallower waters up to 200 m depths. Additionally, samples were taken from the tow fish starting at station 19 and continuing with a temporal resolution of approximately every 7 hours. Moreover, samples from the biology experiments (cf. section 5.27) were analysed. The results of the analysed fish samples show high fluctuations in the replicates. This might be explained by contamination of the sampling tube and low concentrations.

Analysis of ammonium was conducted using the OPA method. After sampling, either the fluorescent OPA reagent was added to the samples immediately or stored in the fridge for maximum 24h period before the addition of the reagent. Thereafter, the samples were incubated for 24 h at room temperature and kept in the dark with tightly closed caps.

Subsequent detection of ammonium was performed on a Carey Eclipse fluorimeter. Calibration was carried out using the external standard addition method using ammonium-free deep ocean waters (> 600 m). Blanks were prepared with ammonium-free deep ocean water.

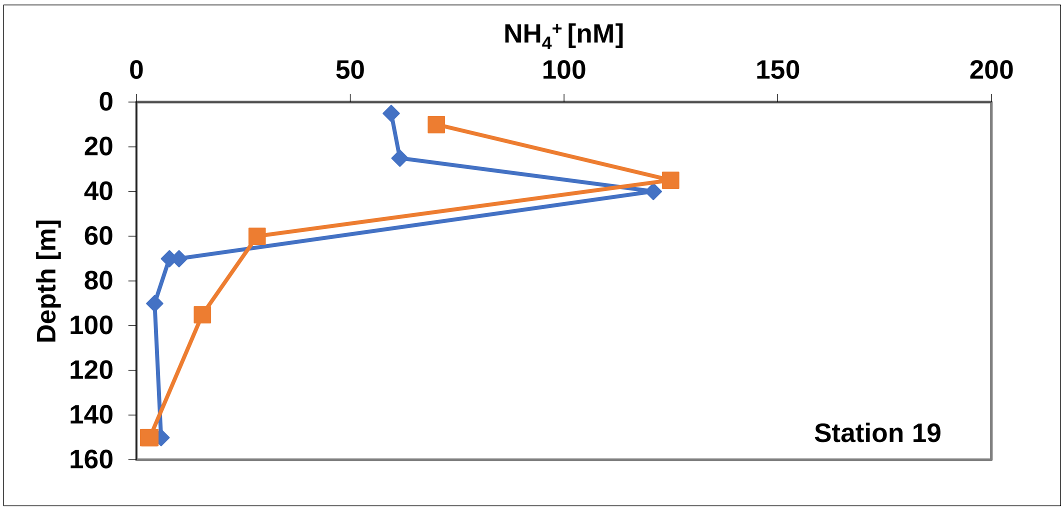


Fig. 5.8 Ammonium concentration over depths in station 19 from BIO-CTD (blue) and SS-CTD cast (orange).

At several stations, samples were taken from the Bio-CTD and the SS-CTD cast. This allowed the comparison of measurements between the different casts and hence the verification of the agreement between the two casts. In Fig. 5.8, as an example, the measured ammonium concentration from two casts over the depths at station 19 is displayed. Both profiles follow similar trends and are hence considered to be in good agreement.

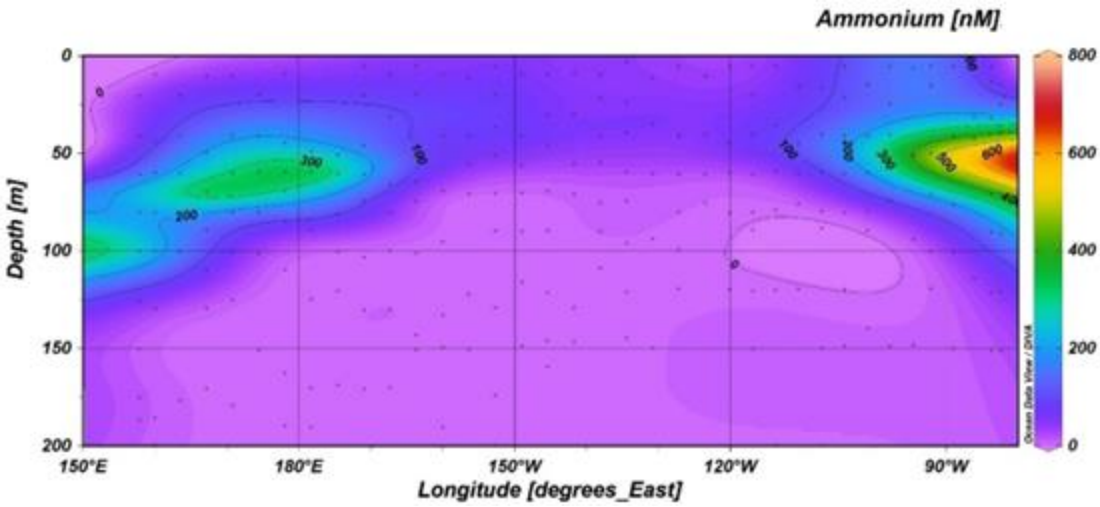


Fig. 5.9 Section of ammonium for SS CTD casts.

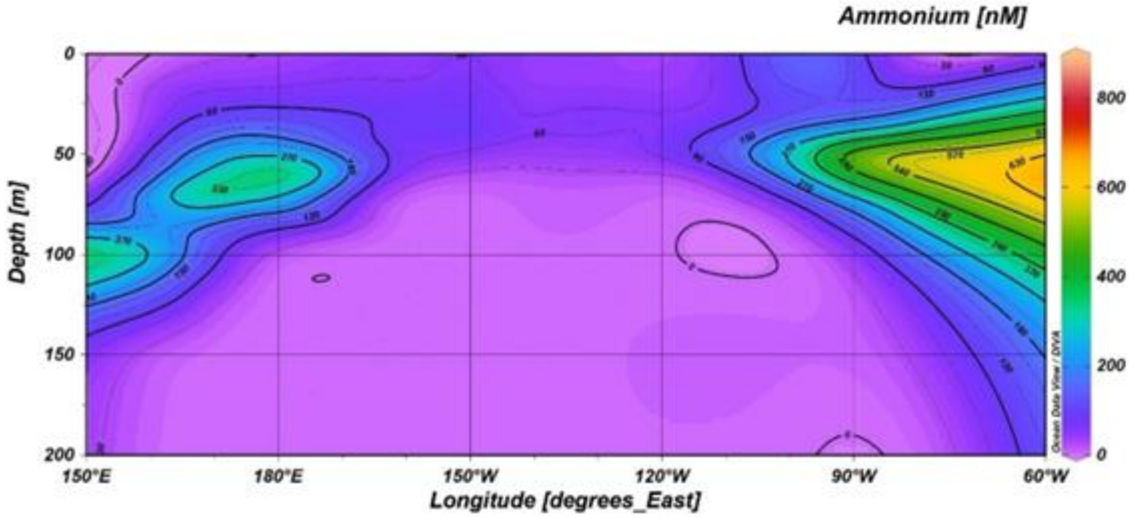


Fig. 5.10 Section of ammonium for biology and SS CTD casts.

5.20 Rainwater Sampling

(A. Imig)

Eleven rainwater samples were taken during the cruise. The samples were collected on the upper deck towards the front of the ship. A funnel with 40 cm diameter, was placed on a collection bottle in 1.4 m height (see Fig. 5.11). Between the 19th April–26th May 2023 period, no or small rain events did not allow the collection of samples. Samples were collected for Hg, trace metal, major ions, nutrients and rare earth elements analysis. Unfiltered and acidified samples for trace metal, major ions and rare earth element samples were collected. An additional filtered (0.2µm PES syringe filters) aliquot was taken from the bulk unfiltered and acidified sample for trace metal and rare earth element analysis.

Fig. 5.11 Graphical display of rainwater sampling setup.

Table 5.5 Overview of rainwater samples including information about date and time and location of sampling.

Sample Number	Date	Time UTC
1	19th April 2023	13-17:42
2	21st April 2023	13:32-15:00
3	11th May 2023	2:35-2:55
4	14th May 2023	17:08-19:35
5	16th May 2023	12:07-12:27
6	19th May 2023	8:15-9:00
7	20th May 2023	0:08-1:00
8	21th May 2023	12:22-14:50
9	24th May 2023	1:48-3:48
10	25th May 2023	9:18-11:22
11	26th May 2023	11:25-11:55

5.21 Underway Carbon Measurements

(R. Schäfer)

From the underway water supply of the RV SONNE, a sink was continuously filled and (total pH scale) pH, total alkalinity, partial pressure of CO_2 (pCO_2) and nitrate measured using automated sensors. The sensor details and sampling intervals can be found in Table 5.6. Underway water was sampled from a water depth of 3 m. To reduce exchange with the atmosphere, the sink was covered with a wooden plate, and water overflowed down the sink.

At three times, beginning (26.04.2023), middle (09.05.2023) and end (26.05.2023) of the cruise, the pH value of equimolal tris(hydroxymethyl)aminomethane (TRIS) buffer (0.04, 0.025, 0.01 M respectively) in artificial seawater (salinity 35) was measured with the pH sensor. The pH values of the buffer were available from primary measurements at Physikalisch-Technische Bundesanstalt (Braunschweig, Germany).

Table 5.6 Sensors and measurement intervals.

Parameter	Sensor	Sampling interval	Details
pH	AquapHOx-L-pH (PyroScience GmbH, Aachen, Germany)	1 min	External pump
pCO_2	CONTROS HydroC (-4H- JENA engineering GmbH, Jena, Germany)	1 min	External pump
nitrate	OPUS (TriOS Mess- und Datentechnik GmbH, Rastede, Germany)	1 min	
alkalinity	Li et al. (2013)	Approx. 7 min	

5.21.1 Discrete Samples

Additionally, discrete samples were taken twice per day (approx. 12 hours apart) in 250 mL borosilicate glass or plastic bottles and poisoned with mercury chloride ($HgCl_2$). The alkalinity and dissolved inorganic carbon for these was then later measured with the same system used for the discrete CTD samples (section 5.22). Temperature, salinity and position data for these samples was exported from the ship's system (Table 12.11).

5.21.2 Data Processing

Preliminary data processing and plotting was done in R (version 4.2.1, R Core Team 2022). Impossible values (such as negative alkalinity), values differing by more than the standard deviation within 24 hours from the mean value of these 24 hours and values from the (auto-) calibration measurements were excluded. With the R package seacarb (version 3.3.1, Gattuso et al. 2022), pH was calculated from alkalinity and pCO_2. The TRIS-measurements were used to estimate an offset and drift of the sensor and do a preliminary correction with the assumption of linear drift. The continuous and discrete alkalinity measurements will be corrected after the cruise.

5.21.3 Preliminary Results

The preliminary results for pCO_2, pH and alkalinity, showed little change along the major part of the cruise track. While sailing out to sea, a decrease of pH and increase of pCO_2 occurred. In the final week, a decrease in pCO_2 and increase of pH was observed (Figs. 5.12 and 5.13). The alkalinity data will need to be corrected for drift after the cruise.

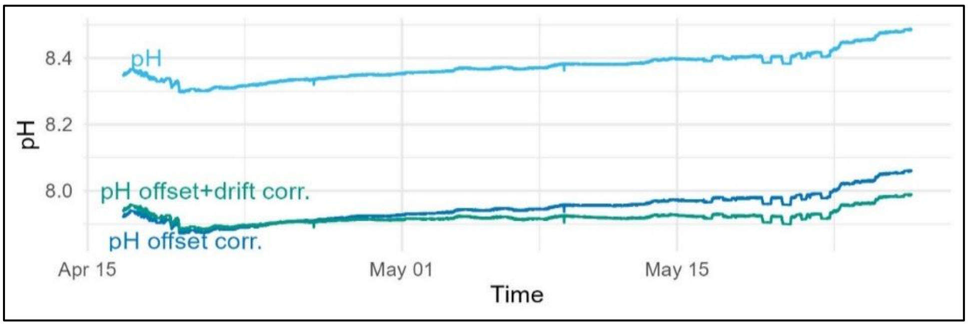


Fig. 5.12 Measured pH value and preliminarily corrected values based on only the first TRIS measurement (offset corr.) and with drift correction based on further TRIS measurements (offset + drift corr.). pH values on the total pH scale.

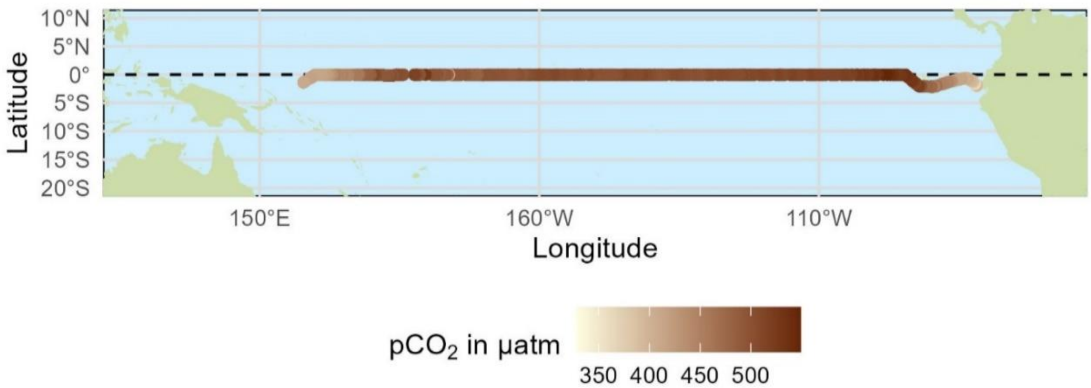


Fig. 5.13 pCO_2 along the cruise track. Map data from R ggplot2 package (Wickham 2016).

5.22 Total alkalinity (TA) and Dissolved Inorganic Carbon (DIC) determination

(M. Norbisrath, A. Nicholas)

The ocean is a major atmospheric carbon dioxide (CO_2) sink. The acid buffering capacity of total alkalinity (TA) regulates the oceanic storage capacity of atmospheric CO_2, and characterizes the marine carbonate system in combination with dissolved inorganic carbon (DIC).

During the cruise SO298, full depth determination of the carbonate system along the EPO transect was conducted by collecting discrete water samples for TA and DIC from the SS-CTD at each station and depth. Samples for TA/DIC were collected bubble free and with an overflow into 300 mL BOD (biological oxygen demand) bottles by using a tube directly connected to the Niskin bottles. To clean and adjust the bottles to the water temperature and avoid bubble formation, they were rinsed with sample water before sampling. The bottles were closed with ground-glass stoppers coated in Apiezon® type M grease and secured with caps until measurement. In case of a delayed measurement, i.e., not within 24 h, the samples were preserved with 300 µL saturated $HgCl_2$ (mercury chloride) to stop biological activity.

The samples were measured with a VINDTA 3C (Versatile INstrument for the Determination of Total dissolved inorganic carbon and Alkalinity, MARIANDA - marine analytics and data), which simultaneously measures TA by potentiometric titration and DIC by coulometric titration, with a precision < 2 µmol kg^{-1} (Shadwick et al. 2011) respectively. A Certified Reference Material (CRM, Batch #198, #201, and #203) provided by Andrew G. Dickson (Scripps Institution of Oceanography) was used for calibration.

Fig. 5.14 VINDTA 3C lab set up for the determination of TA and DIC in the Climate Lab I on RV *SONNE*. From left to right: LAUDA water bath to provide a constant temperature of the samples previously and during measurement, container with NaCL rinsing solution, the VINDTA 3C for TA and DIC titration, PC, and the UIC.Inc coulometer for DIC determination. Below the table: grey boxes with CRMs.

5.23 Trace Gases: Helium, CFC, N_2O, CH_4

(E. Achterberg, J. Löhr)

Helium-^{3}He is a conservative tracer for hydrothermal vent supply, and allows us to trace the a non-buoyant hydrothermal plume because vents are by far the main source of this isotope to the ocean. As Helium is a very low-density gas, samples for helium isotopes were sampled first from the SS-CTD. Seawater samples for helium were collected in a copper pipe, which was connected to the Niskin bottle, with water flowing until bubbles in the tube were removed. While the water was flowing, the pipe was closed using an electrical drill and a ratchet to ensure it was completely closed. Helium isotopes will be analysed at the University of Bremen, as part of a contract.

CFC, N_2O, CH_4-Samples of seawater for analysis of trace gases chlorofluorocarbons (CFCs), nitrous oxide (N_2O) and methane (CH_4) were taken during the research cruise SO298, and preserved for analysis later in the laboratory at the University of Nijmegen (Netherlands) (nitrous oxide and methane) and GEOMAR (CFCs).

The seawater samples for nitrous oxide and methane will be analyzed from the same vial, so only one duplicate per station and depth had to be collected. They were taken from every other station up to depths until 1000 m. The exact stations and depths can be found in Table 12.12.

Fig. 5.15 Set-up of the sampling ampoules for CFC samples from the Niskin bottles.

For this purpose, the sample bottles were labeled with Bedford numbers in advance and, due to the volatility of the trace gases, sampled as soon as possible after the CTD arrived on deck, but at the latest after helium, oxygen and CFCs. With the help of a rubber hose, which was pressed over the valve of the 10 L Niskin bottles, the 20 mL sample containers could be filled and then sealed with a rubber lid. Bubble-free sampling was of importance here. After all vials were filled and sealed airtight using a crimp cap, samples were poisoned using syringes containing 0.5 mL of a saturated mercury(II) chloride solution.

For sampling of CFCs, a total of 120 ampoules were available, and samples were taken from twelve selected stations, each from ten depths. The stations were selected so that measurement results from previous research cruises could be taken as a reference. The depths were mainly sampled only up to 1000 m, since reports show that hardly any CFCs reach deeper waters. Due to a spontaneous change of the station plan shortly before the end of the cruise, a previous station with 15 samples was taken instead of the last two stations. The exact stations and depths can be found in Table 12.13.

Prior to sampling, the vials were labeled with Bedford numbers and assembled as shown in Fig. 5.15, taking care to secure the fill tube just above the bottom of the vial.

Once the CTD was on deck, sampling was done as quickly as possible. Samples deeper than 1000 m were taken first and those above 1000 m depth directly after helium. This was to avoid contamination with air as much as possible. For this purpose, the ampoules were attached to the Niskin bottle in a carrying bag for safety before the filling tube was connected directly to the valve of the Niskin bottle and twice the volume of the ampoule was squeezed through. When the ampoule was removed, the tubes were immediately flame-sealed with Swagelock valves and melting was started as soon as possible in the laboratory.

For sealing one ampoule after the other, it was clamped in a stand. Then, first, the overflow tube was connected to a nitrogen stream, the filling tube was raised to the desired height, just above the ampoule label, and the top sample water was forced out by opening the Swagelock closure, creating an inert headspace. Then, continuing under nitrogen flow, the filling tube was raised as far as possible and the ampoule head was melted off without the sample coming into contact with air.

5.24 Microbial Community Composition and Activity

(F. Wittmers, Y. Wang)

5.24.1 Overview

Biological samples were collected to characterize the microbial community throughout the equatorial Pacific. This included fine-scale resolution sampling of the photic zone as well as systematic sampling across the whole water column. Molecular characterization of the microbial community will be essential to understand the observed nutrient regime and phytoplankton composition as well as chemical data collected on the cruise. Samples were collected on all 39 stations from both, casts focused on the upper 200 m (Bio-CTD casts) as well as whole water column casts (SS-CTD casts). Metagenomes were collected from above, within and below the oxygen minimum zone. RSG and HPG incubations were started at every 2-3 stations. DNA and FCM samples were collected on every station and with ~12 depths resolution.

5.24.2 Amplicon DNA

Water was collected from the CTD in 4 L amber bottles and filtered on 47mm wide 0.2 µm pore sized Supor PES membrane filters (Pall, NY, USA) using a multi-channel vacuum system. Filtration volume varied with 2 L per depth for the upper 200 m of the water column and up to 4 L below that. Filters were folded twice and stored in 2 mL cryovials at -80°C for further processing.

5.24.3 Analytical Flow Cytometry

Two milli-liter (2 mL) of seawater was subsampled from water collected for DNA filtration using a serological pipette. Samples were fixed to a final concentration of 1% glutaraldehyde and vortexed. Samples were split into two 1 mL cryovials, incubated for 20 minutes in the dark at room temperature and subsequently flash frozen in liquid nitrogen before storage at -80°C. For samples below 200 m, only 1 flow cytometry sample was taken.

5.24.4 RedoxSensor Green

Samples for RedoxSensor Green staining and HPG incubations were collected in 150 mL amber bottles from the CTD. Two milli-liter (2 mL) per depth was subsampled into two 1 mL cryovials. One µL of 1 mM RedoxSensor Green reagent in DMSO was added to one of the cryovials and all samples were incubated at *in-situ* temperature for 30 minutes. Post incubation all samples were fixed with 100 µL glycerol-TE solution and incubated for 5 minutes before flash freezing in liquid nitrogen and storage at -80°C.

5.24.5 Homopropargylglycine (HPG) Incubations

Water for HPG incubations was subsampled from 150 mL amber bottles into 50 mL falcon tubes. Reaction volumes varied with 15 mL for the upper 1000 m and 50 mL for all depth below 1000 m. Twenty micro-molar (20 µM) HPG was added to reach a final concentration of 20 nM. Samples were incubated for 6 (<1000 m) or 12 (> 1000 m) hours before being fixed with formaldehyde (final concentration of 4%). Samples were filtered 12-24 hours post fixation on 25 mm 0.2 µm Isopore PC membranes, air-dried until no water was retained on the filter and frozen at -20°C.

5.24.6 Metagenomics

Large volume filtrations for whole genome sequencing were conducted using a peristaltic pump and 142 mm filer membranes. Water was collected from the CTD for selected depths in 20 L carboys. Water from the upper 200 m was filtered serially first through 30 µm mesh, a Versapor 3000 3 µm 142 mm membrane filter followed by a Supor 0.2 µm 142 mm PES membrane filter.

For samples from depths below 200 m, water was filtered on Supor 0.2 µm 142 mm PES membrane filters without a prior size-fractionation.

5.24.7 Lipids

Three liter (3 L) of seawater from the surface, the bottom of the mixed layer, the DCM and ~20 m below the DCM was collected in 4 L amber bottles. Triplicates of 1 L per depth were filtered through 47 mm Durapore 0.22 µm PVDF membrane filters, folded into 2 mL cryovials and stored at -80°C. Samples will be analysed at GEOMAR by Dr. Kevin Becker.

5.25 Nitrogen Fixation on SO298

(Z. Chen)

5.25.1 Objectives

Biological N_2 fixation is a key process which provides bioavailable nitrogen for the growth of phytoplankton that live in the euphotic zone. In some areas of the oligotrophic open ocean, such “new nitrogen” derived by the N_2-fixers can equal to the nitrogen diffused from the deep water, which substantially supports primary production and subsequently export production. Despite its importance, few efforts have been conducted to understand the spatial and temporal distribution of N_2 fixation, and a mechanistic understanding of its controlling factors is still lacking, presenting a major barrier to making accurate projections. To address this, we conducted N_2 fixation rate incubations, and DNA sampling for the analysis of the abundances of key diazotrophic phylotypes. These efforts will be accompanied by a diverse range of ancillary environmental parameters, alongside several nutrient amendment experiments directly testing the response of N_2 fixation rates to supply of potentially limiting nutrients (iron and phosphate).

5.25.2 Sampling information

5.25.2.1 Shallow CTD Sampling

Samples were collected at 19 stations (Table 12.14) during the cruise in the Equatorial Pacific Ocean. Water samples were collected using Niskin bottles at six depths (100%, 50%, 25 m, 10%, DCM, 0.1% PAR depths) throughout the upper 250 m for the determination of nifH gene abundance and for N_2 fixation and primary production rates incubations.

5.25.2.2 Underway Sampling

Sea surface samples were also collected using tow-fish for the determinations of N_2 fixation rate, primary production, nifH gene abundances, and dissolved nutrients.

5.25.3 Parameters and Experiments

5.25.3.1 N_2 Fixation and Primary Production Measurements.

N_2 fixation rates were determined by the $^{15}N_2$ gas (98 atom%, Cambridge Isotope Laboratories, Lot#: 1-25854/X732956) dissolution method (Mohr et al., 2010), combined with a primary production assay using $NaH^{13}CO_3$ (99 atom% 13C, Cambridge Isotope Laboratories). The N_2 fixation and primary production incubations were conducted in duplicate 4 L Nalgene polycarbonate bottles. Samples were spiked with 100 mL $^{15}N_2$ enriched filtered seawater from the same site and incubated on-deck for 24 h. The final $^{15}N_2$ enriched seawater concentration in the incubation bottles was ~3 atom%. $NaH^{13}CO_3$ solution was added at a concentration of 100 µM. After that, the bottles were covered with neutral-density screen to adjust the light to the levels at sampling depths, and then were incubated for 24 h in an on-deck incubator continuously flushed with surface seawater.

5.25.3.2 nifH Gene Abundance

About 4 L seawater samples for DNA extractions were filtered onto 0.22 µm pore-sized membrane filters (Supor200, Pall Gelman, NY, USA) and then frozen in liquid N_2. DNA will be extracted using the QIAamp® DNA Mini Kit (Qiagen) follow the manufacturer's protocol. The quantitative polymerase chain reaction (qPCR) analysis was targeted on the nifH phylotypes of *Trichodesmium* spp., unicellular cyanobacterial UCYN-A1, UCYN-A2, and UCYN-B, Richelia spp. (het-1), and a gamma-proteobacterium (γ-24774A11), using previously designed primers and probe sets (Church et al., 2005a; 2005b; Moisander et al., 2008; Thompson et al., 2014).

5.25.3.3 Bioassay Incubation

Eight on-deck incubation experiments for a duration of 48-hour were carried out in 4 L trace metal clean polycarbonate bottles. Seawater was collected using the trace-metal-clean towed-fish. Bottled seawater was spiked with the following treatments: control, +P, +Fe and +Fe+P. Final incubation concentration of iron was 2 nM Fe and 100 nM phosphate. Bottles were placed in on-deck incubators connected to the ships underway flow-through system to continuously maintain temperatures at that of sea surface waters. Incubators were screened with Blue Lagoon screening (Lee Filters), which maintained irradiance at ~30% of that of the surface. We had spiked $^{15}N_2$ gas and $NaH^{13}CO_3$ for the incubations of N2 fixation and primary production rates. After another 24 hours incubation, experiments were taken down and sampling made for: analysis of POC and PON concentrations and their ^{13}C and ^{15}N stable isotopic abundances, nifH gene abundances of six major diazotrophs.

5.26 Phytoplankton Abundance, Community Composition and Photophysiology

(Z. Yuan, J. Guo, T.B. Robinson)

Samples were collected for characterisation of phytoplankton biomass and, community structure along the cruise transect. As phytoplankton are the key drivers of nutrient and carbon cycling in surface waters, and nutrient and carbon export to deeper waters, these measurements will also be valuable for interpreting chemical data collected on the cruise. Samples were collected at 20 stations (Station numbers 2, 4, 6, 8, 10, 12, 14, 16, 19, 22, 24, 26, 27,29, 31, 33, 35, 36, 38, 39) at 6 depths on a dedicated cast throughout the upper water column (surface to a maximum of 150 m depth) using the stainless steel Bio-CTD. Samples for inorganic and organic nutrients were also sampled at these six depths from the same CTD cast.

5.26.1 Chlorophyll-a Concentrations

Water was collected in 10 L opaque carboys and processed immediately after collection. 100-200 mL samples were filtered onto Fisher MF300 glass fibre filters and extracted for 12-24 h in 10 mL 90% acetone in a -20°C freezer in the dark before measurement on a Turner Designs trilogy fluorometer following Welschmeyer (1994).

5.26.2 High Performance Liquid Chromatography (HPLC)

About 3 L seawater was filtered onto Fisher MF300 glass fibre filters and placed directly into a -80°C freezer. These will be analysed on return to GEOMAR following the method of e.g., Gibb et al. (2000).

5.26.3 POC/PON

Water was collected in 10 L opaque carboys and processed immediately after collection. 4 L was filtered onto pre-combusted Advantec glass fibre filters (25 mm) and frozen at -80°C.

5.26.4 Fast Repetition rate Fluorometry (FRRf)

Fast repetition rate fluorescence measurements enable the calculation of e.g., the so called "normalized variable fluorescence" (Fv/Fm), which can be used as a diagnostic for nutrient stress, especially for iron limitation. A FASTOcean fluorometer (Sensor ID: 14-9740-003) with integrated FASTact laboratory system (Chelsea Technologies LTD., UK) was used to measure in vitro variable fluorescence of phytoplankton samples. Fluorescence light curves were also run for surface and some DCM samples following a protocol of progressively increasing light intensities between 20 and 2000 μmol photons m^{-2} s^{-1} (as described in Browning et al., 2014). Blank filtrates (0.2 μm filtrates) were measured for virtually all samples. All FRRf data will be blank-corrected and fluorescence parameters recalculated upon return to GEOMAR.

5.27 Nutrient Enrichment Bioassay Experiments

(Z. Yuan)

Experiments were conducted to assess the main nutrients limiting to the overall phytoplankton community along the transect (e.g., Browning et al., 2017). Forty-one on-deck incubation experiments for a duration of ~48-h were carried out in either 500 mL or 1 L trace metal clean polycarbonate bottles. Seawater was collected using the trace-metal-clean tow-fish. Filling times were approximately ~15 minutes. Bottled seawater was spiked in triplicate with N (1 μM NO_3^- + 1 μM NH_4^+), Fe (2 nM), and their combination. At several of the sites, additional treatment was also conducted with NO_3^- (2 μM NO_3^-) alone. Initial conditions were sampled in 1 L bottles for all experiments at 3 time points throughout the bottle filling procedure. Triplicate control bottles (1 L) with no nutrients added were also collected, and incubated alongside all treatment experiments. Bottles were placed in on-deck incubators connected to the ship's underway flow-through system to continuously maintain temperatures at that of sea surface waters. Incubators were screened with Blue Lagoon screening (Lee Filters), which maintained irradiance at ~30% of that of the surface ocean. After 48 h incubation, experiments were taken down and measurements were made for chlorophyll-a concentrations, FRRf, and analytical flow cytometry. At several of the sites, additional samples were collected for macronutrients, HPLC and DNA measurements.

5.28 Dilution Experiments

(Z. Yuan)

A total of 6 on-deck incubation experiments were carried out in 1 L trace metal clean polycarbonate bottles. Seawater was collected using the trace metal clean towed-fish into an acid-washed 60 L HDPE carboy, first collecting 12 L unfiltered seawater and then collecting 48 L of filtered (0.2 μm, Pall Acropak) resulting in a ~20% dilution. Total filling times were approximately ~40 min. Incubation bottles were spiked in triplicate with a spectrum of (i) NO_3^- + NH_4^+ (0, 0.1 μM, 0.2

μM, 0.4 μM, 0.8 μM) and Fe (0, 0.1 nM, 0.2 nM, 0.4 nM, 0.8 nM) to provide 25 treatments. Bottles were capped and placed in on-deck incubators connected to the ship's underway flow-through system to continuously maintain temperatures of sea surface waters. Incubators were screened with Blue Lagoon screening (Lee Filters), which maintained irradiance at ~30% of that of the surface ocean. After ~48 h incubation, experiments were taken down and each triplicate replicate was subsampled for collection/analysis of chlorophyll-a and flow cytometry.

6 Ship's Meteorological Station

Not relevant to this cruise.

7 Station List SO298

7.1 Overall Station List

ISP= *in-situ* pumps on GEOMAR SS-CTD. CTD used: GEOMAR stainless steel CTD (SS-CTD) and GEOMAR stainless steel CTD for biology (BIO-CTD), GEOMAR Ultra Clean Titanium CTD for geochemistry (Ti-CTD). Super denotes Superstations with an ISP deployment.

Station	Device Operation	Event Comment	Event Date and Time	Latitude	Longitude	Seafloor Depth (m)
1	SO298_0_Underway-1		2023/05/26 22:35:45	01° 21.224' S	157° 51.805' E	0.000
0	SO298_0_Underway-2		2023/05/26 22:36:04	01° 21.224' S	157° 51.805' E	0.000
0	SO298_0_Underway-3	EM122	2023/05/26 22:36:19	01° 21.223' S	157° 51.804' E	0.000
1	SO298_0_Underway-4	EM710	2023/04/15 12:00:47	02° 30.000' S	080° 59.999' W	104.200
1	SO298_1-1	Ti-CTD	2023/04/15 12:39:28	02° 29.995' S	080° 59.995' W	105.000
1	SO298_1-2	SS-CTD Karussel defekt. Stationsabbruch	2023/04/15 14:58:23	02° 29.993' S	080° 59.993' W	107.810
2	SO298_0_Underway-6	Fisch zu Wasser	2023/04/15 15:02:52	02° 29.990' S	080° 59.995' W	106.550
2	SO298_2-1	SS-CTD	2023/04/15 22:08:26	01° 47.792' S	081° 54.139' W	1705.460
2	SO298_2-2	Ti-CTD	2023/04/15 22:47:25	01° 47.824' S	081° 54.119' W	1709.850
2	SO298_2-3	SS-CTD	2023/04/16 00:57:02	01° 47.818' S	081° 54.110' W	1710.670
3	SO298_3-1	SS-CTD	2023/04/16 07:55:27	01° 08.213' S	082° 27.255' W	1576.010
3	SO298_3-2	Ti-CTD	2023/04/16 09:17:30	01° 08.350' S	082° 27.242' W	1480.490
3 Super	SO298_3-3	ISP	2023/04/16 10:39:03	01° 08.348' S	082° 27.247' W	1479.160
4	SO298_4-1	Bio-CTD	2023/04/16 23:21:32	00° 34.092' S	083° 43.653' W	2643.360
4	SO298_4-2	Ti-CTD	2023/04/16 23:50:38	00° 34.172' S	083° 43.630' W	2646.320
4	SO298_4-3	SS-CTD	2023/04/17 02:03:13	00° 34.187' S	083° 43.587' W	2636.870
5	SO298_5-1	Ti-CTD	2023/04/17 19:29:23	01° 06.000' S	086° 06.038' W	2108.860
5	SO298_5-2	SS-CTD	2023/04/17 21:20:04	01° 06.002' S	086° 06.001' W	2107.230
6	SO298_6-1	bio CTD	2023/04/18 17:53:10	01° 59.959' S	088° 59.948' W	3102.290
6	SO298_6-2	Ti-CTD	2023/04/18 18:30:32	01° 59.961' S	088° 59.943' W	3102.310
6	SO298_6-3	CTD-SS	2023/04/18 20:52:00	01° 59.853' S	089° 00.030' W	3104.040
7 Super	SO298_7-1	ISP	2023/04/19 18:17:14	02° 00.093' S	092° 05.859' W	3308.060

7	SO298_7-2	Ti-CTD	2023/04/19 21:39:00	02° 00.319' S	092° 05.926' W	3304.230
7	SO298_7-3	SS-CTD	2023/04/20 00:03:02	02° 00.354' S	092° 05.902' W	3308.390
8	SO298_8-1	bio-CTD	2023/04/20 21:55:41	00° 00.064' N	094° 34.756' W	3351.780
8	SO298_8-2	Ti-CTD	2023/04/20 22:39:25	00° 00.078' N	094° 34.656' W	3346.130
8	SO298_8-3	SS-CTD	2023/04/21 01:08:21	00° 00.074' N	094° 34.519' W	3335.400
9	SO298_9-1	Ti-CTD	2023/04/21 23:08:18	00° 00.010' S	097° 46.827' W	3304.460
9	SO298_9-2	SS-CTD	2023/04/22 01:22:19	00° 00.003' S	097° 46.830' W	3308.250
10	SO298_10-1	bio-CTD	2023/04/22 23:32:00	00° 00.003' S	100° 58.172' W	3240.770
10	SO298_10-2	Ti CTD	2023/04/23 00:07:35	00° 00.001' S	100° 57.945' W	3242.400
10	SO298_10-3	SS-CTD	2023/04/23 02:29:19	00° 00.260' S	100° 56.842' W	3228.350
11 Super	SO298_11-1	ISP	2023/04/24 02:17:18	00° 00.010' S	104° 10.171' W	3510.170
11	SO298_11-2	Ti-CTD	2023/04/24 05:42:26	00° 00.020' N	104° 08.968' W	3422.920
11	SO298_11-3	SS-CTD	2023/04/24 08:15:17	00° 00.042' N	104° 07.552' W	3388.030
12	SO298_12-1	bio-CTD	2023/04/25 07:38:35	00° 00.031' N	107° 21.492' W	3653.770
12	SO298_12-2	Ti-CTD	2023/04/25 08:12:11	00° 00.009' N	107° 21.188' W	3683.440
12	SO298_12-3	SS-CTD	2023/04/25 10:46:53	00° 00.006' N	107° 19.834' W	3673.690
13	SO298_13-1	Ti-CTD	2023/04/26 09:03:57	00° 00.075' N	110° 32.994' W	3786.610
13	SO298_13-2	SS-CTD	2023/04/26 11:42:03	00° 00.037' N	110° 32.419' W	3804.230
14	SO298_14-1	bio-CTD	2023/04/27 09:48:51	00° 00.023' S	113° 45.075' W	4183.390
14	SO298_14-2	Ti-CTD	2023/04/27 10:17:21	00° 00.098' S	113° 44.620' W	4178.260
14	SO298_14-3	SS-CTD	2023/04/27 13:19:00	00° 00.234' S	113° 43.927' W	4163.480
15	SO298_15-1	SS-CTD	2023/04/28 11:40:55	00° 00.000' S	116° 56.357' W	4134.900
15	SO298_15-2	Ti-CTD	2023/04/28 14:19:56	00° 00.001' N	116° 56.110' W	4132.470
15 Super	SO298_15-3	ISP	2023/04/28 17:20:01	00° 00.004' N	116° 55.529' W	4114.580
16	SO298_16-1	bio CTD	2023/04/29 16:15:04	00° 00.007' N	120° 08.247' W	4698.530
16	SO298_16-2	Ti CTD	2023/04/29 16:46:52	00° 00.042' S	120° 08.002' W	4160.160
16	SO298_16-3	SS CTD	2023/04/29 19:39:52	00° 00.240' S	120° 06.714' W	4199.800
17	SO298_17-1	Ti CTD	2023/04/30 19:05:06	00° 00.003' S	123° 29.668' W	4526.050
17	SO298_17-2	SS-CTD	2023/04/30 22:05:38	00° 00.001' N	123° 29.529' W	4527.280
18 Super	SO298_18-1	ISP	2023/05/01 23:18:40	00° 00.006' S	127° 09.014' W	4545.400
18	SO298_18-2	Ti-CTD	2023/05/02 02:25:20	00° 00.274' S	127° 08.312' W	4444.440
18	SO298_18-3	SS-CTD	2023/05/02 05:20:11	00° 00.341' S	127° 08.136' W	4408.100
19	SO298_19-1	Bio CTD	2023/05/03 06:30:04	00° 00.000' S	130° 47.653' W	4493.140
19	SO298_19-2	Ti-CTD	2023/05/03 07:02:38	00° 00.025' S	130° 47.339' W	4465.330
19	SO298_19-3	SS-CTD	2023/05/03 10:00:19	00° 00.125' S	130° 46.879' W	4450.920
20	SO298_20-1	Ti-CTD	2023/05/04 11:10:33	00° 00.121' N	134° 27.100' W	4100.530
20	SO298_20-2	SS-CTD	2023/05/04 14:04:26	00° 00.149' N	134° 26.707' W	4081.930

21	SO298_21-1	SS-CTD	2023/05/05 14:56:13	00° 00.010' N	138° 06.131' W	4279.290
21	SO298_21-2	Ti-CTD	2023/05/05 17:38:50	00° 00.004' S	138° 05.912' W	4525.050
21 Super	SO298_21-3	ISP	2023/05/05 20:33:41	00° 00.001' S	138° 05.605' W	4270.890
22	SO298_22-1	bio-CTD	2023/05/06 21:37:36	00° 00.014' S	141° 45.006' W	4332.430
22	SO298_22-2	Ti-CTD	2023/05/06 22:05:51	00° 00.178' S	141° 44.553' W	4341.320
22	SO298_22-3	SS-CTD	2023/05/07 01:05:11	00° 00.338' S	141° 44.120' W	4350.100
23	SO298_23-1	Ti-CTD	2023/05/08 02:26:02	00° 00.004' S	145° 24.003' W	4343.020
23	SO298_23-2	SS-CTD	2023/05/08 05:19:00	00° 00.183' S	145° 23.505' W	4328.900
24	SO298_24-1	bio CTD	2023/05/09 05:24:52	00° 00.003' N	149° 02.941' W	4576.730
24	SO298_24-2	Ti-CTD	2023/05/09 05:55:05	00° 00.005' N	149° 02.858' W	4580.750
24	SO298_24-3	SS-CTD	2023/05/09 09:06:45	00° 00.006' N	149° 02.802' W	4577.060
25	SO298_25-2	Ti-CTD	2023/05/10 12:17:01	00° 00.005' N	152° 41.928' W	4536.540
25 Super	SO298_25-3	ISP	2023/05/10 15:24:30	00° 00.044' N	152° 41.581' W	4532.220
26	SO298_26-1	Bio-CTD	2023/05/11 16:03:55	00° 00.037' S	156° 21.121' W	3295.380
26	SO298_26-2	Ti-CTD	2023/05/11 16:34:09	00° 00.043' S	156° 20.940' W	3332.080
26	SO298_26-3	SS-CTD	2023/05/11 18:54:38	00° 00.041' S	156° 20.762' W	3430.820
27	SO298_27-2	SS-CTD	2023/05/12 18:04:05	00° 00.009' S	160° 00.002' W	5160.000
27	SO298_27-3	Ti-CTD	2023/05/12 21:20:52	00° 00.002' N	159° 59.997' W	5158.370
27	SO298_27-1	bio-CTD	2023/05/13 00:54:07	00° 00.003' S	159° 59.996' W	5159.150
28 Super	SO298_28-1	ISP	2023/05/13 22:07:07	00° 00.002' N	163° 38.992' W	4843.190
28	SO298_28-2	Ti-CTD	2023/05/14 01:02:19	00° 00.237' N	163° 38.580' W	4923.120
28	SO298_28-3	SS-CTD	2023/05/14 04:30:36	00° 00.231' N	163° 38.558' W	4925.080
29	SO298_29-1	bio-CTD	2023/05/15 04:27:32	00° 00.001' S	167° 18.097' W	4739.570
29	SO298_29-2	Ti-CTD	2023/05/15 04:57:27	00° 00.003' N	167° 18.103' W	4739.570
29	SO298_29-3	SS-CTD	2023/05/15 08:10:18	00° 00.006' S	167° 18.097' W	4741.500
30	SO298_30-1	SS-CTD	2023/05/16 11:49:37	00° 00.019' N	170° 56.805' W	5366.860
30	SO298_30-2	Ti-CTD	2023/05/16 11:50:02	00° 00.019' N	170° 56.805' W	5372.650
30 Super	SO298_30-3	ISP	2023/05/16 15:32:04	00° 00.030' N	170° 56.824' W	5371.520
31	SO298_31-1	bio-CTD	2023/05/17 15:55:01	00° 00.016' N	174° 36.203' W	5677.880
31	SO298_31-2	Ti-CTD	2023/05/17 16:40:12	00° 00.015' N	174° 36.202' W	5425.620
31	SO298_31-3	SS-CTD	2023/05/17 20:20:47	00° 00.012' N	174° 36.176' W	5426.890
32	SO298_32-1	Ti-CTD	2023/05/18 19:46:35	00° 00.020' S	178° 15.135' W	4926.690
32	SO298_32-2	SS-CTD	2023/05/18 23:06:05	00° 00.021' S	178° 15.138' W	4965.720
33	SO298_33-1	bio CTD	2023/05/19 22:24:38	00° 00.001' N	178° 06.009' E	5399.750
33	SO298_33-2	Ti-CTD	2023/05/19 22:52:26	00° 00.009' N	178° 05.995' E	5399.520
33	SO298_33-3	SS-CTD	2023/05/20 02:26:28	00° 00.008' N	178° 05.994' E	5401.000
34 Super	SO298_34-1	ISP	2023/05/21 01:54:28	00° 00.061' N	174° 26.970' E	4759.790

34	SO298_34-2	Ti-CTD	2023/05/21 05:01:05	00° 00.060' N	174° 26.973' E	4761.030
34	SO298_34-3	SS-CDT	2023/05/21 08:13:40	00° 00.067' N	174° 26.994' E	4762.530
35	SO298_35-1	bio-CTD	2023/05/22 07:13:26	00° 00.012' S	170° 47.884' E	4562.420
35	SO298_35-2	Ti-CTD	2023/05/22 07:41:05	00° 00.011' S	170° 47.879' E	4559.270
35	SO298_35-3	SS-CTD	2023/05/22 10:51:31	00° 00.010' S	170° 47.881' E	4568.460
36	SO298_36-1	bio CTD	2023/05/23 10:40:10	00° 00.136' S	167° 09.129' E	4338.600
36	SO298_36-2	Ti-CTD	2023/05/23 11:08:03	00° 00.138' S	167° 09.131' E	4339.590
36	SO298_36-3	SS-CTD	2023/05/23 14:35:28	00° 00.141' S	167° 09.130' E	4339.890
37	SO298_37-1	SS-CTD	2023/05/24 14:03:43	00° 00.015' S	163° 30.040' E	4447.750
37	SO298_37-2	Ti-CTD	2023/05/24 16:54:24	00° 00.004' S	163° 30.031' E	4448.570
37 Super	SO298_37-3	ISP	2023/05/24 19:54:10	00° 00.005' S	163° 30.030' E	4447.100
38	SO298_38-1	bio-CTD	2023/05/25 18:51:33	00° 00.004' S	160° 00.020' E	2816.530
38	SO298_38-2	Ti-CTD	2023/05/25 19:31:30	00° 00.004' S	160° 00.021' E	2815.090
38	SO298_38-3	SS-CTD	2023/05/25 21:29:18	00° 00.012' S	160° 00.014' E	2816.260
39	SO298_39-1	SS-CTD	2023/05/26 13:56:59	01° 21.363' S	157° 51.216' E	1868.720
39	SO298_39-2	Ti-CTD	2023/05/26 15:22:26	01° 21.357' S	157° 51.220' E	1868.440
39 Super	SO298_39-3	ISP	2023/05/26 16:47:11	01° 21.368' S	157° 51.212' E	1868.890
39	SO298_39-4	bio-CTD	2023/05/26 20:50:28	01° 21.231' S	157° 51.668' E	1876.640

8 Data and Sample Storage and Availability

A cruise summary report (CSR) has been compiled and submitted to DOD (Deutsches Ozeanographisches Datenzentrum), BSH, Hamburg, immediately after the cruise. Part of the cruise was performed in waters under jurisdiction of Ecuador, Nauru and the USA. As requested, the CTD data and this cruise report have been transferred to the respective authorities.

All hydrographic data acquired during the cruise are transferred to BSH, and also stored at the GEOTRACES data base at BODC, Liverpool, U.K., and will be made available to the PANGAEA data base. All trace metal and isotope data to be acquired will also be fed into these data bases and will be made publicly available within 3 years after cruise end (3rd quarter of 2026). All water and particulate and sediment samples are stored at the respective laboratories, where the measurements will be carried out. The Kiel Data Management Team (KDMT) provides an information and data archival system where metadata of the onboard DSHIP-System are collected and are made publicly available. This Ocean Science Information System (OSIS-Kiel) is accessible for all project participants and can be used to share and edit field information (https://portal.geomar.de/metadata/).

Availability of metadata in OSIS, 2 weeks after completion of the cruise and related experiments. Availability of data in OSIS (https://portal.geomar.de/osis): 6 months after completion of the cruise and related experiments.

Table 8.1 lists the target data bases, tentative availability times and responsible scientists.

Hydrography CTD and ADCP and multibeam data are held at DAM and GEOMAR Helmholtz Centre for Ocean Research Kiel and are publicly available immediately after cruise (responsible:

Prof. E. Achterberg).
Dissolved trace metals - samples and data are held at GEOMAR, Kiel (responsible: Prof. E. Achterberg).
Particulate trace metals - samples and data are held at GEOMAR, Kiel (responsible: Prof. E. Achterberg).
Trace element and isotopes (REE, Nd, Ba) - samples and data are held at GEOMAR, Kiel (responsible: Prof. M. Frank).
Stable Fe isotopes - samples and data are held at GEOMAR, Kiel (responsible: Prof. E. Achterberg).
Radium isotopes - samples and data are held at GEOMAR (responsible Prof. E. Achterberg).
High Field Strength Elements and trace element speciation – samples and data are held at the Constructor University Bremen (responsible Prof. A. Koschinsky).
Phytoplankton/productivity – samples and data are held at GEOMAR, Kiel (responsible Dr. T. Browning).
Nitrogen cycling and fixation - samples and data are held at GEOMAR (responsible Dr. T. Browning).
Nutrients, DOC, DOC, alkalinity, carbon cycle - samples and data are held at GEOMAR, Kiel (responsible Prof. E. Achterberg).

Table 8.1 Overview of data availability

Type	Database	Available	Contact
Hydrography	BODC/PANGAEA	June 2026	eachterberg@geomar.de
Nutrients	BODC/PANGAEA	June 2026	eachterberg@geomar.de
Dissolved trace metals	BODC/PANGAEA	June 2026	eachterberg@geomar.de
Particulate trace metals	BODC/PANGAEA	June 2026	eachterberg@geomar.de
High field strength elements / metal speciation	BODC/PANGAEA	June 2026	a.koschinsky@constructor.university
REEs, Nd and Ba isotopes	BODC/PANGAEA	June 2026	mfrank@geomar.de
Stable Fe isotopes	BODC/PANGAEA	June 2026	eachterberg@geomar.de
Radium isotopes	BODC/PANGAEA	June 2026	eachterberg@geomar.de
Nitrogen cycling and fixation	BODC/PANGAEA	June 2026	tbrowning@geomar.de
Phytoplankton/productivity	BODC/PANGAE	June 2026	tbrowning@geomar.de

	A		
Carbonate chemistry, DOC	BODC/PANGAEA	June 2026	eachterberg@geomar.de

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11 Abbreviations

AA	Amino acids
AAIW	Antarctic Intermediate Water
ADCP	Acoustic Doppler Current Profiler
AS	Amino Sugars
BCP	Biological Carbon Pump
BIO-CTD	Shallow trace metal clean water sampling
BOD	Biological Oxygen Demand
BSi	Biogenic Silica
CFC	Chlorofluorocarbon
Chl	Chlorophyll
CRM	Certified Reference Material
CSR	Cruise Summary Report
CTD	Conductivity, Temperature, and Depth
CVAFS	Cold Vapor Automatic Fluorescence Spectrometry
DIC	Dissolved Inorganic Carbon
DOC	Dissolved Organic Carbon
DOD	Deutsches Ozeanographisches Datenzentrum
DGM	Dissolved Gaseous Mercury
EEZ	Exclusive Economic Zone
EPO	Equatorial Pacific Ocean
EPR	East Pacific Rise
EUC	Equatorial Under Current
FEP	Fluorinated ethylene propylene
FRRf	Fast repetition rate fluorometry
GFF	Glass Fibre Filter
GTU	GEOTRACES Cleaning Protocol
HFSE	High Field Strength Element
HgT	Total Hg
HNLC	High Nitrate Low Chlorophyll
HPLC	High Performance Liquid Chromatography
HPG	Homopropargylglycine
ISP	*in situ* Pump
ITF	Indonesian Through Flow
KDMT	Kiel Data Management Team
LADCP	Lowered Acoustic Doppler Current Profiler
LCDW	Lower Circumpolar Deep Water
LDPE	Low-density Polyethylene
MC-ICPMS	Multi-Collector Inductively Coupled Plasma Mass Spectrometry
MeHg	Methylmercury
MIO	Mediterranean Institute of Oceanography
MPI	Max Plank Institute
OMZ	Oxygen Minimum Zone
OPA	o-Phtaladiadehyde
OTE	Ocean Test Equipment
PAR	Photosynthetically Active Radiation
PC	Polycarbonate
PDW	Pacific Deep Water
PES	Polyethersulfone
PET	Polyethylene terephthalate
PFA	Perfluoroalkoxy Alkane
PISCO	Plankton Imager with SCanning Optics

PMT	Photomultiplier Tube
PN	Particulate Nitrogen
POC	Particulate Organic Carbon
POM	Particulate Organic Matter
PON	Particulate Organic Nitrogen
QMA	Quartz Microfiber
REEs	Rare Earth Elements
RMS	Root Mean Squared
RMNS	Reference Material for Nutrients in Seawater
ROV	Remotely Operated Vehicle
RSG	RedoxSensor Green
SAMW	Subantarctic Mode Water
SEC	South Equatorial Current
SPE	Solid Phase Extraction
SS	Stainless Steel
SSS	Sea Surface Salinity
SS-CTD	Stainless Steel CTD
SST	Sea Surface Temperature
TA	Total Alkalinity
TEIs	Trace Elements and Isotopes
Ti-CTD	Titanium CTD (trace metal clean)
TON	Total Oxidized Nitrogen
TRIS	tris(hydroxymethyl)aminomethane
TSG	Thermosalinograph
UCDW	Upper Circumpolar Deep water
UPLC	Ultrahigh Performance Liquid Chromatography
UVP	Underwater Vision Profiler
VMADCP	Vessel Mounted Acoustic Doppler Current Profiler

12 Appendices

12.1 SS-CTD Operation Logs

Table 12.1 Logs of operations done using SS-CTD

Ship Station	CTD Profile #	Extra Info.	Date	Start time [UTC]	LATITUDE	LONGITUDE	Water depth (m)	Pressure seafloor (db)	Add. Sensor
298_2_1	1	Bio	15.04.2023	22:15	01°47,825 S	081°54,110 W	1709	160	Pisco
298_2_3	2		16.04.2023	01:01	01°47,820 S	081°54,113 W	1710	1705	
298_3_1	3		16.04.2023	07:57	01°08,213 S	082°27,262 W	1479	1497	
298_3_3	4	Pump	16.04.2023	11:15	01°08,348 S	082°27,241 W	1483	636	Pisco
298_4_1	5	Bio	16.04.2023	23:23	00°34,097 S	083°43,652 W	2632	166	Pisco
298_4_3	6		17.04.2023	02:03	00°34,187 S	083°43,587 W	2637	2645	
298_5_2	7		17.04.2023	21:25	01°06,002 S	086°06,002 W	2105	2117	
298_6_1	8	Bio	18.04.2023	06:01	01°59,959 S	088°59,944 W	3107	-	Pisco
298_6_3	9		18.04.2023	20:57	01°59,848 S	089°00,047 W	3106	3109	
298_7_1	10	Pump	19.04.2023	18:15	02°00,089 S	092°05,867 W	3304	634	Pisco
298_7_3	11		20.04.2023	00:13	02°00,354 S	092°05,901 W	3309	3325	
298_8_1	12	Bio	20.04.2023	21:55	00°00,069 N	094°34,753 W	3350	306	Pisco
298_8_3	13		21.04.2023	01:09	00°00,076 N	094°34,520 W	3338	3340,9	
298_9_2	14		22.04.2023	01:22	00°00,003 S	097°46,830 W	3304	3319	
298_10_1	15	Bio	22.04.2023	23:34	00°00,000 S	100°58,162 W	3240	305	Pisco
298_10_3	16		23.04.2023	02:29	00°00,258 S	100°56,847 W	3230	3230	
298_11_1	17	Pump	24.04.2023	02:22	00°00,006 S	104°10,136 W	3507	632	Pisco
298_11_3	18		24.04.2023	08:19	00°00,038 N	104°07,506 W	3381	3450	
298_12_1	19	Bio	25.04.2023	07:40	00°00,034 N	107°21,492 W	3899	304	Pisco
298_12_3	20		25.04.2023	10:49	00°00,005 N	107°19,787 W	3674	-	
298_13_2	21		26.04.2023	11:43	00°00,034 N	110°32,387 W	3801	3795	
298_14_1	22	Bio	27.04.2023	09:48	00°00,023 S	113°45,076 W	4183	303	Pisco
298_14_3	23		27.04.2023	13:19	00°00,234 S	113°43,924 W	4166	4181	
298_15_1	24		28.04.2023	11:41	00°00,001 S	116°56,353 W	4137	4167	
298_15_3	25	Pump	28.04.2023	17:20	00°00,003 N	116°55,485 W	4111	602	Pisco
298_16_1	26	Bio	29.04.2023	16:15	00°00,007 N	120°08,245 W	4156	302	Pisco
298_16_3	27		29.04.2023	19:40	00°00,241 S	120°06,710 W	4199	4213	
298_17_2	28		30.04.2023	22:10	00°00,010 S	123°29,462 W	4527	4570	
298_18_1	29	Pump	01.05.2023	23:20	00°00,021 S	127°08,973 W	4545	630	Pisco
298_18_3	30		02.05.2023	05:22	00°00,345 S	127°08,130 W	4409	4450	
298_19_1	31	Bio	03.05.2023	06:30	00°00,002 N	130°47,656 W	4498	317	Pisco
298_19_3	32		03.05.2023	10:03	00°00,146 S	130°46,825 W	4454	4500	
298_20_2	33		04.05.2023	14:04	00°00,148 N	134°26,690 W	4078	4113	
298_21_1	34		05.05.2023	14:56	00°00,011 N	138°06,130 W	4279	4315	

298_21_3	35	Pump	05.05.2023	20:35	00°00,002 S	138°05,568 W	4269	-	Pisco
298_22_1	36	Bio	06.05.2023	21:38	00°00,012 S	141°45,006 W	4331	308	Pisco
298_22_3	37		07.05.2023	01:06	00°00,348 S	141°44,082 W	4348	4393	
298_23_2	38		08.05.2023	05:19	00°00,184 S	145°23,505 W	4328	4370	
298_24_1	39	Bio	09.05.2023	05:25	00°00,004 N	149°02,941 W	4579	308	Pisco
298_24_3	40		09.05.2023	09:07	00°00,007 N	149°02804 W	4577	4623	
298_25_1	41		10.05.2023	09:25	00°00,006 N	152°41,983 W	4219	4580	
298_25_3	42	Pump	10.05.2023	15:29	00°00,055 N	152°41,508 W	4530	-	Pisco
298_26_1	43	Bio	11.05.2023	16:05	00°00,043 S	156°21,119 W	3272	303	Pisco
298_26_3	44		11.05.2023	18:55	00°00,041 S	156°20,762 W	3430	3448	
298_27_1	45		12.05.2023	18:04	00°00,009 S	160°00,004 W	5159	5216	
298_27_3	46	Bio	13.05.2023	00:56	00°00,003 S	159°59,998 W	5159	304	Pisco
298_28_1	47	Pump	13.05.2023	22:10	00°00,002 N	163°38,993 W	4843	626	Pisco
298_28_3	48		14.05.2023	04:34	00°00,233 N	163°38,555 W	4922	4978	
298_29_1	49	Bio	15.05.2023	04:30	00°00,001 N	167°18,100 W	4747	305	Pisco
298_29_3	50		15.05.2023	08:10	00°00,006 S	167°18,097 W	4736	4788	
298_30_1	51		16.05.2023	08:09	00°00,022 N	170°56,782 W	5376	5444	
298_30_3	52	Pump	16.05.2023	15:33	00°00,031 N	170°56,824 W	5369	633	Pisco
298_31_1	53	Bio	17.05.2023	16:11	00°00,015 N	174°36,208 W	5424	304	Pisco
298_31_3	54		17.05.2023	20:22	00°00,012 N	174°36,170 W	5422	5492	
298_32_2	55		18.05.2023	23:06	00°00,022 S	178°15,138 W	4929	5021	
298_33_1	56	Bio	19.05.2023	22:25	00°00,003 N	178°05,997 E	5399	305	Pisco
298_33_3	57		20.05.2023	02:31	00°00,006 N	178°05,992 E	5400	5470	
298_34_1	58	Pump	21.05.2023	01:55	00°00,062 N	174°26,967 E	4760	633	Pisco
298_34_3	59		21.05.2023	08:14	00°00,067 N	174°26,994 E	4763	4811	
298_35_1	60	Bio	22.05.2023	07:14	00°00,012 S	170°47,878 E	4563	303	Pisco
298_35_3	61		22.05.2023	10:52	00°00,010 S	170°47,881 E	4556	4530	
298_36_1	62	Bio	23.05.2023	10:41	00°00,137 S	167°09,135 E	4337	306	Pisco
298_36_3	63		23.05.2023	14:42	00°00,135 S	167°09,128 E	4340	4380	
298_37_1	64		24.05.2023	14:04	00°00,012 S	163°30,039 E	4446	4489	
298_37_3	65	Pump	24.05.2023	19:54	00°00,005 S	163°30,030 E	4448	-	Pisco
298_38_1	66	Bio	25.05.2023	18:53	00°00,009 S	160°00,017 E	2816	303	Pisco
298_38_3	67		25.05.2023	21:29	00°00,012 S	160°00,014 E	2817	2824	
298_39_1	68		26.05.2023	13:57	01°21,363 S	157°51,218 E	1868	1872	
298_39_3	69	Pump	26.05.2023	17:03	01°21,327 S	157°51,351 E	1870	-	Pisco
298_39_4	70	Bio	26.05.2023	22:02	01°21,240 S	157°51,671 E	1876	305	Pisco

12.2 Tow-fish Samples

Table 12.2 Surface water samples taken using the two-fish. Records of latitude, longitude, and salinity wereobtained from the ship's underway system based on the time of sample collection based on the time of sample collection

Sample ID	UTC date (dd:mm:yyyy)	Nutrients	diss TMs	dAl	Latitude (°N)	Longitude (°E)	Br	Pb iso	Fe iso	Cd iso	Oxyan	HFSE	234Th	U iso	Nd/Si /Ba iso	NH4	230Th	Note	Salinity
10001	15-04-23	17:25	17:25	17:25	-2.27	-81.29													32.4153
10002	15-04-23	21:50	21:51	21:51	-1.82	-81.88					21:52	21:52			22:04			Stn. 2	33.6811
10003	16-04-23	03:58	04:00	04:01	-1.63	-82.04													33.3289
10004	16-04-23	05:43	05:44	05:45	-1.41	-82.23													32.7095
10005	16-04-23	15:02	15:03	15:03	-1.13	-82.48												Stn. 3	33.4530
10006	16-04-23	17:22	17:23	17:23	-0.97	-82.83													33.4010
10007	16-04-23	19:08	19:08	19:08	-0.85	-83.09													33.6759
10008	16-04-23	21:16	21:17	21:17	-0.70	-83.43													33.6453
10009	16-04-23	22:56	22:57	22:57	-0.59	-83.68												Stn. 4	33.8183
10010	17-04-23	06:55	06:55	06:55	-0.66	-84.13													33.5405
10011	17-04-23	08:56	08:56	08:56	-0.73	-84.44													33.6449
10012	17-04-23	12:31	12:31	12:31	-0.85	-85.00													33.7937
10013	17-04-23	15:05	15:06	15:07	-0.95	-85.40													33.7885
10014	17-04-23	18:02	18:03	18:03	-1.05	-85.88													33.9074
10015	17-04-23	19:17	19:18	19:18	-1.10	-86.09	19:20											Stn. 5	33.9561
10016	18-04-23	02:22	02:24	02:27	-1.24	-86.57													34.1547
10017	18-04-23	05:04[D]	05:06	05:07	-1.37	-87.00	05:10												34.3025
10018	18-04-23	07:18	07:20	07:21	-1.48	-87.36	07:25												34.3566
10019	18-04-23	10:14	10:16	10:18	-1.62	-87.83	10:19												34.1757
10020	18-04-23	23:27	23:28	23:29	-2.01	-89.01				23:35								Stn. 6	34.7309
10021	19-04-23	02:20	02:21	02:22	-2.10	-89.48													34.5589
10022	19-04-23	05:09	05:10	05:10	-2.11	-89.95													34.8091
10023	19-04-23	07:51	07:51	07:51	-2.09	-90.39													34.9247

10024	19-04-23	11:00	11:03	11:03	-2.06	-90.92												Nutrient sample was not filtered	34.7824
10025	19-04-23	14:12	14:13	14:13	-2.03	-91.45												heavy rain	34.6904
10026	19-04-23	17:41	17:42	17:42	-2.00	-92.03												Stn. 7; rain	35.1295
10027	20-04-23	05:10	05:13	05:14	-1.73	-92.43													35.1499
10028	20-04-23	07:10	07:12	07:13	-1.53	-92.69													35.0837
10029	20-04-23	09:11	09:11	09:11	-1.32	-92.94													34.8265
10030	20-04-23	11:11	11:11	11:11	-1.11	-93.20													34.9390
10031	20-04-23	13:14	13:15	13:16	-0.90	-93.47													35.0704
10032	20-04-23	15:07	15:08	15:09	-0.70	-93.71													34.9936
10033	20-04-23	17:03	17:04	17:04	-0.50	-93.97	17:06											Sunny	34.9400
10034	20-04-23	18:31	18:32	18:33	-0.34	-94.16	18:34												34.9953
10035	20-04-23	20:06	20:07	20:07	-0.18	-94.36	20:08												35.0217
10036	20-04-23	21:34	21:35	21:35	-0.02	-94.55	21:37											Stn. 8	35.0000
10037	21-04-23	07:07	07:07	07:07	0.00	-95.15													34.9364
10038	21-04-23	10:00	10:02	10:02	0.00	-95.63	10:02												34.8646
10039	21-04-23	13:02	13:04	13:08	0.00	-96.13													34.8100
10040	21-04-23	16:07	16:08	16:08	0.00	-96.64												Filter replaced	34.7075
10041	21-04-23	19:03	19:04	19:04	0.00	-97.13													34.9057
10042	22-04-23	03:57	03:58	03:58	0.00	-97.81									Time?; 3*20L			Stn. 9	35.0687
10043	22-04-23	07:05	07:05	07:05	0.00	-98.33													35.1243
10044	22-04-23	10:00	10:02	10:03	0.00	-98.82													35.0234
10045	22-04-23	13:26	13:27	13:28	0.00	-99.38													35.0639
10046	22-04-23	16:20	16:21	16:22	0.00	-99.86													35.0745
10047	22-04-23	18:29	18:30	18:31	0.00	-100.19													35.0734
10048	22-04-23	20:38	20:36	20:36	0.00	-100.51													35.1292

10049	22-04-23	23:07	23:08	23:09	0.00	-100.92				23:06	23:10	23:10						Stn. 10	35.1310
10050	23-04-23				0.00	-100.95									04:55			Stn. 10	35.1501
10051	23-04-23	07:10	07:10	07:10	0.00	-101.30													35.1455
10052	23-04-23	10:05	10:05	10:05	0.00	-101.75													35.0886
10054	23-04-23	14:31	14:32	14:33	0.00	-102.44													35.1632
10055	23-04-23	16:16	16:17	16:17	0.00	-102.70													35.1468
10056	23-04-23	19:30	19:31	19:31	0.00	-103.17													35.1556
10057	23-04-23	22:02	22:07	22:08	0.00	-103.56													35.1878
10058	24-04-23	01:51	01:53	01:54	0.00	-104.13		01:41	01:58		01:48-01:58		01:38	02:05	01:35		02:04	Stn. 11	35.1823
10059	24-04-23	13:10	13:10	13:10	0.00	-104.47													35.1310
10060	24-04-23	16:12	16:13	16:14	0.00	-104.93													35.1102
10061	24-04-23	19:41	19:42	19:42	0.00	-105.46													35.1444
10062	24-04-23	22:34	22:35	22:36	0.00	-105.89													35.1593
10063	25-04-23	01:29	01:31	01:32	0.00	-106.36													35.1321
10064	25-04-23	05:22	05:22	05:22	0.00	-107.00													35.1732
10065	25-04-23	07:05	07:05	07:05	0.00	-107.29												Stn. 12?	35.1772
10066	25-04-23	17:52	17:52	17:52	0.00	-108.05													35.1488
10067	25-04-23	19:20	19:20	19:21	0.00	-108.29													35.1484
10068	25-04-23	21:29	21:31	21:31	0.00	-108.65													35.1886
10069	26-04-23	00:00	00:00	00:00	0.00	-109.07													35.2043
10070	26-04-23	03:48	03:48	03:49	0.00	-109.70													35.2094
10071	26-04-23	06:05	06:05	06:05	0.00	-110.08													35.2173
10072	26-04-23	08:36	08:37	08:38	0.00	-110.50				08:30	08:32-08:35				08:23			Stn. 13	35.1808
10073	26-04-23	16:18	16:18	16:19	0.00	-110.86													35.1761
10074	26-04-23	19:10	19:11	19:11	0.00	-111.34													35.1721
10075	26-04-23	22:07	22:07	22:07	0.00	-111.82													35.2265
10076	27-04-23	01:25	01:26	01:27	0.00	-112.38													35.2373
10078	27-04-23	04:00	04:01	04:01	0.00	-112.81													35.2450
10079	27-04-23	06:59	07:00	07:00	0.00	-113.30													35.2480
10080	27-04-23	09:26	09:27	09:28	0.00	-113.71					09:24	09:24						Stn. 14	35.2104

10081	27-04-23	19:30	19:31	19:32	0.00	-114.28													35.2188
10082	27-04-23	22:57	23:02	23:03	0.00	-114.87													35.2509
10083	28-04-23	01:35	01:35	01:35	0.00	-115.29													35.2523
10084	28-04-23	04:33	04:36	04:37	0.00	-115.79													35.2574
10085	28-04-23	07:25	07:25	07:25	0.00	-116.26													35.2654
10086	28-04-23	11:13	11:14	11:15	0.00	-116.90		10:59	11:10				11:04	10:56				Stn. 15	35.2318
10087	28-04-23	23:21	23:21	23:21	0.00	-117.36													35.2696
10088	29-04-23	02:01	02:06	02:06	0.00	-117.82													35.2746
10089	29-04-23	05:05	05:07	05:08	0.00	-118.32													35.2816
10090	29-04-23	08:05	08:05	08:05	0.00	-118.81													35.2345
10091	29-04-23	11:10	11:10	11:10	0.00	-119.32													35.2228
10092	29-04-23	14:10	14:10	14:10	0.00	-119.82													35.2157
10093	29-04-23	15:51	15:52	15:53	0.00	-120.10					15:50	15:50						Stn. 16	35.2145
10094	30-04-23	00:55	00:55	00:55	0.00	-120.50													35.2495
10095	30-04-23	04:11	04:12	04:13	0.00	-121.04													35.2398
10096	30-04-23	07:00	07:00	07:00	0.00	-121.51													35.2328
10097	30-04-23	09:06	09:07	09:08	0.00	-121.86													35.1873
10098	30-04-23	13:04	13:06	13:08	0.00	-122.53													35.1765
10099	30-04-23	16:16	16:17	16:18	0.00	-123.06													35.1746
10100	30-04-23	18:40	18:41	18:42	0.00	-123.46									18:44-18:58			Stn. 17	35.1822
10101	01-05-23	03:50	03:51	03:52	0.00	-123.92													35.2483
10102	01-05-23	18:22	18:23	18:24	0.00	-126.35													35.2320
10103	01-05-23	20:28	20:28	20:28	0.00	-126.70													35.2764
10104	01-05-23	22:59	23:00	23:01	0.00	-127.12		02-05-23 09:06	22:53	22:57	23:02	23:02	23:07	23:07	23:15			Stn. 18	35.2798
10105	02-05-23	12:08	12:08	12:08	0.00	-127.78	12:10												35.2245
10106	02-05-23	15:17	15:17	15:17	0.00	-128.30	15:17												35.2233
10107	02-05-23	18:07	18:08	18:10	0.00	-128.78	18:11												35.1821
10108	02-05-23	21:15	21:15	21:15	0.00	-129.30	21:15												35.1983

10109	03-05-23	00:07	00:10	00:11	0.00	-129.78	00:13												35.2451
10110	03-05-23	03:03	03:03	03:03	0.00	-130.26	03:04												35.2859
10111	03-05-23	06:02	06:03	06:04	0.00	-130.76	06:06									06:08		Stn. 19	35.3045
10112	03-05-23	15:17	15:19	15:20	0.00	-131.15													35.2911
10113	03-05-23	18:14	18:15	18:15	0.00	-131.64													35.2701
10114	03-05-23	21:11	21:15	21:18	0.00	-132.14													35.3132
10115	04-05-23	00:40	00:40	00:40	0.00	-132.71													35.3107
10116	04-05-23	03:04	03:05	03:07	0.00	-133.11													35.3094
10117	04-05-23	06:00	06:00	06:00	0.00	-133.61													35.3031
10118	04-05-23	08:46	08:46	08:46	0.00	-134.07													35.2518
10119	04-05-23	16:52	16:53	16:54	0.00	-134.46					16:55	16:55			17:05	16:51		Stn. 20	35.2552
10120	04-05-23	20:07	20:07	20:07	0.00	-135.00													35.3102
10121	04-05-23	21:59	22:01	22:04	0.00	-135.31													35.3207
10122	05-05-23	01:59	01:59	01:59	0.00	-135.98													35.3388
10123	05-05-23	05:03	05:03	05:03	0.00	-136.49													35.3284
10124	05-05-23	08:00	08:03	08:04	0.00	-136.99													35.2924
10125	05-05-23	11:20	11:20	11:20	0.00	-137.53													35.2526
10126	05-05-23	23:48	23:49	23:50	0.00	-138.09		00:05	00:02				23:46	23:46	00:15	23:51	23:57	Stn. 21	35.2708
10127	06-05-23	03:02	03:03	03:04	0.00	-138.65													35.2919
10128	06-05-23	06:05	06:05	06:05	0.00	-139.17													35.2924
10129	06-05-23	09:01	09:03	09:05	0.00	-139.68													35.2525
10130	06-05-23	12:05	12:05	12:05	0.00	-140.16													35.2530
10131	06-05-23	15:01	15:04	15:05	0.00	-140.67													35.2714
10132	07-05-23	04:36	04:37	04:38	0.00	-141.78					04:39-04:42					04:31		Stn. 22	35.3005
10133	07-05-23	13:07	13:07	13:07	0.00	-143.20													35.2722
10134	07-05-23	16:35	16:35	16:35	0.00	-143.77													35.3049
10135	07-05-23	20:03	20:04		0.00	-144.31										20:02			35.3720
10136	07-05-23	09:55	09:58	09:59	0.00	-142.67										10:02			35.2563
10137	07-05-23	23:46	23:46		0.00	-144.96										23:44			35.3924
10138	08-05-23	02:01	02:02		0.00	-145.35										02:03		Stn. 23	35.4050

10139	08-05-23	12:15	12:15		0.00	-146.08													35.3625
10140	08-05-23	15:57	15:58		0.00	-146.73										15:56			35.3409
10141	08-05-23	19:36	19:36		0.00	-147.37													35.3731
10142	08-05-23	22:11	22:13		0.00	-147.82										22:14			35.3649
10143	09-05-23	01:36	01:37		0.00	-148.42										01:38			35.3562
10144	09-05-23	04:58	04:58		0.00	-149.00					04:58	04:58				04:58		Stn. 24	35.3622
10145	09-05-23	15:15	15:15		0.00	-149.58										15:15			35.3443
10146	09-05-23	18:14	18:15		0.00	-150.10													35.3581
10147	09-05-23	21:07	21:08		0.00	-150.60										21:06			35.4179
10148	10-05-23	00:06	00:07		0.00	-151.12												Old filter	35.4291
10149	10-05-23	00:11	00:12		0.00	-151.14												New filter	35.4281
10150	10-05-23	04:07	04:08		0.00	-151.82										04:09			35.4129
10151	10-05-23	06:22	06:22		0.00	-152.21													35.4100
10152	10-05-23	09:01	09:02		0.00	-152.66		08:48	08:59	09:10	09:03-09:06		08:52	09:00	08:30-08:44			Stn. 25	35.3630
10153	10-05-23	22:01	22:02		0.00	-153.21													35.4006
10154	11-05-23	01:17	01:18		0.00	-153.77													35.3928
10155	11-05-23	04:10	04:10	04:10	0.00	-154.27													35.3637
10156	11-05-23	07:01	07:02	07:03	0.00	-154.78										07:04			35.3395
10157	11-05-23	10:03	10:04	10:04	0.00	-155.29										10:02			35.2727
10158	11-05-23	13:18	13:18	13:18	0.00	-155.88													35.2901
10159	11-05-23	15:46	15:47	15:48	0.00	-156.32										15:45		Stn. 26	35.3043
10160	12-05-23	00:00	00:00	00:00	0.00	-156.83										00:00			35.3534
10161	12-05-23	02:57		02:58	0.00	-157.37										03:00			35.3707
10162	12-05-23	05:58	05:58	05:58	0.00	-157.90													35.4017
10163	12-05-23	09:00	09:00	09:00	0.00	-158.43										09:00			35.3711
10164	12-05-23	12:03	12:03	12:03	0.00	-158.97													35.3739
10165	12-05-23	15:03	15:03	15:04	0.00	-159.50										15:06			35.3766

10166	12-05-23	17:41	17:42	17:42	0.00	-159.96					17:40	17:40						Stn. 27	35.3808
10167	13-05-23	04:45	04:45	04:45	0.00	-160.57										04:45			35.4208
10168	13-05-23	07:29	07:28	07:28	0.00	-161.04													35.4023
10169	13-05-23	10:30	10:32	10:33	0.00	-161.59										10:33			35.3731
10170	13-05-23	13:30	13:30	13:30	0.00	-162.13													35.3766
10171	13-05-23	16:45	16:45	16:45	0.00	-162.71										16:45			35.3907
10172	13-05-23	19:32	19:33	19:34	0.00	-163.21													35.3978
10173	13-05-23	21:48	21:49	21:49	0.00	-163.63		21:45	21:55				21:59	21:50	22:09	21:51		Stn. 28	35.4317
10174	14-05-23	10:48	10:48	10:48	0.00	-164.16													35.4008
10175	14-05-23	14:10	14:10	14:10	0.00	-164.76										14:10			35.4050
10176	14-05-23	17:02	17:06	17:06	0.00	-165.28										17:07			35.3993
10177	14-05-23	20:10	20:10		0.00	-165.82										20:10			35.4300
10178	15-05-23	01:44	01:44	01:45	0.00	-166.83													35.4022
10179	15-05-23	04:04	04:05	04:06	0.00	-167.25					04:03	04:03				04:04		Stn. 29	35.4039
10180	15-05-23	15:07	15:08	15:08	0.00	-167.89													35.3394
10181	15-05-23	18:10	18:08	18:08	0.00	-168.44										18:14			35.3391
10182	15-05-23	20:55	20:55	20:55	0.00	-168.95													35.3973
10183	16-05-23	00:19	00:17	00:18	0.00	-169.56										00:20			35.4108
10184	16-05-23	03:03	03:05	03:06	-0.09	-170.06													35.4289
10185	16-05-23	06:02	06:04	06:05	-0.02	-170.60													35.4360
10186	16-05-23	07:48	07:49	07:51	0.00	-170.92		07:30	07:40	07:47	07:42-07:44		07:34	07:41		07:35		Stn. 30	nan
10187	16-05-23	11:00	11:00	11:00	0.00	-170.95										11:00			nan
10188	17-05-23	00:28	00:28	00:29	0.00	-171.95													35.4172
10189	17-05-23	03:27	03:28	03:30	0.00	-172.34										03:30			35.4164
10190	17-05-23	06:33	06:34	06:34	0.00	-172.91													35.4192
10191	17-05-23	09:50	09:48	09:49	0.00	-173.50													nan
10192	17-05-23	12:25	12:25	12:27	0.00	-173.98													nan
10193	18-05-23	00:01	00:02	00:03	0.00	-174.63										00:04		Stn. 31	35.3797
10194	18-05-23	02:32	02:33	02:33	0.00	-175.10													35.3859
10195	18-05-23	05:40	05:41	05:42	0.00	-175.67													35.3984

10196	18-05-23	08:27	08:28	08:28	0.00	-176.19										08:29			nan
10197	18-05-23	11:33	11:34	11:35	0.00	-176.75													nan
10198	18-05-23	14:35	14:36	14:37	0.00	-177.31										14:34			nan
10199	18-05-23	17:33	17:31	17:32	0.00	-177.85													nan
10200	18-05-23	19:29	19:30	19:31	0.00	-178.22					19:26	19:26				19:28		Stn. 32	35.4312
10201	19-05-23	05:32	05:33	05:34	0.00	-178.83													35.4525
10202	19-05-23	08:37	08:38	08:39	0.00	-179.40										08:40		Rain	nan
10203	19-05-23	11:37	11:37	11:38	-0.06	-179.94													nan
10204	19-05-23	14:29	14:29	14:32	0.00	179.54										14:32			nan
10205	19-05-23	17:37	17:37	17:38	0.00	178.96													nan
10206	19-05-23	20:06	20:04	20:05	0.00	178.51													35.4305
10207	19-05-23	22:02	22:04	22:05	0.00	178.14												Stn. 33	35.4187
10208	20-05-23	08:58	09:00	08:59	0.00	177.55													nan
10209	20-05-23	12:07	12:08	12:09	0.00	176.97													nan
10210	20-05-23	15:03	15:04	15:04	0.00	176.43													nan
10211	20-05-23	18:00	18:01	18:02	0.00	175.88													nan
10212	20-05-23	21:51	21:53	21:52	0.00	175.17										21:54			35.3437
10213	21-05-23	01:33	01:34	01:35	0.00	174.49		01:22			01:30	01:30	01:19	01:31	01:53	01:24[T]		Stn. 34	35.4860
10214	21-05-23	14:15	14:15	14:15	-0.11	173.95												Rain	nan
10215	21-05-23	17:00	17:01	17:02	-0.18	173.45										14:15		Rain	nan
10216	21-05-23	20:05	20:05	20:06	-0.14	172.88										20:08			35.4047
10217	21-05-23	23:10	23:11	23:12	-0.10	172.30													35.4218
10218	22-05-23	02:04	02:05	02:06	-0.06	171.75										02:07			35.4222
10219	22-05-23	04:35	04:36	04:38	-0.03	171.27										04:38			35.4093
10220	22-05-23	06:54	06:55	06:56	0.00	170.84					06:51-06:54				06:50; 2L	06:58[D]		Stn. 35	35.4402
10221	22-05-23	17:15	17:13	17:14	0.00	170.20													nan
10222	22-05-23	20:03	20:04	20:05	0.00	169.71													35.3733
10223	22-05-23	23:03	23:04	23:05	0.00	169.18													35.4302
10224	23-05-23	02:07	02:05	02:07	0.00	168.64										02:08			35.4476

10225	23-05-23	05:02	05:00	05:01	0.00	168.12													35.2660
10226	23-05-23	07:30	07:30	07:30	0.00	167.68													35.2737
10227	23-05-23	10:09	10:10	10:11	0.00	167.20										10:12		Stn. 36	35.3160
10228	23-05-23	20:20	20:21	20:22	0.00	166.68													35.2424
10229	23-05-23	23:03	23:03	23:04	0.00	166.15										23:05			35.3135
10230	24-05-23	01:00	01:01	01:02	0.00	165.80													34.9969
10231	24-05-23	04:59	04:57	04:58	-0.02	165.13										05:00		Rain	34.7920
10232	24-05-23	08:04	08:04	08:04	0.00	164.55													35.2200
10233	24-05-23	10:32	10:33	10:34	0.00	164.11													35.2328
10234	24-05-23	12:55	12:56	12:57	0.00	163.68		13:05	12:48	12:44			13:01	12:58	13:15-13:25	13:07	12:54	Stn. 37	35.2358
10235	25-05-23	01:56	01:57	01:57	0.00	162.97													35.0768
10236	25-05-23	05:00	05:00	05:01	0.00	162.44													35.1622
10237	25-05-23	08:02	08:00	08:01	0.00	161.91										08:03			34.9405
10238	25-05-23	11:04	11:06	11:06	0.00	161.36										11:06		Heavy rain	34.7536
10239	25-05-23	14:05	14:06	14:06	0.00	160.82													34.8144
10240	25-05-23	17:00	17:01	17:02	0.00	160.30													34.7521
10241	25-05-23	18:35	18:36	18:37	0.00	160.02									19:22	18:39[D]		Stn. 38	34.6295
10242	26-05-23	01:35	01:36	01:37	-0.19	159.69													34.7635
10243	26-05-23	04:09	04:09	04:10	-0.44	159.31										04:11			34.7466
10244	26-05-23	07:03	07:04	07:05	-0.71	158.87										07:06			34.7699
10245	26-05-23	10:00[D]	10:01	10:02	-1.00	158.42										10:03[D]			34.8858
10246	26-05-23	12:02	12:00	12:01	-1.18	158.13										12:03			34.8675
10247	26-05-23	13:46[D]	13:47	13:48	-1.35	157.86		13:26	13:37	13:32	13:39-13:42; V iso at 14:04		13:58	13:48	14:05-14:38	14:00[T]	13:55	Stn. 39; rain	34.8383

D: Samples collected in duplicates
T: Samples collected in triplicates

12.3 Samples Collected Using *In-situ* Pumps

Table 12.3 Samples taken from *in-situ* pumps (51 µm).

Station	**51 µm**															
	Depth (m)	**POM**	**AA**	**AS**	**N iso.**	**BSi**	**Th234**	**PIC-δ^{13}C**	**F**	**Hg**	**Si iso.**	**Ba iso.**	**Microscopy**	**Synchrotron**	**Metagenomics**	**REE**
ST-3	40, 120, 200, 400, 600	5	5	5		5	5	5	5		5	5	5		5	
ST-7	40, 70, 120, 200, 400, 600	6	6	6	6	6	6	6	6		6	6	6	6	6	
ST-11	40, 80, 200, 370, 600	5	5	5	5	5	5	5	5		5	5	5	5	5	
ST-15	40, 80, 120, 200, 370, 600	6	6	6	6	6	6	6		6	6	6	6	6	6	
ST-18	60, 80, 120, 200, 370, 600	6	6	6	6	6	6	6	6		6	6	6	6	6	6
ST-21	55, 90, 115, 200, 355, 600	6	6	6	6	6	6	6		6	6	6	6	6	6	6
ST-25	50, 90, 130, 200, 350, 600	6	6	6	6	6	6	6		6	6	6	6	6	6	6
ST-28	50, 100, 135,	6	6	6	6	6	6	6	6		6	6	6	6	6	6

	200, 350, 600															
ST-30	45, 100, 125, 200, 370, 600	6	6	6	6	6	6	6		6	6	6	6	6	6	6
ST-34	60, 100, 150, 200, 420, 600	6	6	6	6	6	6	6		6	6	6	6	6	6	6
ST-37	60, 100, 175, 210, 410, 630	6	6	6	6	6	6	6	6		6	6	6	6	6	6
ST-39	60, 100, 160, 200, 420, 600	6	6	6	6	6	6	6		6	6	6	6	6	6	6

Table 12.4 Samples taken from *in-situ* pumps (1 µm)

Station	**1 µm**												
	Depth (m)	**POM**	**AA**	**AS**	**N iso.**	**PIC-δ^{13}C**	**F**	**Hg**	**Si iso.**	**Ba iso.**	**Microscopy**	**Synchrotron**	**Metagenomics**	**REE**
ST-3	15, 40, 120, 200, 400, 600	6	6	6		6	6		6	6	6		6	
ST-7	15, 40, 70, 120, 200, 400, 600	7	7	7	7	7	7		7	7	7	7	7	
ST-11	40, 80, 200, 370, 600	5	5	5	5	5	5		5	5	5	5	5	
ST-15	20, 40, 80, 120,	7	7	7	7	7		7	7	7	7	7	7	

	200, 370, 600													
ST-18	20, 60, 80, 120, 200, 370, 600	7	7	7	7	7	7		7	7	7	7	7	7
ST-21	20, 55, 90, 115, 200, 355, 600	7	7	7	7	7		7	7	7	7	7	7	7
ST-25	20, 50, 90, 130, 200, 350, 600	7	7	7	7	7		7	7	7	7	7	7	7
ST-28	20, 50, 100, 135, 200, 350, 600	7	7	7	7	7	7		7	7	7	7	7	7
ST-30	20, 45, 100, 125, 200, 370, 600	7	7	7	7	7		7	7	7	7	7	7	7
ST-34	20, 60, 100, 150, 200, 420, 600	7	7	7	7	7		6	7	7	7	7	7	7
ST-37	20, 60, 100, 175, 210, 410, 630	7	7	7	7	7	7		7	7	7	7	7	7
ST-39	20, 60, 100, 160, 200, 420, 600	7	7	7	7	7		7	7	7	7	7	7	7

12.4 Dissolved Oxygen Samples and Data

Table 12.5 Total oxygen samples taken, including station numbers and casts, and the results of the Winkler titration.

Date	Station No.	Profile /Cast	Bedford No.	Bottle No.	Bottle factor	Factor Sodium thiosulphate	titr. (mL) Sodium thiosulphate	O_2 [µM]
18/04/2023	6	2	SO298-20107	23	50.280	0.99324593	2.680	133.33
18/04/2023	6	2	SO298-20107	27	50.631	0.99324593	2.670	133.75
18/04/2023	6	2	SO298-20113	31	46.772	0.99324593	2.010	92.90
18/04/2023	6	2	SO298-20113	33	52.175	0.99324593	1.790	92.23
18/04/2023	6	2	SO298-20117	34	46.337	0.99324593	0.640	28.98
18/04/2023	6	2	SO298-20117	37	49.538	0.99324593	0.610	29.51
18/04/2023	6	2	SO298-20118	40	51.795	0.99324593	0.200	9.76
18/04/2023	6	2	SO298-20118	73	49.516	0.99324593	0.190	8.84
18/04/2023	6	2	SO298-20119	99	49.758	0.99324593	0.070	2.95
18/04/2023	6	2	SO298-20119	185	50.613	0.99324593	0.080	3.50
18/04/2023	6	2	SO298-20125	241	46.990	0.99324593	2.240	104.07
18/04/2023	6	2	SO298-20125	246	47.850	0.99324593	2.210	104.55
18/04/2023	6	3	SO298-40129	195	50.044	0.99324593	2.710	134.19
18/04/2023	6	3	SO298-40129	198	49.969	0.99324593	2.710	133.99
18/04/2023	6	3	SO298-40130	7	50.270	0.99324593	2.690	133.80
18/04/2023	6	3	SO298-40130	200	50.104	0.99324593	2.810	139.33
18/04/2023	6	3	SO298-40142	250	47.290	0.99324593	0.130	5.62
18/04/2023	6	3	SO298-40142	257	47.000	0.99324593	0.300	13.52
18/04/2023	6	3	SO298-40145	269	47.130	0.99324593	1.930	89.86
18/04/2023	6	3	SO298-40145	274	46.620	0.99324593	1.960	90.28
18/04/2023	6	3	SO298-40150	280	46.540	0.99324593	4.590	211.70
18/04/2023	6	3	SO298-40150	286	46.710	0.99324593	4.580	212.01
19/04/2023	7	2	SO298-20131	15	46.588	0.99206349	3.050	140.49
19/04/2023	7	2	SO298-20131	28	52.044	0.99206349	2.760	141.97
19/04/2023	7	2	SO298-20132	36	52.191	0.99206349	2.530	130.46
19/04/2023	7	2	SO298-20132	39	52.482	0.99206349	2.490	129.11
19/04/2023	7	2	SO298-20136	64	49.629	0.99206349	2.280	111.75
19/04/2023	7	2	SO298-20136	74	50.324	0.99206349	2.150	106.82
19/04/2023	7	2	SO298-20138	77	49.411	0.99206349	1.850	90.18
19/04/2023	7	2	SO298-20138	81	50.068	0.99206349	1.670	82.44
19/04/2023	7	2	SO298-20145	88	49.620	0.99206349	2.150	105.33
19/04/2023	7	2	SO298-20145	98	49.624	0.99206349	2.130	104.35
19/04/2023	7	3	SO298-40151	92	50.214	0.99206349	2.870	142.46
19/04/2023	7	3	SO298-40151	184	49.789	0.99206349	2.820	138.78
19/04/2023	7	3	SO298-40154	196	49.979	0.99206349	2.870	141.79
19/04/2023	7	3	SO298-40154	237	46.660	0.99206349	3.080	142.10
19/04/2023	7	3	SO298-40161	238	47.770	0.99206349	2.240	105.67
19/04/2023	7	3	SO298-40161	243	46.540	0.99206349	2.340	107.56

19/04/2023	7	3	SO298-40165	252	47.950	0.99206349	1.830	86.56
19/04/2023	7	3	SO298-40165	264	46.800	0.99206349	1.830	84.49
19/04/2023	7	3	SO298-40172	265	47.040	0.99206349	0.370	16.79
19/04/2023	7	3	SO298-40172	268	47.000	0.99206349	0.350	15.84
21/04/2023	8	2	SO298-20155	7	50.270	0.99206349	2.740	136.13
21/04/2023	8	2	SO298-20155	23	50.280	0.99206349	2.740	136.16
21/04/2023	8	2	SO298-20165	27	50.631	0.99206349	0.990	49.21
21/04/2023	8	2	SO298-20165	31	46.772	0.99206349	1.080	49.63
21/04/2023	8	2	SO298-20166	33	52.175	0.99206349	0.570	28.97
21/04/2023	8	2	SO298-20166	34	46.337	0.99206349	0.620	28.03
21/04/2023	8	2	SO298-20167	37	49.538	0.99206349	0.210	9.81
21/04/2023	8	2	SO298-20167	73	49.516	0.99206349	0.210	9.81
21/04/2023	8	2	SO298-20176	99	49.758	0.99206349	3.940	193.98
21/04/2023	8	2	SO298-20176	185	50.613	0.99206349	3.860	193.30
21/04/2023	8	3	SO298-40195	195	50.044	0.99206349	2.750	136.02
21/04/2023	8	3	SO298-40195	198	49.969	0.99206349	2.750	135.81
21/04/2023	8	3	SO298-40197	199	49.739	0.99206349	2.770	136.18
21/04/2023	8	3	SO298-40197	200	50.104	0.99206349	2.750	136.18
21/04/2023	8	3	SO298-40202	241	46.990	0.99206349	2.160	100.21
21/04/2023	8	3	SO298-40202	246	47.850	0.99206349	2.110	99.67
21/04/2023	8	3	SO298-40209	250	47.290	0.99206349	0.340	15.47
21/04/2023	8	3	SO298-40209	257	47.000	0.99206349	0.350	15.84
21/04/2023	8	3	SO298-40211	269	47.130	0.99206349	2.330	108.46
21/04/2023	8	3	SO298-40211	274	46.620	0.99206349	2.360	108.67
22/04/2023	9	1	SO298-20178	15	46.588	0.99166997	2.960	136.28
22/04/2023	9	1	SO298-20178	28	52.044	0.99166997	2.670	137.27
22/04/2023	9	1	SO298-20184	36	52.191	0.99166997	1.980	101.94
22/04/2023	9	1	SO298-20184	39	52.482	0.99166997	1.970	101.99
22/04/2023	9	1	SO298-20192	64	49.629	0.99166997	0.170	7.86
22/04/2023	9	1	SO298-20192	74	50.324	0.99166997	0.170	7.97
22/04/2023	9	1	SO298-20196	77	49.411	0.99166997	1.760	85.73
22/04/2023	9	1	SO298-20196	81	50.068	0.99166997	1.760	86.87
22/04/2023	9	1	SO298-20201	88	49.620	0.99166997	4.150	203.70
22/04/2023	9	1	SO298-20201	92	50.214	0.99166997	4.110	204.15
22/04/2023	9	2	SO298-40217	98	49.624	0.99166997	2.800	137.28
22/04/2023	9	2	SO298-40217	184	49.789	0.99166997	2.780	136.75
22/04/2023	9	2	SO298-40224	196	49.979	0.99166997	1.820	89.69
22/04/2023	9	2	SO298-40224	237	46.660	0.99166997	1.970	90.68
22/04/2023	9	2	SO298-40225	238	47.770	0.99166997	1.600	75.31
22/04/2023	9	2	SO298-40225	243	46.540	0.99166997	1.630	74.75
22/04/2023	9	2	SO298-40228	252	47.950	0.99166997	0.160	7.12
22/04/2023	9	2	SO298-40228	264	46.800	0.99166997	0.160	6.95
22/04/2023	9	2	SO298-40238	265	47.040	0.99166997	4.410	205.24

22/04/2023	9	2	SO298-40238	268	47.000	0.99166997	4.410	205.06
23/04/2023	10	2	SO298-20202	15	46.588	0.99206349	2.980	137.25
23/04/2023	10	2	SO298-20202	23	50.280	0.99206349	2.770	137.66
23/04/2023	10	2	SO298-20208	27	50.631	0.99206349	2.100	104.96
23/04/2023	10	2	SO298-20208	28	52.044	0.99206349	2.040	104.79
23/04/2023	10	2	SO298-20216	31	46.772	0.99206349	0.210	9.27
23/04/2023	10	2	SO298-20216	33	52.175	0.99206349	0.190	9.30
23/04/2023	10	2	SO298-20219	34	46.337	0.99206349	2.300	105.25
23/04/2023	10	2	SO298-20219	37	49.538	0.99206349	2.150	105.16
23/04/2023	10	2	SO298-20225	39	52.482	0.99206349	3.950	205.12
23/04/2023	10	2	SO298-20225	64	49.629	0.99206349	4.310	211.70
23/04/2023	10	3	SO298-40239	73	49.516	0.99206349	2.820	138.02
23/04/2023	10	3	SO298-40239	81	50.068	0.99206349	2.800	138.57
23/04/2023	10	3	SO298-40248	92	50.214	0.99206349	1.570	77.70
23/04/2023	10	3	SO298-40248	98	49.624	0.99206349	1.580	77.28
23/04/2023	10	3	SO298-40252	99	49.758	0.99206349	0.180	8.38
23/04/2023	10	3	SO298-40252	199	49.739	0.99206349	0.170	7.88
23/04/2023	10	3	SO298-40256	200	50.104	0.99206349	2.290	113.32
23/04/2023	10	3	SO298-40256	257	47.000	0.99206349	2.440	113.29
23/04/2023	10	3	SO298-40260	269	47.130	0.99206349	4.400	205.24
23/04/2023	10	3	SO298-40260	274	46.620	0.99206349	4.450	205.34
24/04/2023	11	1	SO298-40261	7	50.270	0.99206349	0.180	8.46
24/04/2023	11	1	SO298-40261	36	52.191	0.99206349	0.180	8.79
24/04/2023	11	1	SO298-40276	74	50.324	0.99206349	2.480	123.30
24/04/2023	11	1	SO298-40276	77	49.411	0.99206349	2.510	122.53
24/04/2023	11	1	SO298-40282	88	49.620	0.99206349	4.170	204.76
24/04/2023	11	1	SO298-40282	184	49.789	0.99206349	4.130	203.49
24/04/2023	11	2	SO298-20226	237	46.660	0.99206349	3.260	150.43
24/04/2023	11	2	SO298-20226	238	47.770	0.99206349	3.150	148.79
24/04/2023	11	2	SO298-20231	241	46.990	0.99206349	3.740	173.87
24/04/2023	11	2	SO298-20231	243	46.540	0.99206349	2.750	126.49
24/04/2023	11	2	SO298-20240	246	47.850	0.99206349	0.160	7.11
24/04/2023	11	2	SO298-20240	250	47.290	0.99206349	0.160	7.02
24/04/2023	11	2	SO298-20242	252	47.950	0.99206349	2.080	98.45
24/04/2023	11	2	SO298-20242	264	46.800	0.99206349	2.130	98.41
24/04/2023	11	2	SO298-20249	265	47.040	0.99206349	4.360	202.99
24/04/2023	11	2	SO298-20249	268	47.000	0.99206349	4.370	203.28
24/04/2023	11	3	SO298-40283	185	50.613	0.99206349	3.000	150.12
24/04/2023	11	3	SO298-40283	195	50.044	0.99206349	3.020	149.42
24/04/2023	11	3	SO298-40297	196	49.979	0.99206349	1.860	91.71
24/04/2023	11	3	SO298-40297	198	49.969	0.99206349	1.850	91.20
24/04/2023	11	3	SO298-40298	73	49.516	0.99206349	1.500	73.18
24/04/2023	11	3	SO298-40298	64	49.629	0.99206349	1.510	73.84
24/04/2023	11	3	SO298-40302	269	47.130	0.99206349	0.990	45.81
24/04/2023	11	3	SO298-40302	274	46.620	0.99206349	1.010	46.24
25/04/2023	12	2	SO298-20250	15	46.588	0.99166997	3.420	157.53

25/04/2023	12	2	SO298-20250	23	50.280	0.99166997	3.180	158.04
25/04/2023	12	2	SO298-20256	27	50.631	0.99166997	2.280	113.96
25/04/2023	12	2	SO298-20256	28	52.044	0.99166997	2.210	113.53
25/04/2023	12	2	SO298-20264	31	46.772	0.99166997	0.160	6.94
25/04/2023	12	2	SO298-20264	33	52.175	0.99166997	0.150	7.23
25/04/2023	12	2	SO298-20268	34	46.337	0.99166997	2.610	119.46
25/04/2023	12	2	SO298-20268	37	49.538	0.99166997	2.440	119.36
25/04/2023	12	2	SO298-20273	39	52.482	0.99166997	3.950	205.04
25/04/2023	12	2	SO298-20273	81	50.068	0.99166997	4.130	204.55
25/04/2023	12	3	SO298-40305	52	50.479	0.99166997	3.190	159.17
25/04/2023	12	3	SO298-40305	84	50.169	0.99166997	3.210	159.19
25/04/2023	12	3	SO298-40311	200	50.104	0.99166997	2.270	112.28
25/04/2023	12	3	SO298-40311	251	46.900	0.99166997	2.440	113.00
25/04/2023	12	3	SO298-40317	99	49.758	0.99166997	0.180	8.37
25/04/2023	12	3	SO298-40317	199	49.739	0.99166997	0.160	7.38
25/04/2023	12	3	SO298-40322	92	50.214	0.99166997	2.500	123.98
25/04/2023	12	3	SO298-40322	98	49.624	0.99166997	2.520	123.50
25/04/2023	12	3	SO298-40326	254		0.99166997	4.520	#DIV/0!
25/04/2023	12	3	SO298-40326	257	47.000	0.99166997	4.450	206.93
26/04/2023	13	1	SO298-20274	7	50.270	0.99166997	3.200	159.01
26/04/2023	13	1	SO298-20274	36	52.191	0.99166997	3.090	159.39
26/04/2023	13	1	SO298-20276	64	49.629	0.99166997	2.870	140.74
26/04/2023	13	1	SO298-20276	73	49.516	0.99166997	2.880	140.91
26/04/2023	13	1	SO298-20288	77	49.411	0.99166997	3.710	181.28
26/04/2023	13	1	SO298-20288	88	49.620	0.99166997	3.710	182.05
26/04/2023	13	1	SO298-20290	184	49.789	0.99166997	2.030	99.72
26/04/2023	13	1	SO298-20290	185	50.613	0.99166997	1.990	99.36
26/04/2023	13	1	SO298-20296	195	50.044	0.99166997	2.460	121.57
26/04/2023	13	1	SO298-20296	196	49.979	0.99166997	2.500	123.40
26/04/2023	13	2	SO298-40327	198	49.969	0.99166997	3.230	159.54
26/04/2023	13	2	SO298-40327	237	46.660	0.99166997	3.480	160.55
26/04/2023	13	2	SO298-40330	283	47.150	0.99166997	2.660	123.89
26/04/2023	13	2	SO298-40330	241	46.990	0.99166997	2.710	125.80
26/04/2023	13	2	SO298-40332	264	46.800	0.99166997	2.410	111.37
26/04/2023	13	2	SO298-40332	265	47.040	0.99166997	2.370	110.07
26/04/2023	13	2	SO298-40335	243	46.540	0.99166997	1.810	83.06
26/04/2023	13	2	SO298-40335	246	47.850	0.99166997	1.790	84.45
26/04/2023	13	2	SO298-40340	250	47.290	0.99166997	0.220	9.83
26/04/2023	13	2	SO298-40340	252	47.950	0.99166997	0.210	9.50
27/04/2023	14	2	SO298-20298	15	46.588	0.99206349	3.490	160.83
27/04/2023	14	2	SO298-20298	23	50.280	0.99206349	3.230	160.60
27/04/2023	14	2	SO298-20299	27	50.631	0.99206349	3.220	161.22
27/04/2023	14	2	SO298-20299	28	52.044	0.99206349	3.130	161.07
27/04/2023	14	2	SO298-20312	31	46.772	0.99206349	0.170	7.41
27/04/2023	14	2	SO298-20312	33	52.175	0.99206349	0.150	7.23

27/04/2023	14	2	SO298-20316	34	46.337	0.99206349	2.570	117.67
27/04/2023	14	2	SO298-20316	37	49.538	0.99206349	2.400	117.44
27/04/2023	14	2	SO298-20320	39	52.482	0.99206349	3.690	191.59
27/04/2023	14	2	SO298-20320	52	50.479	0.99206349	3.810	190.28
27/04/2023	14	3	SO298-40349	81	50.068	0.99206349	3.300	163.40
27/04/2023	14	3	SO298-40349	84	50.169	0.99206349	3.270	162.24
27/04/2023	14	3	SO298-40356	92	50.214	0.99206349	2.110	104.60
27/04/2023	14	3	SO298-40356	98	49.624	0.99206349	2.150	105.34
27/04/2023	14	3	SO298-40363	200	50.104	0.99206349	0.180	8.44
27/04/2023	14	3	SO298-40363	251	46.900	0.99206349	0.190	8.36
27/04/2023	14	3	SO298-40366	257	47.000	0.99206349	2.780	129.14
27/04/2023	14	3	SO298-40366	268	47.000	0.99206349	2.800	130.08
28/04/2023	15	1	SO298-40393	7	50.270	0.99166997	3.270	162.50
28/04/2023	15	1	SO298-40393	36	52.191	0.99166997	3.150	162.50
28/04/2023	15	1	SO298-40403	64	49.629	0.99166997	2.450	120.07
28/04/2023	15	1	SO298-40403	73	49.516	0.99166997	2.430	118.82
28/04/2023	15	1	SO298-40407	77	49.411	0.99166997	1.910	93.08
28/04/2023	15	1	SO298-40407	88	49.620	0.99166997	1.910	93.48
28/04/2023	15	1	SO298-40413	184	49.789	0.99166997	1.070	52.32
28/04/2023	15	1	SO298-40413	185	50.613	0.99166997	1.060	52.69
28/04/2023	15	2	SO298-20322	195	50.044	0.99166997	3.270	161.77
28/04/2023	15	2	SO298-20322	196	49.979	0.99166997	3.200	158.09
28/04/2023	15	2	SO298-20328	198	49.969	0.99166997	2.310	113.96
28/04/2023	15	2	SO298-20328	237	46.660	0.99166997	2.490	114.74
28/04/2023	15	2	SO298-20336	238	47.770	0.99166997	0.170	7.56
28/04/2023	15	2	SO298-20336	241	46.990	0.99166997	0.160	6.98
28/04/2023	15	2	SO298-20342	243	46.540	0.99166997	3.050	140.29
28/04/2023	15	2	SO298-20342	246	47.850	0.99166997	2.980	140.92
28/04/2023	15	2	SO298-20344	250	47.290	0.99166997	3.870	181.00
28/04/2023	15	2	SO298-20344	252	47.950	0.99166997	3.830	181.63
29/04/2023	16	2	SO298-20346	15	46.588	0.99324593	3.590	165.65
29/04/2023	16	2	SO298-20346	23	50.280	0.99324593	3.280	163.29
29/04/2023	16	2	SO298-20352	27	50.631	0.99324593	2.250	112.63
29/04/2023	16	2	SO298-20352	28	52.044	0.99324593	2.200	113.19
29/04/2023	16	2	SO298-20360	31	46.772	0.99324593	2.940	136.10
29/04/2023	16	2	SO298-20360	33	52.175	0.99324593	2.620	135.24
29/04/2023	16	2	SO298-20362	34	46.337	0.99324593	2.470	113.21
29/04/2023	16	2	SO298-20362	37	49.538	0.99324593	2.330	114.14
29/04/2023	16	2	SO298-20368	39	52.482	0.99324593	3.560	185.04
29/04/2023	16	2	SO298-20368	52	50.479	0.99324593	3.730	186.50
29/04/2023	16	3	SO298-40416	81	50.068	0.99324593	3.290	163.10
29/04/2023	16	3	SO298-40416	84	50.169	0.99324593	3.290	163.43
29/04/2023	16	3	SO298-40421	92	50.214	0.99324593	2.320	115.20
29/04/2023	16	3	SO298-40421	98	49.624	0.99324593	2.330	114.34
29/04/2023	16	3	SO298-40424	99	49.758	0.99324593	1.740	85.49
29/04/2023	16	3	SO298-40424	199	49.739	0.99324593	1.730	84.96

29/04/2023	16	3	SO298-40431	200	50.104	0.99324593	2.330	115.44
29/04/2023	16	3	SO298-40431	251	46.900	0.99324593	2.470	114.58
29/04/2023	16	3	SO298-40435	257	47.000	0.99324593	3.970	184.85
29/04/2023	16	3	SO298-40435	268	47.000	0.99324593	3.990	185.78
1/05/2023	17	1	SO298-20370	7	50.270	0.99403579	3.340	166.39
1/05/2023	17	1	SO298-20370	36	52.191	0.99403579	3.190	164.96
1/05/2023	17	1	SO298-20376	64	49.629	0.99403579	2.430	119.37
1/05/2023	17	1	SO298-20376	77	49.411	0.99403579	2.440	119.34
1/05/2023	17	1	SO298-20385	73	49.516	0.99403579	0.200	9.34
1/05/2023	17	1	SO298-20385	88	49.620	0.99403579	0.200	9.36
1/05/2023	17	1	SO298-20388	184	49.789	0.99403579	1.890	93.03
1/05/2023	17	1	SO298-20388	185	50.613	0.99403579	1.880	94.07
1/05/2023	17	1	SO298-20392	195	50.044	0.99403579	4.030	199.96
1/05/2023	17	1	SO298-20392	196	49.979	0.99403579	4.040	200.20
1/05/2023	17	2	SO298-40437	198	49.969	0.99403579	3.310	163.90
1/05/2023	17	2	SO298-40437	237	46.660	0.99403579	3.590	166.03
1/05/2023	17	2	SO298-40441	238	47.770	0.99403579	2.540	120.12
1/05/2023	17	2	SO298-40444	241	46.990	0.99403579	2.080	96.68
1/05/2023	17	2	SO298-40447	243	46.540	0.99403579	1.730	79.56
1/05/2023	17	2	SO298-40450	246	47.850	0.99403579	0.240	10.93
1/05/2023	17	2	SO298-40453	250	47.290	0.99403579	2.710	126.91
1/05/2023	17	2	SO298-40453	252	47.950	0.99403579	2.680	127.25
1/05/2023	17	2	SO298-40458	264	46.800	0.99403579	4.390	203.75
1/05/2023	17	2	SO298-40458	265	47.040	0.99403579	4.370	203.86
2/05/2023	18	2	SO298-20394	15	46.588	0.99285147	3.590	165.58
2/05/2023	18	2	SO298-20394	23	50.280	0.99285147	3.300	164.22
2/05/2023	18	2	SO298-20401	27	50.631	0.99285147	2.260	113.09
2/05/2023	18	2	SO298-20401	28	52.044	0.99285147	2.210	113.66
2/05/2023	18	2	SO298-20409	31	46.772	0.99285147	0.280	12.52
2/05/2023	18	2	SO298-20409	33	52.175	0.99285147	0.250	12.42
2/05/2023	18	2	SO298-20411	34	46.337	0.99285147	2.360	108.10
2/05/2023	18	2	SO298-20411	37	49.538	0.99285147	2.230	109.17
2/05/2023	18	2	SO298-20416	39	52.482	0.99285147	3.770	195.91
2/05/2023	18	2	SO298-20416	52	50.479	0.99285147	3.930	196.45
2/05/2023	18	3	SO298-40481	81	50.068	0.99285147	3.330	165.02
2/05/2023	18	3	SO298-40483	84	50.169	0.99285147	3.310	164.36
2/05/2023	18	3	SO298-40483	92	50.214	0.99285147	3.320	165.01
2/05/2023	18	3	SO298-40483	98	49.624	0.99285147	3.330	163.56
2/05/2023	18	3	SO298-40484	99	49.758	0.99285147	3.300	162.52
2/05/2023	18	3	SO298-40484	199	49.739	0.99285147	3.300	162.46
2/05/2023	18	3	SO298-40484	200	50.104	0.99285147	3.280	162.66
2/05/2023	18	3	SO298-40486	251	46.900	0.99285147	3.050	141.54
2/05/2023	18	3	SO298-40493	257	47.000	0.99285147	2.540	118.05
2/05/2023	18	3	SO298-40499	268	47.000	0.99285147	1.630	75.58
3/05/2023	19	2	SO298-20418	7	50.270	0.99245732	3.280	163.13

3/05/2023	19	2	SO298-20425	15	46.588	0.99245732	2.440	112.34
3/05/2023	19	2	SO298-20425	23	50.280	0.99245732	2.230	110.77
3/05/2023	19	2	SO298-20425	36	52.191	0.99245732	2.140	110.31
3/05/2023	19	2	SO298-20432	64	49.629	0.99245732	0.680	32.99
3/05/2023	19	2	SO298-20433	77	49.411	0.99245732	0.490	23.52
3/05/2023	19	2	SO298-20433	73	49.516	0.99245732	0.500	24.07
3/05/2023	19	2	SO298-20433	88	49.620	0.99245732	0.480	23.13
3/05/2023	19	2	SO298-20435	184	49.789	0.99245732	2.490	122.53
3/05/2023	19	2	SO298-20440	185	50.613	0.99245732	3.820	191.37
3/05/2023	19	3	SO298-40503	195	50.044	0.99245732	3.310	163.89
3/05/2023	19	3	SO298-40504	196	49.979	0.99245732	3.290	162.68
3/05/2023	19	3	SO298-40504	198	49.969	0.99245732	3.280	162.15
3/05/2023	19	3	SO298-40504	237	46.660	0.99245732	3.550	163.92
3/05/2023	19	3	SO298-40508	241	46.990	0.99245732	2.690	124.97
3/05/2023	19	3	SO298-40509	246	47.850	0.99245732	2.540	120.13
3/05/2023	19	3	SO298-40517	250	47.290	0.99245732	0.570	26.27
3/05/2023	19	3	SO298-40517	252	47.950	0.99245732	0.560	26.16
3/05/2023	19	3	SO298-40517	264	46.800	0.99245732	0.560	25.53
3/05/2023	19	3	SO298-40524	265	47.040	0.99245732	4.250	197.93
4/05/2023	20	1	SO298-20442	27	50.631	0.99206349	3.240	162.22
4/05/2023	20	1	SO298-20448	28	52.044	0.99206349	2.290	117.70
4/05/2023	20	1	SO298-20448	31	46.772	0.99206349	2.560	118.31
4/05/2023	20	1	SO298-20448	33	52.175	0.99206349	2.290	118.00
4/05/2023	20	1	SO298-20455	34	46.337	0.99206349	0.620	28.03
4/05/2023	20	1	SO298-20456	37	49.538	0.99206349	0.660	31.93
4/05/2023	20	1	SO298-20456	39	52.482	0.99206349	0.630	32.27
4/05/2023	20	1	SO298-20456	52	50.479	0.99206349	0.670	33.04
4/05/2023	20	1	SO298-20459	81	50.068	0.99206349	2.590	128.14
4/05/2023	20	1	SO298-20464	84	50.169	0.99206349	3.830	190.11
4/05/2023	20	2	SO298-40525	92	50.214	0.99206349	3.270	162.38
4/05/2023	20	2	SO298-40531	98	49.624	0.99206349	1.910	93.52
4/05/2023	20	2	SO298-40531	99	49.758	0.99206349	1.910	93.78
4/05/2023	20	2	SO298-40531	199	49.739	0.99206349	1.900	93.25
4/05/2023	20	2	SO298-40532	200	50.104	0.99206349	1.650	81.50
4/05/2023	20	2	SO298-40535	238	47.770	0.99206349	0.610	28.42
4/05/2023	20	2	SO298-40535	243	46.540	0.99206349	0.620	28.15
4/05/2023	20	2	SO298-40535	251	46.900	0.99206349	0.620	28.37
4/05/2023	20	2	SO298-40539	257	47.000	0.99206349	2.810	130.54
4/05/2023	20	2	SO298-40546	268	47.000	0.99206349	4.330	201.41
5/05/2023	21	2	SO298-20466	195	50.044	0.99245732	3.370	166.87
5/05/2023	21	2	SO298-20472	196	49.979	0.99245732	2.330	115.06
5/05/2023	21	2	SO298-20472	198	49.969	0.99245732	2.340	115.53
5/05/2023	21	2	SO298-20472	237	46.660	0.99245732	2.520	116.22
5/05/2023	21	2	SO298-20480	241	46.990	0.99245732	0.550	25.17
5/05/2023	21	2	SO298-20480	246	47.850	0.99245732	0.550	25.63
5/05/2023	21	2	SO298-20480	250	47.290	0.99245732	0.540	24.86

5/05/2023	21	2	SO298-20481	252	47.950	0.99245732	1.320	62.33
5/05/2023	21	2	SO298-20485	264	46.800	0.99245732	3.230	149.55
5/05/2023	21	2	SO298-20488	268	47.000	0.99245732	4.110	191.23
7/05/2023	22	2	SO298-20490	7	50.270	0.99403579	3.360	167.39
7/05/2023	22	2	SO298-20494	15	46.588	0.99403579	2.710	125.02
7/05/2023	22	2	SO298-20496	23	50.280	0.99403579	2.240	111.44
7/05/2023	22	2	SO298-20496	36	52.191	0.99403579	2.160	111.53
7/05/2023	22	2	SO298-20496	64	49.629	0.99403579	2.260	110.99
7/05/2023	22	2	SO298-20502	73	49.516	0.99403579	0.610	29.52
7/05/2023	22	2	SO298-20502	77	49.411	0.99403579	0.610	29.46
7/05/2023	22	2	SO298-20502	88	49.620	0.99403579	0.600	29.09
7/05/2023	22	2	SO298-20509	184	49.789	0.99403579	2.970	146.48
7/05/2023	22	2	SO298-20512	185	50.613	0.99403579	3.830	192.18
7/05/2023	22	3	SO298-40591	27	50.631	0.99403579	3.360	168.59
7/05/2023	22	3	SO298-40592	28	52.044	0.99403579	2.790	143.80
7/05/2023	22	3	SO298-40597	31	46.772	0.99403579	4.280	198.51
7/05/2023	22	3	SO298-40597	33	52.175	0.99403579		-0.53
7/05/2023	22	3	SO298-40597	34	46.337	0.99403579		-0.47
7/05/2023	22	3	SO298-40600	37	49.538	0.99403579	0.610	29.53
7/05/2023	22	3	SO298-40600	39	52.482	0.99403579	0.590	30.24
7/05/2023	22	3	SO298-40600	52	50.479	0.99403579	0.600	29.59
7/05/2023	22	3	SO298-40601	81	50.068	0.99403579	0.970	47.77
7/05/2023	22	3	SO298-40612	84	50.169	0.99403579	3.980	197.97
8/05/2023	23	1	SO298-20514	92	50.214	0.99364070	3.370	167.63
8/05/2023	23	1	SO298-20519	98	49.624	0.99364070	2.560	125.72
8/05/2023	23	1	SO298-20519	99	49.758	0.99364070	2.550	125.57
8/05/2023	23	1	SO298-20519	195	50.044	0.99364070	2.530	125.30
8/05/2023	23	1	SO298-20523	196	49.979	0.99364070	1.720	84.91
8/05/2023	23	1	SO298-20527	198	49.969	0.99364070	0.660	32.26
8/05/2023	23	1	SO298-20527	199	49.739	0.99364070	0.660	32.11
8/05/2023	23	1	SO298-20527	200	50.104	0.99364070	0.660	32.35
8/05/2023	23	1	SO298-20531	237	46.660	0.99364070	2.880	133.05
8/05/2023	23	1	SO298-20536	238	47.770	0.99364070	3.930	186.05
8/05/2023	23	2	SO298-40613	241	46.990	0.99364070	3.610	168.07
8/05/2023	23	2	SO298-40614	243	46.540	0.99364070	3.600	166.00
8/05/2023	23	2	SO298-40617	246	47.850	0.99364070	2.540	120.28
8/05/2023	23	2	SO298-40621	250	47.290	0.99364070	1.760	82.22
8/05/2023	23	2	SO298-40621	251	46.900	0.99364070	1.760	81.54
8/05/2023	23	2	SO298-40621	252	47.950	0.99364070	1.740	82.41
8/05/2023	23	2	SO298-40624	257	47.000	0.99364070	0.810	37.35
8/05/2023	23	2	SO298-40624	264	46.800	0.99364070	0.830	38.12
8/05/2023	23	2	SO298-40624	265	47.040	0.99364070	0.800	36.91
8/05/2023	23	2	SO298-40634	268	47.000	0.99364070	4.150	193.33
9/05/2023	24	2	SO298-20538	7	50.270	0.99324593	3.610	179.74
9/05/2023	24	2	SO298-20546	15	46.588	0.99324593	2.150	99.01

9/05/2023	24	2	SO298-20546	23	50.280	0.99324593	1.990	98.87
9/05/2023	24	2	SO298-20546	27	50.631	0.99324593	1.980	99.05
9/05/2023	24	2	SO298-20548	28	52.044	0.99324593	1.670	85.79
9/05/2023	24	2	SO298-20551	31	46.772	0.99324593	1.050	48.30
9/05/2023	24	2	SO298-20551	33	52.175	0.99324593	0.640	32.63
9/05/2023	24	2	SO298-20551	34	46.337	0.99324593	0.670	30.36
9/05/2023	24	2	SO298-20555	36	52.191	0.99324593	2.500	129.06
9/05/2023	24	2	SO298-20560	37	49.538	0.99324593	3.970	194.83
9/05/2023	24	3	SO298-40635	39	52.482	0.99324593	3.470	180.35
9/05/2023	24	3	SO298-40637	52	50.479	0.99324593	2.920	145.89
9/05/2023	24	3	SO298-40644	64	49.629	0.99324593	1.750	85.76
9/05/2023	24	3	SO298-40644	73	49.516	0.99324593	1.760	86.05
9/05/2023	24	3	SO298-40644	77	49.411	0.99324593	1.750	85.38
9/05/2023	24	3	SO298-40647	81	50.068	0.99324593	0.680	33.30
9/05/2023	24	3	SO298-40647	84	50.169	0.99324593	0.680	33.37
9/05/2023	24	3	SO298-40647	88	49.620	0.99324593	0.690	33.50
9/05/2023	24	3	SO298-40650	184	49.789	0.99324593	2.780	136.97
9/05/2023	24	3	SO298-40656	185	50.613	0.99324593	4.010	201.07
10/05/2023	25	2	SO298-20562	241	46.990	0.99324593	3.910	182.01
10/05/2023	25	2	SO298-20570	243	46.540	0.99324593	2.200	101.22
10/05/2023	25	2	SO298-20574	246	47.850	0.99324593	1.430	67.47
10/05/2023	25	2	SO298-20574	250	47.290	0.99324593	1.440	67.15
10/05/2023	25	2	SO298-20574	251	46.900	0.99324593	1.450	67.07
10/05/2023	25	2	SO298-20575	252	47.950	0.99324593	0.680	31.90
10/05/2023	25	2	SO298-20575	257	47.000	0.99324593	0.700	32.20
10/05/2023	25	2	SO298-20575	264	46.800	0.99324593	0.710	32.53
10/05/2023	25	2	SO298-20579	265	47.040	0.99324593	2.810	130.81
10/05/2023	25	2	SO298-20581	268	47.000	0.99324593	3.430	159.64
12/05/2023	26	2	SO298-20586	7	50.270	0.99443119	3.100	154.46
12/05/2023	26	2	SO298-20589	15	46.588	0.99443119	2.730	126.00
12/05/2023	26	2	SO298-20591	23	50.280	0.99443119	2.220	110.49
12/05/2023	26	2	SO298-20591	27	50.631	0.99443119	2.200	110.25
12/05/2023	26	2	SO298-20591	28	52.044	0.99443119	2.150	110.74
12/05/2023	26	2	SO298-20599	31	46.772	0.99443119	0.640	29.29
12/05/2023	26	2	SO298-20599	33	52.175	0.99443119	0.610	31.12
12/05/2023	26	2	SO298-20599	34	46.337	0.99443119	0.670	30.40
12/05/2023	26	2	SO298-20604	36	52.191	0.99443119	2.490	128.70
12/05/2023	26	2	SO298-20608	37	49.538	0.99443119	3.900	191.62
12/05/2023	26	3	SO298-40701	39	52.482	0.99443119	3.030	157.60
12/05/2023	26	3	SO298-40706	52	50.479	0.99443119	2.220	110.92
12/05/2023	26	3	SO298-40706	64	49.629	0.99443119	2.250	110.54
12/05/2023	26	3	SO298-40706	73	49.516	0.99443119	2.250	110.29
12/05/2023	26	3	SO298-40709	77	49.411	0.99443119	1.760	85.97
12/05/2023	26	3	SO298-40711	81	50.068	0.99443119	1.130	55.75
12/05/2023	26	3	SO298-40712	84	50.169	0.99443119	0.650	31.92
12/05/2023	26	3	SO298-40712	88	49.620	0.99443119	0.680	33.05

12/05/2023	26	3	SO298-40712	184	49.789	0.99443119	0.690	33.66
12/05/2023	26	3	SO298-40722	185	50.613	0.99443119	3.940	197.79
13/05/2023	27	1	SO298-40724	52	50.479	0.99285147	3.620	180.91
13/05/2023	27	1	SO298-40727	92	50.214	0.99285147	2.670	132.60
13/05/2023	27	1	SO298-40727	98	49.624	0.99285147	2.690	132.03
13/05/2023	27	1	SO298-40727	99	49.758	0.99285147	2.670	131.40
13/05/2023	27	1	SO298-40732	195	50.044	0.99285147	1.810	89.42
13/05/2023	27	1	SO298-40736	196	49.979	0.99285147	0.740	36.21
13/05/2023	27	1	SO298-40736	198	49.969	0.99285147	0.740	36.20
13/05/2023	27	1	SO298-40736	199	49.739	0.99285147	0.750	36.53
13/05/2023	27	1	SO298-40739	200	50.104	0.99285147	2.660	131.81
13/05/2023	27	1	SO298-40744	237	46.660	0.99285147	4.360	201.51
13/05/2023	27	2	SO298-20610	238	47.770	0.99285147	4.200	198.71
13/05/2023	27	2	SO298-20613	241	46.990	0.99285147	3.300	153.48
13/05/2023	27	2	SO298-20618	243	46.540	0.99285147	2.340	107.65
13/05/2023	27	2	SO298-20618	246	47.850	0.99285147	2.250	106.40
13/05/2023	27	2	SO298-20618	250	47.290	0.99285147	2.280	106.57
13/05/2023	27	2	SO298-20623	252	47.950	0.99285147	1.000	47.12
13/05/2023	27	2	SO298-20623	257	47.000	0.99285147	1.010	46.65
13/05/2023	27	2	SO298-20623	264	46.800	0.99285147	1.020	46.92
13/05/2023	27	2	SO298-20626	265	47.040	0.99285147	2.220	103.20
13/05/2023	27	2	SO298-20632	268	47.000	0.99285147	4.190	195.04
14/05/2023	28	2	SO298-20634	7	50.270	0.99403579	3.920	195.37
14/05/2023	28	2	SO298-20637	15	46.588	0.99403579	3.350	154.66
14/05/2023	28	2	SO298-20644	23	50.280	0.99403579	1.780	88.45
14/05/2023	28	2	SO298-20644	27	50.631	0.99403579	1.750	87.56
14/05/2023	28	2	SO298-20644	28	52.044	0.99403579	1.710	87.93
14/05/2023	28	2	SO298-20647	31	46.772	0.99403579	0.830	38.11
14/05/2023	28	2	SO298-20647	33	52.175	0.99403579	0.750	38.36
14/05/2023	28	2	SO298-20647	34	46.337	0.99403579	0.840	38.22
14/05/2023	28	2	SO298-20649	36	52.191	0.99403579	1.940	100.11
14/05/2023	28	2	SO298-20656	37	49.538	0.99403579	4.090	200.90
15/05/2023	29	2	SO298-20658	52	50.479	0.99352224	3.860	193.07
15/05/2023	29	2	SO298-20663	92	50.214	0.99352224	2.520	125.21
15/05/2023	29	2	SO298-20663	98	49.624	0.99352224	2.550	125.22
15/05/2023	29	2	SO298-20663	99	49.758	0.99352224	2.550	125.55
15/05/2023	29	2	SO298-20668	195	50.044	0.99352224	1.760	87.00
15/05/2023	29	2	SO298-20671	196	49.979	0.99352224	1.190	58.58
15/05/2023	29	2	SO298-20671	198	49.969	0.99352224	1.200	59.06
15/05/2023	29	2	SO298-20671	199	49.739	0.99352224	1.200	58.79
15/05/2023	29	2	SO298-20674	200	50.104	0.99352224	2.740	135.88
15/05/2023	29	2	SO298-20680	237	46.660	0.99352224	4.240	196.08
15/05/2023	29	3	SO298-40790	238	47.770	0.99352224	4.050	191.73
15/05/2023	29	3	SO298-40792	241	46.990	0.99352224	3.210	149.38
15/05/2023	29	3	SO298-40794	243	46.540	0.99352224	2.750	126.68

15/05/2023	29	3	SO298-40798	250	47.290	0.99352224	1.910	89.26
15/05/2023	29	3	SO298-40798	251	46.900	0.99352224	1.910	88.52
15/05/2023	29	3	SO298-40798	252	47.950	0.99352224	1.890	89.55
15/05/2023	29	3	SO298-40802	257	47.000	0.99352224	1.080	49.95
15/05/2023	29	3	SO298-40802	264	46.800	0.99352224	1.090	50.20
15/05/2023	29	3	SO298-40802	265	47.040	0.99352224	1.080	49.99
15/05/2023	29	3	SO298-40809	268	47.000	0.99352224	4.230	197.04
16/05/2023	30	1	SO298-40813	7	50.270	0.99364070	3.920	195.29
16/05/2023	30	1	SO298-40815	15	46.588	0.99364070	3.250	149.97
16/05/2023	30	1	SO298-40815	23	50.280	0.99364070	3.000	149.37
16/05/2023	30	1	SO298-40815	27	50.631	0.99364070	2.990	149.91
16/05/2023	30	1	SO298-40825	28	52.044	0.99364070	1.710	87.90
16/05/2023	30	1	SO298-40832	31	46.772	0.99364070	1.070	49.25
16/05/2023	30	1	SO298-40832	33	52.175	0.99364070	0.950	48.72
16/05/2023	30	1	SO298-40832	34	46.337	0.99364070	1.080	49.25
16/05/2023	30	2	SO298-20682	39	52.482	0.99364070	3.880	201.80
16/05/2023	30	2	SO298-20689	64	49.629	0.99364070	2.340	114.89
16/05/2023	30	2	SO298-20692	73	49.516	0.99364070	1.770	86.58
16/05/2023	30	2	SO298-20692	77	49.411	0.99364070	1.770	86.40
16/05/2023	30	2	SO298-20692	81	50.068	0.99364070	1.770	87.55
16/05/2023	30	2	SO298-20695	84	50.169	0.99364070	1.090	53.82
16/05/2023	30	2	SO298-20699	88	49.620	0.99364070	2.610	128.18
16/05/2023	30	2	SO298-20702	184	49.789	0.99364070	3.690	182.05
16/05/2023	30	2	SO298-20702	185	50.613	0.99364070	3.630	182.04
16/05/2023	30	2	SO298-20702	246	47.850	0.99364070	3.830	181.61
16/05/2023	30	3	SO298-40837	36	52.191	0.99364070	2.240	115.63
16/05/2023	30	3	SO298-40850	37	49.538	0.99364070	4.050	198.85
17/05/2023	31	2	SO298-20706	39	52.482	0.99403579	3.770	196.14
17/05/2023	31	2	SO298-20711	64	49.629	0.99403579	2.560	125.79
17/05/2023	31	2	SO298-20713	73	49.516	0.99403579	2.270	111.23
17/05/2023	31	2	SO298-20713	77	49.411	0.99403579	2.280	111.48
17/05/2023	31	2	SO298-20713	81	50.068	0.99403579	2.260	111.97
17/05/2023	31	2	SO298-20719	84	50.169	0.99403579	1.150	56.84
17/05/2023	31	2	SO298-20719	88	49.620	0.99403579	1.170	57.20
17/05/2023	31	2	SO298-20719	184	49.789	0.99403579	1.170	57.40
17/05/2023	31	2	SO298-20721	185	50.613	0.99403579	2.650	132.81
17/05/2023	31	2	SO298-20728	246	47.850	0.99403579	4.180	198.33
17/05/2023	31	3	SO298-40856	7	50.270	0.99403579	3.930	195.87
17/05/2023	31	3	SO298-40861	15	46.588	0.99403579	2.780	128.27
17/05/2023	31	3	SO298-40861	23	50.280	0.99403579	2.550	126.94
17/05/2023	31	3	SO298-40861	27	50.631	0.99403579	2.520	126.31
17/05/2023	31	3	SO298-40863	28	52.044	0.99403579	2.180	112.25
17/05/2023	31	3	SO298-40868	31	46.772	0.99403579	1.260	58.10
17/05/2023	31	3	SO298-40868	33	52.175	0.99403579	1.120	57.55
17/05/2023	31	3	SO298-40868	34	46.337	0.99403579	1.280	58.48
17/05/2023	31	3	SO298-40871	36	52.191	0.99403579	2.620	135.39

17/05/2023	31	3	SO298-40877	37	49.538	0.99403579	4.090	200.90
18/05/2023	32	1	SO298-20730	52	50.479	0.99601594	3.920	196.57
18/05/2023	32	1	SO298-20735	92	50.214	0.99601594	2.830	141.03
18/05/2023	32	1	SO298-20736	98	49.624	0.99601594	2.710	133.44
18/05/2023	32	1	SO298-20736	99	49.758	0.99601594	2.710	133.80
18/05/2023	32	1	SO298-20736	195	50.044	0.99601594	2.690	133.57
18/05/2023	32	1	SO298-20745	196	49.979	0.99601594	2.620	129.91
18/05/2023	32	1	SO298-20745	198	49.969	0.99601594	2.640	130.88
18/05/2023	32	1	SO298-20745	199	49.739	0.99601594	2.650	130.78
18/05/2023	32	1	SO298-20749	200	50.104	0.99601594	3.270	162.68
18/05/2023	32	1	SO298-20752	237	46.660	0.99601594	4.320	200.29
18/05/2023	32	2	SO298-40878	238	47.770	0.99601594	4.130	196.02
18/05/2023	32	2	SO298-40879	241	46.990	0.99601594	4.190	195.62
18/05/2023	32	2	SO298-40890	243	46.540	0.99601594	1.520	69.98
18/05/2023	32	2	SO298-40890	250	47.290	0.99601594	1.500	70.17
18/05/2023	32	2	SO298-40890	251	46.900	0.99601594	1.520	70.53
18/05/2023	32	2	SO298-40891	252	47.950	0.99601594	1.310	62.08
18/05/2023	32	2	SO298-40891	257	47.000	0.99601594	1.330	61.78
18/05/2023	32	2	SO298-40891	264	46.800	0.99601594	1.340	61.98
18/05/2023	32	2	SO298-40893	265	47.040	0.99601594	2.940	137.27
18/05/2023	32	2	SO298-40898	268	47.000	0.99601594	4.270	199.41
20/05/2023	33	2	SO298-20754	7	50.270	0.99561928	3.950	197.18
20/05/2023	33	2	SO298-20760	15	46.588	0.99561928	2.910	134.50
20/05/2023	33	2	SO298-20763	23	50.280	0.99561928	2.240	111.62
20/05/2023	33	2	SO298-20763	27	50.631	0.99561928	2.220	111.39
20/05/2023	33	2	SO298-20763	28	52.044	0.99561928	2.180	112.43
20/05/2023	33	2	SO298-20768	31	46.772	0.99561928	1.360	62.85
20/05/2023	33	2	SO298-20768	33	52.175	0.99561928	1.220	62.84
20/05/2023	33	2	SO298-20768	34	46.337	0.99561928	1.380	63.19
20/05/2023	33	2	SO298-20772	36	52.191	0.99561928	3.220	166.79
20/05/2023	33	2	SO298-20776	37	49.538	0.99561928	3.990	196.29
20/05/2023	33	3	SO298-40900	39	52.482	0.99561928	3.800	198.02
20/05/2023	33	3	SO298-40901	52	50.479	0.99561928	3.930	197.00
20/05/2023	33	3	SO298-40902	64	49.629	0.99561928	3.980	196.15
20/05/2023	33	3	SO298-40902	77	49.411	0.99561928	3.980	195.29
20/05/2023	33	3	SO298-40902	81	50.068	0.99561928	3.950	196.39
20/05/2023	33	3	SO298-40906	84	50.169	0.99561928	2.580	128.36
20/05/2023	33	3	SO298-40907	88	49.620	0.99561928	2.610	128.43
20/05/2023	33	3	SO298-40907	184	49.789	0.99561928	2.600	128.38
20/05/2023	33	3	SO298-40907	185	50.613	0.99561928	2.550	127.98
20/05/2023	33	3	SO298-40920	246	47.850	0.99561928	4.120	195.79
21/05/2023	34	1	SO298-40922	250	47.290	0.99601594	1.630	76.29
21/05/2023	34	1	SO298-40922	251	46.900	0.99601594	1.640	76.13
21/05/2023	34	1	SO298-40922	257	47.000	0.99601594	1.630	75.83
21/05/2023	34	1	SO298-40939	264	46.800	0.99601594	2.860	132.84

21/05/2023	34	1	SO298-40943	265	47.040	0.99601594	4.320	201.92
21/05/2023	34	2	SO298-20778	196	49.979	0.99601594	3.930	195.13
21/05/2023	34	2	SO298-20781	198	49.969	0.99601594	3.080	152.78
21/05/2023	34	2	SO298-20785	199	49.739	0.99601594	2.440	120.37
21/05/2023	34	2	SO298-20785	200	50.104	0.99601594	2.410	119.76
21/05/2023	34	2	SO298-20785	237	46.660	0.99601594	2.630	121.75
21/05/2023	34	2	SO298-20791	238	47.770	0.99601594	1.720	81.35
21/05/2023	34	2	SO298-20791	241	46.990	0.99601594	1.750	81.43
21/05/2023	34	2	SO298-20791	243	46.540	0.99601594	1.780	82.04
21/05/2023	34	2	SO298-20793	252	47.950	0.99601594	3.000	142.79
21/05/2023	34	2	SO298-20800	268	47.000	0.99601594	4.150	193.79
21/05/2023	34	3	SO298-40947	73	49.516	0.99601594	3.970	195.29
21/05/2023	34	3	SO298-40950	92	50.214	0.99601594	3.040	151.53
21/05/2023	34	3	SO298-40956	98	49.624	0.99601594	2.650	130.47
21/05/2023	34	3	SO298-40956	99	49.758	0.99601594	2.650	130.83
21/05/2023	34	3	SO298-40956	195	50.044	0.99601594	2.630	130.58
22/05/2023	35	2	SO298-20802	7	50.270	0.99641291	3.890	194.34
22/05/2023	35	2	SO298-20808	15	46.588	0.99641291	2.800	129.50
22/05/2023	35	2	SO298-20810	23	50.280	0.99641291	2.340	116.72
22/05/2023	35	2	SO298-20810	27	50.631	0.99641291	2.320	116.53
22/05/2023	35	2	SO298-20810	28	52.044	0.99641291	2.270	117.18
22/05/2023	35	2	SO298-20814	31	46.772	0.99641291	1.760	81.55
22/05/2023	35	2	SO298-20814	33	52.175	0.99641291	1.590	82.13
22/05/2023	35	2	SO298-20814	34	46.337	0.99641291	1.780	81.71
22/05/2023	35	2	SO298-20821	36	52.191	0.99641291	3.480	180.44
22/05/2023	35	2	SO298-20824	37	49.538	0.99641291	4.000	196.94
22/05/2023	35	3	SO298-40968	39	52.482	0.99641291	3.730	194.52
22/05/2023	35	3	SO298-40972	52	50.479	0.99641291	2.600	130.26
22/05/2023	35	3	SO298-40972	64	49.629	0.99641291	2.650	130.54
22/05/2023	35	3	SO298-40972	77	49.411	0.99641291	2.650	129.96
22/05/2023	35	3	SO298-40975	81	50.068	0.99641291	2.010	99.77
22/05/2023	35	3	SO298-40979	84	50.169	0.99641291	1.770	87.97
22/05/2023	35	3	SO298-40979	88	49.620	0.99641291	1.780	87.50
22/05/2023	35	3	SO298-40979	184	49.789	0.99641291	1.760	86.81
22/05/2023	35	3	SO298-40980	185	50.613	0.99641291	2.960	148.76
22/05/2023	35	3	SO298-40988	246	47.850	0.99641291	4.270	203.10
24/05/2023	36	2	SO298-20826	73	49.516	0.99641291	3.780	185.99
24/05/2023	36	2	SO298-20829	92	50.214	0.99641291	2.840	141.59
24/05/2023	36	2	SO298-20831	98	49.624	0.99641291	2.650	130.53
24/05/2023	36	2	SO298-20831	99	49.758	0.99641291	2.640	130.38
24/05/2023	36	2	SO298-20831	195	50.044	0.99641291	2.620	130.13
24/05/2023	36	2	SO298-20839	196	49.979	0.99641291	1.630	80.66
24/05/2023	36	2	SO298-20839	198	49.969	0.99641291	1.630	80.65
24/05/2023	36	2	SO298-20839	199	49.739	0.99641291	1.630	80.28
24/05/2023	36	2	SO298-20842	200	50.104	0.99641291	2.950	146.77
24/05/2023	36	2	SO298-20848	237	46.660	0.99641291	4.410	204.56

24/05/2023	36	3	SO298-40989	238	47.770	0.99641291	3.920	186.10
24/05/2023	36	3	SO298-40989	241	46.990	0.99641291	3.990	186.34
24/05/2023	36	3	SO298-40989	243	46.540	0.99641291	4.030	186.41
24/05/2023	36	3	SO298-40990	250	47.290	0.99641291	3.650	171.51
24/05/2023	36	3	SO298-40991	251	46.900	0.99641291	3.380	157.47
24/05/2023	36	3	SO298-40992	252	47.950	0.99641291	2.990	142.37
24/05/2023	36	3	SO298-40993	257	47.000	0.99641291	2.920	136.27
24/05/2023	36	3	SO298-40993	264	46.800	0.99641291	2.900	134.76
24/05/2023	36	3	SO298-40993	265	47.040	0.99641291	2.890	134.98
24/05/2023	36	3	SO298-40996	268	47.000	0.99641291	2.450	114.26
25/05/2023	37	1	SO298-41013	7	50.270	0.99601594	3.660	182.74
25/05/2023	37	1	SO298-41013	15	46.588	0.99601594	3.940	182.35
25/05/2023	37	1	SO298-41013	23	50.280	0.99601594	3.630	181.28
25/05/2023	37	1	SO298-41015	27	50.631	0.99601594	3.090	155.31
25/05/2023	37	1	SO298-41020	28	52.044	0.99601594	2.640	136.32
25/05/2023	37	1	SO298-41022	31	46.772	0.99601594	2.660	123.44
25/05/2023	37	1	SO298-41026	33	52.175	0.99601594	1.890	97.69
25/05/2023	37	1	SO298-41032	34	46.337	0.99601594	1.690	77.52
25/05/2023	37	1	SO298-41032	36	52.191	0.99601594	1.510	77.96
25/05/2023	37	1	SO298-41032	73	49.516	0.99601594	1.590	77.91
25/05/2023	37	2	SO298-20850	52	50.479	0.99601594	3.700	185.51
25/05/2023	37	2	SO298-20854	39	52.482	0.99601594	2.720	141.65
25/05/2023	37	2	SO298-20854	64	49.629	0.99601594	2.880	141.86
25/05/2023	37	2	SO298-20858	77	49.411	0.99601594	2.360	115.64
25/05/2023	37	2	SO298-20858	81	50.068	0.99601594	2.860	142.11
25/05/2023	37	2	SO298-20858	185	50.613	0.99601594	2.300	115.43
25/05/2023	37	2	SO298-20866	88	49.620	0.99601594	2.850	140.35
25/05/2023	37	2	SO298-20866	184	49.789	0.99601594	2.850	140.83
25/05/2023	37	2	SO298-20869	84	50.169	0.99601594	3.720	185.37
25/05/2023	37	2	SO298-20872	246	47.850	0.99601594	4.230	201.11
26/05/2023	38	2	SO298-20874	39	52.482	0.99364070	2.630	136.62
26/05/2023	38	2	SO298-20876	64	49.629	0.99364070	2.650	130.17
26/05/2023	38	2	SO298-20885	92	50.214	0.99364070	1.720	85.31
26/05/2023	38	2	SO298-20885	98	49.624	0.99364070	1.740	85.29
26/05/2023	38	2	SO298-20885	99	49.758	0.99364070	1.740	85.52
26/05/2023	38	2	SO298-20887	198	49.969	0.99364070	1.560	76.95
26/05/2023	38	2	SO298-20887	257	47.000	0.99364070	1.660	77.04
26/05/2023	38	2	SO298-20887	264	46.800	0.99364070	1.670	77.18
26/05/2023	38	2	SO298-20888	265	47.040	0.99364070	2.490	115.90
26/05/2023	38	2	SO298-20896	268	47.000	0.99364070	4.240	197.53
26/05/2023	38	3	SO298-41055	52	50.479	0.99364070	2.750	137.42
26/05/2023	38	3	SO298-41055	199	49.739	0.99364070	2.750	135.41
26/05/2023	38	3	SO298-41055	200	50.104	0.99364070	2.760	136.90
26/05/2023	38	3	SO298-41056	237	46.660	0.99364070	2.940	135.83
26/05/2023	38	3	SO298-41059	238	47.770	0.99364070	2.320	109.63

26/05/2023	38	3	SO298-41059	241	46.990	0.99364070	2.360	109.71
26/05/2023	38	3	SO298-41059	243	46.540	0.99364070	2.380	109.59
26/05/2023	38	3	SO298-41060	250	47.290	0.99364070	2.150	100.54
26/05/2023	38	3	SO298-41068	251	46.900	0.99364070	2.960	137.46
26/05/2023	38	3	SO298-41074	252	47.950	0.99364070	4.180	198.67
27/05/2023	39	2	SO298-20898	7	50.270	0.99403579	2.460	122.41
27/05/2023	39	2	SO298-20901	27	50.631	0.99403579	2.250	112.72
27/05/2023	39	2	SO298-20904	28	52.044	0.99403579	1.930	99.31
27/05/2023	39	2	SO298-20906	31	46.772	0.99403579	2.110	97.62
27/05/2023	39	2	SO298-20911	33	52.175	0.99403579	2.140	110.46
27/05/2023	39	2	SO298-20918	34	46.337	0.99403579	3.390	155.67

12.5 Samples for Oxyanion, HFSE, Cr and V Redox Speciation, V Isotopes, and Sequential and Ultra-filtration

Table 12.6 Samples collected for oxyanion, HFSE, Cr and V redox speciation, V isotopes, and sequential and ultra-filtration.

					Samples collected/processed (ml)						
Station	Sample ID	Latitude	Longitude	Depth (m)	Oxyanion	HFSE	Ligands	Cr, V redox	V	Sequential	Ultra-
SO298_001	SO298-2001	-2.500	-81.000	104.0	100	100					
SO298_001	SO298-2002	-2.500	-81.000	89.9	100	100					
SO298_001	SO298-2003	-2.500	-81.000	80.6	100	100					
SO298_001	SO298-2004	-2.500	-81.000	66.9	100	100					
SO298_001	SO298-2005	-2.500	-81.000	54.7	100	100					
SO298_001	SO298-2006	-2.500	-81.000	43.9	100	100					
SO298_001	SO298-2007	-2.500	-81.000	34.7	100	100					
SO298_001	SO298-2008	-2.500	-81.000	25.5	100	100					
SO298_001	SO298-2009	-2.500	-81.000	15.6	100	100					
SO298_002	SO298-20010	-1.797	-81.902	1693	100	100	125	250			
SO298_002	SO298-20012	-1.797	-81.902	1601	100	100	125	250		2000	
SO298_002	SO298-20013	-1.797	-81.902	1450	100	100	125	250			
SO298_002	SO298-20014	-1.797	-81.902	1300	100	100	125	250			
SO298_002	SO298-20015	-1.797	-81.902	1200	100	100	125	250			
SO298_002	SO298-20016	-1.797	-81.902	1101	100	100	125	250			
SO298_002	SO298-20017	-1.797	-81.902	1000	100	100	125	250			
SO298_002	SO298-20019	-1.797	-81.902	800	100	100	125	250			
SO298_002	SO298-20021	-1.797	-81.902	600	100	100	125	250			
SO298_002	SO298-20022	-1.797	-81.902	500	100	100	125	250			
SO298_002	SO298-20023	-1.797	-81.902	450	100	100	125	250			
SO298_002	SO298-20024	-1.797	-81.902	400	100	100	125	250			
SO298_002	SO298-20026	-1.797	-81.902	300	100	100	125	250		2000	
SO298_002	SO298-20027	-1.797	-81.902	250	100	100	125	250			
SO298_002	SO298-20028	-1.797	-81.902	200	100	100	125	250			
SO298_002	SO298-20029	-1.797	-81.902	150	100	100	125	250			
SO298_002	SO298-20030	-1.797	-81.902	100	100	100	125	250			

SO298_002	SO298-20031	-1.797	-81.902	70	100	100	125	250			
SO298_002	SO298-20032	-1.797	-81.902	44	100	100	125	250			
SO298_002	SO298-20033	-1.797	-81.902	20	100	100	125	250		2000	
SO298_002	SO298-10002	-1.797	-81.902	Tow-fish	100	100					
SO298_004	SO298-20059	-0.570	-83.727	2500	100	100					
SO298_004	SO298-20060	-0.570	-83.727	2200	100	100					
SO298_004	SO298-20061	-0.570	-83.727	1800	100	100					
SO298_004	SO298-20063	-0.570	-83.727	1200	100	100					
SO298_004	SO298-20065	-0.570	-83.727	800	100	100					
SO298_004	SO298-20068	-0.570	-83.727	500	100	100					
SO298_004	SO298-20070	-0.570	-83.727	400	100	100					
SO298_004	SO298-20071	-0.570	-83.727	360	100	100					
SO298_004	SO298-20073	-0.570	-83.727	260	100	100					
SO298_004	SO298-20074	-0.570	-83.727	230	100	100					
SO298_004	SO298-20076	-0.570	-83.727	150	100	100					
SO298_004	SO298-20078	-0.570	-83.727	90	100	100					
SO298_004	SO298-20079	-0.570	-83.727	70	100	100					
SO298_004	SO298-20080	-0.570	-83.727	40	100	100					
SO298_004	SO298-20081	-0.570	-83.727	15	100	100					
SO298_005	SO298-20083	-1.100	-86.100	2080	100	100	125	250			
SO298_005	SO298-20085	-1.100	-86.100	2000	100	100	125	250	2000	2000	
SO298_005	SO298-20086	-1.100	-86.100	1900	100	100	125	250			
SO298_005	SO298-20088	-1.100	-86.100	1500	100	100	125	250			
SO298_005	SO298-20091	-1.100	-86.100	800	100	100	125	250			
SO298_005	SO298-20093	-1.100	-86.100	550	100	100	125	250	2000		
SO298_005	SO298-20094	-1.100	-86.100	450	100	100	125	250	2000		
SO298_005	SO298-20095	-1.100	-86.100	400	100	100	125	250	2000		
SO298_005	SO298-20096	-1.100	-86.100	375	100	100	125	250		2000	~ 6000
SO298_005	SO298-20097	-1.100	-86.100	300	100	100	125	250			
SO298_005	SO298-20098	-1.100	-86.100	250	100	100	125	250			
SO298_005	SO298-20100	-1.100	-86.100	150	100	100	125	250			
SO298_005	SO298-20102	-1.100	-86.100	85	100	100	125	250			

SO298_005	SO298-20103	-1.100	-86.100	60	100	100	125	250			
SO298_005	SO298-20104	-1.100	-86.100	35	100	100	125	250	2000	2000	
SO298_005	SO298-20105	-1.100	-86.100	20	100	100	125	250			
SO298_007	SO298-20130	-2.005	-92.099	3300	100	100					
SO298_007	SO298-20131	-2.005	-92.099	2900	100	100					
SO298_007	SO298-20133	-2.005	-92.099	2300	100	100					
SO298_007	SO298-20135	-2.005	-92.099	2100	100	100					
SO298_007	SO298-20137	-2.005	-92.099	1700	100	100					
SO298_007	SO298-20139	-2.005	-92.099	1000	100	100					
SO298_007	SO298-20140	-2.005	-92.099	800	100	100					
SO298_007	SO298-20140	-2.005	-92.099	800	100	100					
SO298_007	SO298-20140	-2.005	-92.099	800	100	100					
SO298_007	SO298-20142	-2.005	-92.099	475	100	100					
SO298_007	SO298-20143	-2.005	-92.099	400	100	100					
SO298_007	SO298-20146	-2.005	-92.099	200	100	100					
SO298_007	SO298-20147	-2.005	-92.099	150	100	100					
SO298_007	SO298-20149	-2.005	-92.099	100	100	100					
SO298_007	SO298-20150	-2.005	-92.099	70	100	100					
SO298_007	SO298-20152	-2.005	-92.099	40	100	100					
SO298_007	SO298-20153	-2.005	-92.099	20	100	100					
SO298_007	SO298-10026	-2.005	-92.099	Tow-fish	100	100					
SO298_008	SO298-20154	0.001	-94.578	3314	100	100	125	250			
SO298_008	SO298-20155	0.001	-94.578	3100	100	100	125	250			
SO298_008	SO298-20157	0.001	-94.578	2300	100	100	125	250		2000	
SO298_008	SO298-20159	0.001	-94.578	2100	100	100	125	250			
SO298_008	SO298-20161	0.001	-94.578	1700	100	100	125	250			
SO298_008	SO298-20164	0.001	-94.578	800	100	100	125	250			
SO298_008	SO298-20165	0.001	-94.578	600	100	100	125	250			
SO298_008	SO298-20166	0.001	-94.578	475	100	100	125	250			
SO298_008	SO298-20167	0.001	-94.578	390	100	100	125	250		2000	
SO298_008	SO298-20170	0.001	-94.578	200	100	100	125	250			
SO298_008	SO298-20172	0.001	-94.578	120	100	100	125	250			

SO298_008	SO298-20174	0.001	-94.578	75	100	100	125	250			
SO298_008	SO298-20175	0.001	-94.578	55	100	100	125	250			
SO298_008	SO298-20176	0.001	-94.578	40	100	100	125	250		2000	
SO298_008	SO298-10036	0.001	-94.578	Tow-fish	100	100	125	250			
SO298_010	SO298-20202	0.000	-100.966	3225	100	100					
SO298_010	SO298-20204	0.000	-100.966	2600	100	100					
SO298_010	SO298-20206	0.000	-100.966	2200	100	100					
SO298_010	SO298-20208	0.000	-100.966	2000	100	100					
SO298_010	SO298-20210	0.000	-100.966	1250	100	100					
SO298_010	SO298-20212	0.000	-100.966	800	100	100					
SO298_010	SO298-20213	0.000	-100.966	600	100	100					
SO298_010	SO298-20215	0.000	-100.966	420	100	100					
SO298_010	SO298-20216	0.000	-100.966	370	100	100					
SO298_010	SO298-20218	0.000	-100.966	200	100	100					
SO298_010	SO298-20221	0.000	-100.966	90	100	100					
SO298_010	SO298-20222	0.000	-100.966	75	100	100					
SO298_010	SO298-20223	0.000	-100.966	60	100	100					
SO298_010	SO298-20224	0.000	-100.966	40	100	100					
SO298_010	SO298-20225	0.000	-100.966	20	100	100					
SO298_010	SO298-10049	0.000	-100.966	Tow-fish	100	100					
SO298_011	SO298-20226	0.000	-104.151	3492	100	100	125	250			
SO298_011	SO298-20228	0.000	-104.151	3200	100	100	125	250			
SO298_011	SO298-20230	0.000	-104.151	2500	100	100	125	250			
SO298_011	SO298-20232	0.000	-104.151	2200	100	100	125	250			
SO298_011	SO298-20234	0.000	-104.151	2000	100	100	125	250			
SO298_011	SO298-20237	0.000	-104.151	800	100	100	125	250			
SO298_011	SO298-20238	0.000	-104.151	600	100	100	125	250			
SO298_011	SO298-20240	0.000	-104.151	370	100	100	125	250			
SO298_011	SO298-20241	0.000	-104.151	300	100	100	125	250			
SO298_011	SO298-20242	0.000	-104.151	200	100	100	125	250			
SO298_011	SO298-20244	0.000	-104.151	120	100	100	125	250			
SO298_011	SO298-20245	0.000	-104.151	90	100	100	125	250			

SO298_011	SO298-20247	0.000	-104.151	60	100	100	125	250			
SO298_011	SO298-20248	0.000	-104.151	40	100	100	125	250			
SO298_011	SO298-20249	0.000	-104.151	20	100	100	125	250			
SO298_011	SO298-10058	0.000	-104.151	Tow-fish	100	100	125	250			
SO298_013	SO298-20275	0.001	-110.540	3600	100	100	125	250			
SO298_013	SO298-20276	0.001	-110.540	3100	100	100	125	250		2000	
SO298_013	SO298-20276	0.001	-110.540	3100	100	100				2000	
SO298_013	SO298-20278	0.001	-110.540	2500	100	100	125	250			
SO298_013	SO298-20280	0.001	-110.540	2100	100	100	125	250			
SO298_013	SO298-20282	0.001	-110.540	1500	100	100	125	250			
SO298_013	SO298-20284	0.001	-110.540	1000	100	100	125	250			
SO298_013	SO298-20285	0.001	-110.540	800	100	100	125	250			
SO298_013	SO298-20287	0.001	-110.540	450	100	100	125	250			
SO298_013	SO298-20288	0.001	-110.540	360	100	100	125	250		2000	
SO298_013	SO298-20290	0.001	-110.540	500	100	100	125	250			
SO298_013	SO298-20292	0.001	-110.540	120	100	100	125	250			
SO298_013	SO298-20294	0.001	-110.540	75	100	100	125	250			
SO298_013	SO298-20295	0.001	-110.540	60	100	100	125	250			
SO298_013	SO298-20296	0.001	-110.540	40	100	100	125	250		2000	
SO298_013	SO298-20297	0.001	-110.540	20	100	100	125	250			
SO298_013	SO298-10072	0.001	-110.540	Tow-fish	100	100	125	250			
SO298_014	SO298-20299	-0.003	-113.739	3800	100	100	125	250			
SO298_014	SO298-20300	-0.003	-113.739	3200	100	100	125	250			
SO298_014	SO298-20302	-0.003	-113.739	2500	100	100	125	250			
SO298_014	SO298-20304	-0.003	-113.739	2100	100	100	125	250			
SO298_014	SO298-20306	-0.003	-113.739	1500	100	100	125	250			
SO298_014	SO298-20308	-0.003	-113.739	1000	100	100	125	250			
SO298_014	SO298-20309	-0.003	-113.739	800	100	100	125	250			
SO298_014	SO298-20311	-0.003	-113.739	450	100	100	125	250			
SO298_014	SO298-20312	-0.003	-113.739	370	100	100	125	250			
SO298_014	SO298-20314	-0.003	-113.739	200	100	100	125	250			
SO298_014	SO298-20316	-0.003	-113.739	120	100	100	125	250			

SO298_014	SO298-20318	-0.003	-113.739	75	100	100	125	250			
SO298_014	SO298-20319	-0.003	-113.739	60	100	100	125	250			
SO298_014	SO298-20320	-0.003	-113.739	45	100	100	125	250			
SO298_014	SO298-20321	-0.003	-113.739	20	100	100	125	250			
SO298_014	SO298-10080	-0.003	-113.739	Tow-fish	100	100					
SO298_016	SO298-20346	-0.001	-120.134	4123	100	100					
SO298_016	SO298-20348	-0.001	-120.134	3200	100	100					
SO298_016	SO298-20350	-0.001	-120.134	2500	100	100					
SO298_016	SO298-20352	-0.001	-120.134	2100	100	100					
SO298_016	SO298-20354	-0.001	-120.134	1500	100	100					
SO298_016	SO298-20356	-0.001	-120.134	1000	100	100					
SO298_016	SO298-20357	-0.001	-120.134	800	100	100					
SO298_016	SO298-20359	-0.001	-120.134	450	100	100					
SO298_016	SO298-20360	-0.001	-120.134	362	100	100					
SO298_016	SO298-20362	-0.001	-120.134	200	100	100					
SO298_016	SO298-20364	-0.001	-120.134	120	100	100					
SO298_016	SO298-20366	-0.001	-120.134	71	100	100					
SO298_016	SO298-20367	-0.001	-120.134	60	100	100					
SO298_016	SO298-20368	-0.001	-120.134	45	100	100					
SO298_016	SO298-20369	-0.001	-120.134	20	100	100					
SO298_016	SO298-10093	-0.001	-120.134	Tow-fish	100	100					
SO298_018	SO298-20394	-0.004	-127.139	4393	100	100					
SO298_018	SO298-20396	-0.004	-127.139	3900	100	100					
SO298_018	SO298-20398	-0.004	-127.139	2700	100	100					
SO298_018	SO298-20399	-0.004	-127.139	2500	100	100					
SO298_018	SO298-20401	-0.004	-127.139	2100	100	100					
SO298_018	SO298-20403	-0.004	-127.139	1500	100	100					
SO298_018	SO298-20406	-0.004	-127.139	800	100	100					
SO298_018	SO298-20408	-0.004	-127.139	450	100	100					
SO298_018	SO298-20409	-0.004	-127.139	376	100	100					
SO298_018	SO298-20411	-0.004	-127.139	200	100	100					
SO298_018	SO298-20413	-0.004	-127.139	100	100	100					

SO298_018	SO298-20414	-0.004	-127.139	80	100	100					
SO298_018	SO298-20415	-0.004	-127.139	60	100	100					
SO298_018	SO298-20416	-0.004	-127.139	40	100	100					
SO298_018	SO298-20417	-0.004	-127.139	20	100	100					
SO298_018	SO298-10104	-0.004	-127.139	Tow-fish	100	100					
SO298_020	SO298-20442	-0.002	-134.451	4066	100	100					
SO298_020	SO298-20444	-0.002	-134.451	3500	100	100					
SO298_020	SO298-20446	-0.002	-134.451	2700	100	100					
SO298_020	SO298-20447	-0.002	-134.451	2500	100	100					
SO298_020	SO298-20449	-0.002	-134.451	2100	100	100					
SO298_020	SO298-20451	-0.002	-134.451	1400	100	100					
SO298_020	SO298-20453	-0.002	-134.451	800	100	100					
SO298_020	SO298-20455	-0.002	-134.451	450	100	100					
SO298_020	SO298-20456	-0.002	-134.451	360	100	100					
SO298_020	SO298-20459	-0.002	-134.451	150	100	100					
SO298_020	SO298-20461	-0.002	-134.451	100	100	100					
SO298_020	SO298-20462	-0.002	-134.451	75	100	100					
SO298_020	SO298-20463	-0.002	-134.451	60	100	100					
SO298_020	SO298-20464	-0.002	-134.451	63	100	100					
SO298_020	SO298-20465	-0.002	-134.451	20	100	100					
SO298_020	SO298-10119	-0.002	-134.451	Tow-fish	100	100					
SO298_022	SO298-20491	-0.003	-141.742	4000	100	100	125	250		2000	
SO298_022	SO298-20492	-0.003	-141.742	3100	100	100	125	250			
SO298_022	SO298-20494	-0.003	-141.742	2500	100	100	125	250			
SO298_022	SO298-20496	-0.003	-141.742	2100	100	100	125	250			
SO298_022	SO298-20498	-0.003	-141.742	1400	100	100	125	250			
SO298_022	SO298-20500	-0.003	-141.742	800	100	100	125	250			
SO298_022	SO298-20501	-0.003	-141.742	600	100	100	125	250			
SO298_022	SO298-20502	-0.003	-141.742	4501	100	100	125	250		2000	~4500
SO298_022	SO298-20504	-0.003	-141.742	3521	100	100	125	250			
SO298_022	SO298-20506	-0.003	-141.742	200	100	100	125	250			
SO298_022	SO298-20508	-0.003	-141.742	130	100	100	125	250			

SO298_022	SO298-20510	-0.003	-141.742	65	100	100	125	250			
SO298_022	SO298-20511	-0.003	-141.742	50	100	100	125	250			
SO298_022	SO298-20512	-0.003	-141.742	40	100	100	125	250		2000	
SO298_022	SO298-20513	-0.003	-141.742	20	100	100	125	250			
SO298_022	SO298-10132	-0.003	-141.742	Tow-fish	100	100	125	250			
SO298_024	SO298-20539	0.000	-145.048	4400	100	100					
SO298_024	SO298-20540	0.000	-145.048	3700	100	100					
SO298_024	SO298-20542	0.000	-145.048	2700	100	100					
SO298_024	SO298-20543	0.000	-145.048	2500	100	100					
SO298_024	SO298-20545	0.000	-145.048	2100	100	100					
SO298_024	SO298-20546	0.000	-145.048	1750	100	100					
SO298_024	SO298-20549	0.000	-145.048	800	100	100					
SO298_024	SO298-20551	0.000	-145.048	420	100	100					
SO298_024	SO298-20552	0.000	-145.048	360	100	100					
SO298_024	SO298-20553	0.000	-145.048	280	100	100					
SO298_024	SO298-20555	0.000	-145.048	150	100	100					
SO298_024	SO298-20556	0.000	-145.048	120	100	100					
SO298_024	SO298-20558	0.000	-145.048	70	100	100					
SO298_024	SO298-20559	0.000	-145.048	55	100	100					
SO298_024	SO298-20561	0.000	-145.048	20	100	100					
SO298_024	SO298-10144	0.000	-145.048	Tow-fish	100	100					
SO298_025	SO298-20562	0.000	-152.699	4519	100	100	125	250			
SO298_025	SO298-20564	0.000	-152.699	3700	100	100	125	250			
SO298_025	SO298-20566	0.000	-152.699	2700	100	100	125	250			
SO298_025	SO298-20567	0.000	-152.699	2500	100	100	125	250			
SO298_025	SO298-20569	0.000	-152.699	2100	100	100	125	250			
SO298_025	SO298-20571	0.000	-152.699	1400	100	100	125	250			
SO298_025	SO298-20573	0.000	-152.699	800	100	100	125	250			
SO298_025	SO298-20575	0.000	-152.699	460	100	100	125	250			
SO298_025	SO298-20577	0.000	-152.699	270	100	100	125	250			
SO298_025	SO298-20579	0.000	-152.699	175	100	100	125	250			
SO298_025	SO298-20580	0.000	-152.699	130	100	100	125	250			

SO298_025	SO298-20582	0.000	-152.699	70	100	100	125	250			
SO298_025	SO298-20583	0.000	-152.699	50	100	100	125	250			
SO298_025	SO298-20584	0.000	-152.699	35	100	100	125	250			
SO298_025	SO298-20585	0.000	-152.699	20	100	100	125	250			
SO298_025	SO298-10152	0.000	-152.699	Tow-fish	100	100	125	250			
SO298_027	SO298-20610	0.000	-160.000	5137	100	100					
SO298_027	SO298-20612	0.000	-160.000	4200	100	100					
SO298_027	SO298-20614	0.000	-160.000	2700	100	100					
SO298_027	SO298-20615	0.000	-160.000	2500	100	100					
SO298_027	SO298-20617	0.000	-160.000	2100	100	100					
SO298_027	SO298-20619	0.000	-160.000	1300	100	100					
SO298_027	SO298-20621	0.000	-160.000	800	100	100					
SO298_027	SO298-20623	0.000	-160.000	450	100	100					
SO298_027	SO298-20625	0.000	-160.000	270	100	100					
SO298_027	SO298-20627	0.000	-160.000	150	100	100					
SO298_027	SO298-20628	0.000	-160.000	135	100	100					
SO298_027	SO298-20630	0.000	-160.000	70	100	100					
SO298_027	SO298-20631	0.000	-160.000	55	100	100					
SO298_027	SO298-20632	0.000	-160.000	40	100	100					
SO298_027	SO298-20633	0.000	-160.000	20	100	100					
SO298_027	SO298-10166	0.000	-160.000	Tow-fish	100	100					
SO298_029	SO298-20658	0.000	-167.302	4721	100	100					
SO298_029	SO298-20660	0.000	-167.302	4100	100	100					
SO298_029	SO298-20662	0.000	-167.302	2700	100	100					
SO298_029	SO298-20663	0.000	-167.302	2500	100	100					
SO298_029	SO298-20665	0.000	-167.302	2100	100	100					
SO298_029	SO298-20667	0.000	-167.302	1300	100	100					
SO298_029	SO298-20669	0.000	-167.302	800	100	100					
SO298_029	SO298-20671	0.000	-167.302	425	100	100					
SO298_029	SO298-20673	0.000	-167.302	280	100	100					
SO298_029	SO298-20675	0.000	-167.302	160	100	100					
SO298_029	SO298-20676	0.000	-167.302	140	100	100					

SO298_029	SO298-20678	0.000	-167.302	80	100	100					
SO298_029	SO298-20679	0.000	-167.302	65	100	100					
SO298_029	SO298-20680	0.000	-167.302	45	100	100					
SO298_029	SO298-20681	0.000	-167.302	20	100	100					
SO298_029	SO298-10179	0.000	-167.302	Tow-fish	100	100					
SO298_030	SO298-20682	0.000	-170.947	5357	100	100	125	250			
SO298_030	SO298-20684	0.000	-170.947	4400	100	100	125	250			
SO298_030	SO298-20686	0.000	-170.947	2700	100	100	125	250			
SO298_030	SO298-20687	0.000	-170.947	2500	100	100	125	250			
SO298_030	SO298-20689	0.000	-170.947	2100	100	100	125	250			
SO298_030	SO298-20691	0.000	-170.947	1400	100	100	125	250			
SO298_030	SO298-20693	0.000	-170.947	800	100	100	125	250			
SO298_030	SO298-20695	0.000	-170.947	410	100	100	125	250			
SO298_030	SO298-20696	0.000	-170.947	370	100	100	125	250			
SO298_030	SO298-20698	0.000	-170.947	200	100	100	125	250			
SO298_030	SO298-20699	0.000	-170.947	170	100	100	125	250			
SO298_030	SO298-20700	0.000	-170.947	125	100	100	125	250			
SO298_030	SO298-20701	0.000	-170.947	100	100	100	125	250			
SO298_030	SO298-20703	0.000	-170.947	60	100	100	125	250			
SO298_030	SO298-20704	0.000	-170.947	45	100	100	125	250			
SO298_030	SO298-10186	0.000	-170.947	Tow-fish	100	100	125	250			
SO298_032	SO298-20730	0.000	-178.252	4949	100	100					
SO298_032	SO298-20731	0.000	-178.252	4969	100	100					
SO298_032	SO298-20732	0.000	-178.252	4700	100	100					
SO298_032	SO298-20734	0.000	-178.252	3500	100	100					
SO298_032	SO298-20736	0.000	-178.252	2700	100	100					
SO298_032	SO298-20737	0.000	-178.252	2500	100	100					
SO298_032	SO298-20739	0.000	-178.252	1800	100	100					
SO298_032	SO298-20741	0.000	-178.252	1000	100	100					
SO298_032	SO298-20743	0.000	-178.252	600	100	100					
SO298_032	SO298-20746	0.000	-178.252	190	100	100					
SO298_032	SO298-20748	0.000	-178.252	155	100	100					

SO298_032	SO298-20749	0.000	-178.252	125	100	100					
SO298_032	SO298-20751	0.000	-178.252	70	100	100					
SO298_032	SO298-20752	0.000	-178.252	50	100	100					
SO298_032	SO298-10200	0.000	-178.252	Tow-fish	100	100					
SO298_034	SO298-20778	0.001	174.450	4743	100	100					
SO298_034	SO298-20779	0.001	174.450	4663	100	100					
SO298_034	SO298-20780	0.001	174.450	4300	100	100					
SO298_034	SO298-20782	0.001	174.450	2800	100	100					
SO298_034	SO298-20784	0.001	174.450	2500	100	100					
SO298_034	SO298-20786	0.001	174.450	1800	100	100					
SO298_034	SO298-20789	0.001	174.450	800	100	100					
SO298_034	SO298-20791	0.001	174.450	420	100	100					
SO298_034	SO298-20792	0.001	174.450	340	100	100					
SO298_034	SO298-20794	0.001	174.450	200	100	100					
SO298_034	SO298-20795	0.001	174.450	150	100	100					
SO298_034	SO298-20796	0.001	174.450	130	100	100					
SO298_034	SO298-20798	0.001	174.450	80	100	100					
SO298_034	SO298-20799	0.001	174.450	60	100	100					
SO298_034	SO298-20800	0.001	174.450	45	100	100					
SO298_034	SO298-10213	0.001	174.450	Tow-fish	100	100					
SO298_035	SO298-20802	0.000	170.798	4542	100	100	125	250			
SO298_035	SO298-20803	0.000	170.798	4462	100	100	125	250			
SO298_035	SO298-20805	0.000	170.798	3600	100	100	125	250	2000	2000	
SO298_035	SO298-20807	0.000	170.798	2700	100	100	125	250			
SO298_035	SO298-20809	0.000	170.798	2190	100	100	125	250			
SO298_035	SO298-20811	0.000	170.798	1400	100	100	125	250			
SO298_035	SO298-20814	0.000	170.798	625	100	100	125	250	2000		
SO298_035	SO298-20815	0.000	170.798	422	100	100	125	250		2000	~6000
SO298_035	SO298-20817	0.000	170.798	240	100	100	125	250			
SO298_035	SO298-20819	0.000	170.798	178	100	100	125	250			
SO298_035	SO298-20820	0.000	170.798	117	100	100	125	250			
SO298_035	SO298-20822	0.000	170.798	85	100	100	125	250			

SO298_035	SO298-20823	0.000	170.798	60	100	100	125	250			
SO298_035	SO298-20824	0.000	170.798	40	100	100	125	250			
SO298_035	SO298-20825	0.000	170.798	20	100	100	125	250	2000	2000	
SO298_035	SO298-10220	0.000	170.798	Tow-fish	100	100	125	250			
SO298_037	SO298-20853	0.000	163.501	3500				250	2000		
SO298_037	SO298-20862	0.000	163.501	630				250	2000		
SO298_037	SO298-20863	0.000	163.501	530				250	2000		
SO298_037	SO298-20865	0.000	163.501	270				250	2000		
SO298_037	SO298-20873	0.000	163.501	20				250	2000		
SO298_039	SO298-20898	-1.356	157.854	1850	100	100	125	250			
SO298_039	SO298-20899	-1.356	157.854	1810	100	100	125	250			
SO298_039	SO298-20900	-1.356	157.854	1760	100	100	125	250			
SO298_039	SO298-20901	-1.356	157.854	1600	100	100	125	250			
SO298_039	SO298-20902	-1.356	157.854	1400	100	100	125	250		2000	
SO298_039	SO298-20902	-1.356	157.854	1400	100	100	125	250			
SO298_039	SO298-20902	-1.356	157.854	1400	100	100	125	250			
SO298_039	SO298-20903	-1.356	157.854	1200	100	100	125	250	2000		
SO298_039	SO298-20904	-1.356	157.854	1000	100	100	125	250			
SO298_039	SO298-20905	-1.356	157.854	860	100	100	125	250			
SO298_039	SO298-20906	-1.356	157.854	700	100	100	125	250			
SO298_039	SO298-20907	-1.356	157.854	600	100	100	125	250	2000		
SO298_039	SO298-20908	-1.356	157.854	460	100	100	125	250	2000		
SO298_039	SO298-20909	-1.356	157.854	400	100	100	125			2000	~7500
SO298_039	SO298-20910	-1.356	157.854	400				250	2000		
SO298_039	SO298-20911	-1.356	157.854	320	100	100	125	250			
SO298_039	SO298-20912	-1.356	157.854	240	100	100	125	250			
SO298_039	SO298-20913	-1.356	157.854	200	100	100	125	250			
SO298_039	SO298-20914	-1.356	157.854	175	100	100	125	250			
SO298_039	SO298-20915	-1.356	157.854	150	100	100	125	250			
SO298_039	SO298-20916	-1.356	157.854	125	100	100	125	250			
SO298_039	SO298-20917	-1.356	157.854	100	100	100	125	250			
SO298_039	SO298-20918	-1.356	157.854	80	100	100	125	250			

SO298_039	SO298-20919	-1.356	157.854	60	100	100	125	250			
SO298_039	SO298-20920	-1.356	157.854	40	100	100	125	250		2000	
SO298_039	SO298-20921	-1.356	157.854	20	100	100	125	250			
SO298_039	SO298-10247	-1.356	157.854	Tow-fish	100	100	125	250	2000		

12.6 Sampling Plan for Metallomics

Table 12.7 Sampling plan for metallomics, targeted protein and RNA

Station No.	Metallomics	Targeted protein	RNA
ST-2	2 L × 6 depths	4 L × 2 depths	4 L × 2 depths
ST-4	2 L × 6 depths	4 L × 2 depths	4 L × 2 depths
ST-6	2 L × 6 depths	-	-
ST-8	2 L × 6 depths	4 L × 2 depths	4 L × 2 depths
ST-10	2 L × 6 depths	4 L × 2 depths	4 L × 2 depths
ST-12	2 L × 6 depths	-	-
ST-14	-	4 L × 2 depths	4 L × 2 depths
ST-16	2 L × 6 depths	4 L × 2 depths	4 L × 2 depths
ST-19	2 L × 6 depths	4 L × 2 depths	4 L × 2 depths
ST-22	2 L × 6 depths	4 L × 2 depths	4 L × 2 depths
ST-24	2 L × 6 depths	4 L × 2 depths	4 L × 2 depths
ST-26	2 L × 6 depths	4 L × 2 depths	4 L × 2 depths
ST-27	2 L × 6 depths	4 L × 2 depths	4 L × 2 depths
ST-29	2 L × 6 depths	4 L × 2 depths	4 L × 2 depths
ST-31	2 L × 6 depths	4 L × 1 depth	4 L × 1 depth
ST-33	2 L × 6 depths	4 L × 2 depths	4 L × 2 depths
ST-35	2 L × 6 depths	4 L × 2 depths	4 L × 2 depths
ST-38	-	4 L × 2 depths	4 L × 2 depths
ST-39	2 L × 6 depths	4 L × 1 depth	4 L × 1 depth

Table 12.8 Incubation plan for Fe-enrichment experiments

Experiment No.	Date	Control	Fe enrichment
Ex -01	17-04-2023	4 L × 3 bottles	4 L × 3 bottles
Ex -02	21-04-2023	4 L × 3 bottles	4 L × 3 bottles
Ex -03	25-04-2023	4 L × 3 bottles	4 L × 3 bottles
Ex -04	01-05-2023	4 L × 3 bottles	4 L × 3 bottles
Ex -05	05-05-2023	4 L × 3 bottles	4 L × 3 bottles
Ex -06	08-05-2023	4 L × 3 bottles	4 L × 3 bottles
Ex -07	11-05-2023	4 L × 3 bottles	4 L × 3 bottles
Ex -08	15-05-2023	4 L × 3 bottles	4 L × 3 bottles
Ex -09	18-05-2023	4 L × 3 bottles	4 L × 3 bottles
Ex -10	21-05-2023	4 L × 3 bottles	4 L × 3 bottles

Ex -11	24-05-2023	4 L × 3 bottles	4 L × 3 bottles
Ex -12	26-05-2023	4 L × 3 bottles	4 L × 3 bottles

12.7 Samples Collected for Radium (Ra) Isotopes

Table 12.9 Samples collected from the In-situ pumps for Ra-228 and Ra-226 analysis

	Station 3	**Station 7**	**Station 11**	**Station 15**	**Station 18**	**Station 21**	**Station 25**
Depth (m)	40	40	40	40	60	55	50
	70	70	80	80	80	90	90
	120	120	120	120	120	120	130
	200	200	370	200	200	200	200
	400	400	600	370	370	355	350
		600		600	600	600	600
	Station 28	**Station 30**	**Station 34**	**Station 37**			
Depth (m)	50	50	60	60			
	100	100	100	100			
	135	140	150	160			
	200	200	200	200			
	350	360	420	400			
	600	600	600	600			

Table 12.10 Samples collected from the CTD for Ra-226 analysis by mass spectrometry

Station	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**11**	**13**
Depth (m)	75	15	5	5	100	120	75	40	120
	200	50	120	120	200	200	95	60	250
	300	70	200	260	400	400	200	120	500
	400	120	330	400	750	800	400	370	1000
	700	200	400	700	1000	1000	550	400	1500
	1000	400	600	1900	1700	1500	1000	600	1900
	1300	600	1000	2000	2100	2000	1700	1000	2100
	1700	900	1500	2080	2300	2200	2200	2000	2300
		1000	2000	2100	3120	2500	2700	2700	2500
		1299	2650			3000	2900	3000	2700
						3280	3120	3200	3300
							3350	3800	3820
Station	**15**	**16**	**17**	**18**	**21**	**22**	**24**	**25**	**28**
	40	80	120	20	20	55	70	20	75
	80	120	250	40	40	70	125	40	100
	200	200	500	80	75	130	220	50	135

	370	360	1000	120	95	200	480	70	200
	600	450	1250	200	120	380	800	90	350
Depth (m)	1000	800	1900	360	200	470	1300	120	420
	1500	1000	2100	600	340	1000	2100	150	600
	1900	1500	2300	1000	600	2100	2500	200	1000
	2500	2100	2500	1500	1000	2500	4000	270	1800
	3000	2500	3000	1900	1250	3200	4335	360	2700
	3200	3200	3700	2500	1900	4380		450	3400
	3800	3800	4450	3100	2500			600	4300
	4077	4137		3500	2700			800	4780
				3900	3100			1000	5170
				4300	3700			1400	
				4480	4300			1800	
					4400			2100	
								2300	
								2500	
								2700	
								3500	
								4300	
								4500	
Station	**30**	**32**	**33**	**34**	**35**	**37**	**39**		
	50	50	10	80	1400	100	100		
	80	70	45	100	1980	160	150		
	100	90	55	160	2190	200	200		
	140	125	70	200	2500	400	260		
	200	155	110	340	2700	600	400		
	360	190	157	420	3000	1000	600		
	430	260	190	600	3600	1800	700		
	600	420	270	800		2500	850		
	1000	600	420	1000		3000	1200		
Depth (m)	1800	800	600	1800		3500	1700		
	2100	1000	800	2100		4315	1890		
	2500	1300	1000	2700		4400	1950		
	2700	1800	1300	3400			1980		
	3300	2100	2500	4750					
	4400	2700	2700	4840					
	5300	3000	3000						
	5515	4100	4000						
		4700	4800						
		5537	5062						
		5637	5152						

12.8 Samples for Underway Carbon Measurements

Table 12.11 Metadata for discrete samples for underway carbon

ID	Date and time	Longitude	Latitude	T (ext.) in °C	Salinity
1	2023-04-15 23:45:00	-81.901883	-1.796967	28.691	33.8019
2	2023-04-16 11:45:00	-82.45405	-1.139383	28.438	33.5291
3	2023-04-16 23:45:00	-83.727233	-0.56945	28.75	33.7948
4	2023-04-17 11:45:00	-84.879967	-0.828467	28.266	33.7988
5	2023-04-17 23:45:00	-86.151583	-1.114683	28.43	33.9436
6	2023-04-18 12:45:00	-88.220733	-1.741233	28.581	34.5037
7	2023-04-19 00:45:00	-89.22155	-2.0445	28.567	34.6955
8	2023-04-19 12:45:00	-91.204967	-2.045	27.648	34.7298
9	2023-04-20 00:45:00	-92.098283	-2.0059	26.769	35.1475
10	2023-04-20 12:45:00	-93.405533	-0.946683	27.445	35.0677
11	2023-04-21 00:45:00	-94.57515	0.00115	27.558	34.9971
12	2023-04-21 12:45:00	-96.078867	-0.0001	27.909	34.8355
13	2023-04-22 00:45:00	-97.780433	-0.00005	28.349	35.0707
14	2023-04-22 12:45:00	-99.267733	-0.000083	27.944	35.0515
15	2023-04-23 00:45:00	-100.958383	-0.001717	27.653	35.1427
16	2023-04-23 13:45:00	-102.322567	-0.000083	27.398	35.1575
17	2023-04-24 01:45:00	-104.107883	-0.000017	27.529	35.1837
18	2023-04-24 13:45:00	-104.562	-0.000133	27.097	35.1303
19	2023-04-25 01:45:00	-106.39985	-0.00005	27.549	35.1388
20	2023-04-25 13:45:00	-107.36665	-0.000017	27.215	35.1461
21	2023-04-26	-109.358367	0	27.346	35.2055

	01:45:00				
22	2023-04-26 13:45:00	-110.537583	0.000017	27.263	35.175
23	2023-04-27 01:45:00	-112.428767	0	27.698	35.2374
24	2023-04-27 13:45:00	-113.730733	-0.004467	27.284	35.2123
25	2023-04-28 01:45:00	-115.3185	0	27.622	35.2527
26	2023-04-28 13:45:00	-116.9373	-0.000083	27.292	35.2285
27	2023-04-29 01:45:00	-117.757717	-0.000033	27.901	35.2732
28	2023-04-29 14:45:00	-119.91435	-0.0001	27.303	35.2154
29	2023-04-30 02:45:00	-120.7976	0.000033	27.416	35.2413
30	2023-04-30 14:45:00	-122.803033	-0.00005	27.161	35.1704
31	2023-05-01 02:45:00	-123.73685	-0.000017	27.384	35.2434
32	2023-05-01 14:45:00	-125.7429	-0.000067	27.171	35.2286
33	2023-05-02 02:45:00	-127.137267	-0.00515	27.621	35.281
34	2023-05-02 14:45:00	-128.212967	-0.000067	27.238	35.2148
35	2023-05-03 02:45:00	-130.204833	0.000033	27.406	35.2795
36	2023-05-03 14:45:00	-131.05545	-0.000033	27.371	35.2866
37	2023-05-04 02:45:00	-133.055667	0	27.934	35.3136
38	2023-05-04 14:45:00	-134.444033	0.0022	27.469	35.2559
39	2023-05-05 03:45:00	-136.2696	0.00005	27.729	35.3302
40	2023-05-05 15:45:00	-138.100367	-0.000033	27.509	35.2228
41	2023-05-06 03:45:00	-138.766183	0	27.734	35.2928
42	2023-05-06 15:45:00	-140.7882	-0.000083	27.457	35.2691
43	2023-05-07 03:45:00	-141.728933	-0.00755	27.591	35.3009
44	2023-05-07 15:45:00	-143.633933	-0.000117	27.524	35.3009

45	2023-05-08 03:45:00	-145.397267	-0.0011	27.845	35.4047
46	2023-05-08 15:45:00	-146.694433	-0.000067	27.683	35.3404
47	2023-05-09 03:45:00	-148.78635	0.000017	28.047	35.3572
48	2023-05-09 16:45:00	-149.835183	-0.0001	27.811	35.351
49	2023-05-10 04:45:00	-151.9247	0	28.128	35.4133
50	2023-05-10 16:45:00	-152.67865	0.005	27.857	35.3603
51	2023-05-11 04:45:00	-154.3729	0.000017	28.287	35.3577
52	2023-05-11 16:45:00	-156.3484	-0.00075	27.88	35.3045
53	2023-05-12 04:45:00	-157.686067	0	28.202	35.4073
54	2023-05-12 16:45:00	-159.7937	-0.0001	28.039	35.379
55	2023-05-13 04:45:00	-160.571117	0	28.523	35.4202
56	2023-05-13 17:45:00	-162.890167	-0.0001	28.231	35.3938
57	2023-05-14 05:45:00	-163.64255	0.00395	28.686	35.4397
58	2023-05-14 17:45:00	-165.393917	-0.000067	28.474	35.3977
59	2023-05-15 05:45:00	-167.30165	-0.000017	28.635	35.3998
60	2023-05-15 17:45:00	-168.365183	-0.0001	28.462	35.3366
61	2023-05-16 05:45:00	-170.543733	-0.02515	28.896	35.4368
62	2023-05-16 17:45:00	-170.946983	0.0003	28.416	35
63	2023-05-17 05:45:00	-172.754067	0	28.952	35.4071
64	2023-05-17 18:45:00	-174.6034	-0.00005	28.637	35.3842
65	2023-05-18 06:45:00	-175.869717	0	28.966	35.4072
66	2023-05-18 18:45:00	-178.0783	0	28.796	35.4336
67	2023-05-19 06:45:00	-179.0525	0	29.133	35.4512
68	2023-05-19	178.752733	-0.000017	28.923	35.4405

	18:45:00				
69	2023-05-20 06:45:00	177.965533	0.00005	29.281	35.4033
70	2023-05-20 18:45:00	175.748767	0	29.113	35.2963
71	2023-05-21 06:45:00	174.449533	0.001033	29.575	35.507
72	2023-05-21 18:45:00	173.127867	-0.159367	29.253	35.4376
73	2023-05-22 06:45:00	170.87015	-0.0048	29.695	35.4402
74	2023-05-22 18:45:00	169.9342	0.000017	29.534	35.4586
75	2023-05-23 06:45:00	167.810917	-0.000033	30.117	35.3297
76	2023-05-23 19:45:00	166.788483	-0.000133	29.899	35.2498
77	2023-05-24 07:45:00	164.605917	-0.000017	29.681	35.1607
78	2023-05-24 19:45:00	163.5001	-0.000017	29.935	35.1724
79	2023-05-25 07:45:00	161.953767	0	30.225	34.9031
80	2023-05-25 19:45:00	160	0.000083	29.831	34.6146
81	2023-05-26 07:45:00	158.767617	-0.7786	30.063	34.834
82	2023-05-26 19:45:00	157.860267	-1.353933	29.793	34.6825

12.9 Trace Gases (N_2O, CH_4, and CFCs) Samples

Table 12.12 List of stations and depths where samples for N_2O and CH_4 were taken.

Station	2	4	6	8	10	12	14	16	18	20	22
Depth (m)	1000	1000	1000	1300	1000	1000	1000	1000	1000	1000	1000
	700	600	750	1000	800	800	800	800	800	800	700
	400	400	450	750	600	500	550	550	600	550	470
	300	360	400	550	450	370	450	450	360	370	380
	200	200	250	450	370	300	360	360	270	250	350
	120	120	150	400	270	250	270	270	200	145	200
	75	70	150	325	200	200	200	200	120	120	150
	50	40	120	250	140	140	120	120	100	100	130
	20	15	80	200	90	120	80	80	80	75	120
	10	5	60	150	75	100	60	60	60	60	100
			45	95	60	80	35	45	40	40	90
			40	75	40	55	5	5	5	25	80
			35	50	15	45				5	70
			25	5		35					60
			15			30					55
			5			25					50
						15					40
						5					30
											20
											10
											5

Station	24	26	28	30	32	34	36	37	38	39	
Depth (m)	1000	1000	1000	1000	1000	1000	1000	1000	800	1200	
	800	800	800	800	800	800	800	800	600	843	
	600	600	600	600	600	600	600	600	400	700	
	480	450	420	410	410	420	420	500	260	600	
	360	360	350	370	290	340	260	400	200	454	
	220	280	270	290	190	260	200	260	160	400	
	150	200	200	200	130	200	160	200	130	260	
	125	150	145	170	100	150	150	160	100	200	
	90	125	135	125	80	100	130	100	80	175	
	70	100	100	100	65	80	120	80	60	150	
	55	75	75	75	45	60	100	60	40	140	
	40	60	65	60		45	100	40	10	125	
	10	40	50	45		20	80	20		120	
		10	20	20			60			100	
			5	5			45			100	
							40			80	
							30			80	
							20			65	
							5			60	
										55	
										45	
										40	
										40	
										25	
										20	
										5	

Table 12.13 List of stations and depths where samples for CFC were taken.

Station	6	8	13	16	21	25	29	33	36	38	39
Depth (m)	1000	1000	1000	1000	1000	1000	1000	800	800	1000	1824
	750	700	800	800	600	600	800	600	600	800	1200
	550	559	500	550	470	460	600	420	420	600	843
	400	400	360	450	355	350	360	270	280	420	700
	250	257	250	360	270	270	170	190	215	260	600
	150	148	120	270	200	200	130	165	170	185	454
	100	93	75	120	90	130	100	110	110	100	400
	76	75	60	80	75	70	80	70	90	80	240
	40	5	45	60	55	35	65	60	50	45	184
	5		15	5	10	5	10	10	10	10	125
											100
											80
											60
											40
											20

12.10 Samples for Nitrogen Fixation Measurements

Table 12.14 Sampling from shallow BIO-CTD

Sample No.	Station	Date (UTC)	Time (UTC)	Latitude	Longitude
2#	SO298_3_2	2023-04-15	23:45	-1.80	-81.90
4#	SO298_3_4	2023-04-17	01:12	-0.57	-83.73
6#	SO298_3_6	2023-04-18	20:10	-2.00	-89.00
8#	SO298_3_8	2023-04-20	00:15	0.00	-94.58
10#	SO298_3_10	2023-04-23	01:15	0.00	-100.97
12#	SO298_3_12	2023-04-25	09:35	0.00	-107.36
14#	SO298_3_14	2023-04-27	11:35	0.00	-113.75
16#	SO298_3_16	2023-04-29	17:40	0.00	-120.36
19#	SO298_3_19	2023-05-03	08:00	0.00	-130.79
22#	SO298_3_22	2023-05-06	23:30	0.00	-141.75
24#	SO298_3_24	2023-05-08	01:40	0.00	-149.05
26#	SO298_3_26	2023-05-11	18:20	0.00	-156.35
27#	SO298_3_27	2023-05-13	02:20	0.00	-160.00
29#	SO298_3_29	2023-05-15	06:00	0.00	-167.30
31#	SO298_3_31	2023-05-18	17: 50	0.00	-174.60
33#	SO298_3_33	2023-05-20	00:30	0.00	178.10
35#	SO298_3_35	2023-05-22	08:30	0.00	170.80
36#	SO298_3_36	2023-05-23	12:00	0.00	167.15
38#	SO298_3_38	2023-05-25	20:20	0.00	160.00

Table 12.15 Sampling from Underway

Sample No.	Date (UTC)	Time (UTC)	Latitude	Longitude
UW-1	2023-04-16	19:10	-0.97	-82.83
Station 7	2023-04-19	19:09	-2.00	-92.10
Station 9	2023-04-22	02:42	0.00	-97.78
Station 17	2023-04-30	22:50	0.00	-123.49
Station 18	2023-05-01	22:50	0.00	-127.15
Station 20	2023-05-04	17:30	0.00	-134.45
Station 21	2023-05-05	22:00	0.00	-138.09
Station 23	2023-05-08	01:40	0.00	-145.39
Station 25	2023-05-10	06:40	0.00	-152.69
Station 28	2023-05-13	06:00	0.00	-163.65
Station 30	2023-05-16	20:30	0.00	-170.95
Station 32	2023-05-19	22:00	0.00	-178.25
Station 34	2023-05-22	02:30	0.00	174.45
Station 37	2023-05-24	11:20	0.00	163.50

Table 12.16 Bioassay incubations

Experiment No.	Date (UTC)	Time (UTC)	Latitude	Longitude	Incubation period (h)
1#	2023-04-16	17:52	-0.97	-82.83	48
2#	2023-04-20	21:55	0.00	-94.58	48
3#	2023-04-25	06:20	0.00	-107.36	48
4#	2023-05-04	05:50	0.00	-130.79	48
5#	2023-05-09	04:20	0.00	-149.05	48
6#	2023-05-12	23:20	0.00	-160.00	48
7#	2023-05-19	20:30	0.00	-174.60	48
8#	2023-05-24	11:20	0.00	163.50	55

12.11 Bioassay Experiments Metadata

Table 12.17 List of experiments dates and times

Experiment number	UTC Date	UTC Time
1	16.04.2022	01:25
2	17.04.2022	01:12
3	18.04.2022	02:00
4	19.04.2022	01:52
5	20.04.2022	02:30
6	21.04.2022	01:00
7	22.04.2022	01:10
8	23.04.2022	02:30
9	24.04.2022	02:45
10	25.04.2022	02:50
11	26.04.2022	02:45
12	27.04.2022	02:45
13	28.04.2022	03:20
14	29.04.2022	03:35
15	30.04.2022	03:20
16	01.05.2022	02:50
17	02.05.2022	03:30
18	03.05.2022	04:30
19	04.05.2022	04:40
20	05.05.2022	05:20
21	06.05.2022	05:40
22	07.05.2022	05:40
23	08.05.2022	04:15
24	09.05.2022	04:40
25	10.05.2022	06:00
26	11.05.2022	06:30
27	12.05.2022	06:09
28	13.05.2022	06:20
29	14.05.2022	06:40

30	15.05.2022	07:13
31	16.05.2022	07:17
32	17.05.2022	07:02
33	18.05.2022	07:28
34	19.05.2022	07:46
35	20.05.2022	08:06
36	21.05.2022	08:06
37	22.05.2022	07:16
38	23.05.2022	08:24
39	24.05.2022	08:55
40	25.05.2022	08:50
41	26.05.2022	08:52

12.12 Dilution Experiments Metadata

Table 12.18 List of experiments dates and times

Experiment number	UTC Date	UTC Time
1	18.04.2023	00:30
2	26.04.2023	22:20
3	04.05.2023	02:50
4	11.05.2023	03:30
5	18.05.2023	04:45
6	23.05.2023	04:40