RV INVESTIGATOR

HYDROCHEMISTRY DATA PROCESSING REPORT

Voyage:	IN2025_V04
Chief Scientist	Dr. Rich Little
Voyage title:	Untangling the causes of change over 25 years in the southeast marine ecosystem - Voyage 4
Report compiled by:	Stephen Tibben and Pavie Nanthasurasak

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Executive Summary

Voyage Objectives

Southeast Australia's marine waters are part of a global ocean warming hotspot, where the East Australian Current is pushing southward and warming the region at four times the global average. These changes have led to shifts in species distributions, abundance, and ecosystem dynamics, with marine heatwaves adding further stress. Within this hotspot lies the Southeast Marine Park Network (SE-MPN), established to protect biodiversity and support long-term ecological health. However, it remains unclear whether the network is mitigating the observed changes or being impacted by them. Addressing this uncertainty is essential for improving conservation strategies and managing Australia's marine heritage.

This region also supports vital fisheries, including the Southern and Eastern Scalefish and Shark Fishery, which provides much of the fresh fish to Melbourne and Sydney. Over the past two decades, notable changes in fish catch rates and species composition point to significant ecological shifts—possibly driven by climate change, fishing pressure, or both. To better understand these changes, this project repeated ecosystem surveys last conducted 25 years ago, establishing new biological and environmental baselines. IN2025_V04 was the final in a series of four surveys designed to investigate how fish communities, habitats, and food webs have changed, and to inform more adaptive management of marine parks, fisheries, and other ocean industries.

The voyage operated in two 12-hour shifts to collect data on demersal fish communities, benthic habitats, water column structure, and prey availability using trawls, CTDs, mid-water nets, and a deep towed camera.

General Hydrochemistry Information

Water samples collected during CTD deployments were processed in the ship’s hydrochemistry laboratory and analysed for key parameters, including nutrients, dissolved oxygen, and salinity. Dissolved inorganic carbon and total alkalinity samples were also collected at selected stations to continue the time series established during previous voyages, with these samples to be analysed on shore by the CSIRO carbon team. Additionally, Thermosalinograph (TSG) samples were continuously collected throughout the voyage, with on-board measurements of their salinity used to calibrate the ship's underway system.

Please cite the following manuscript when reporting or publishing data for silicate, phosphate, nitrate+nitrite (NO_x) and nitrite:

Rees, C., L. Pender, K. Sherrin, C. Schwanger, P. Hughes, S. Tibben, A. Marouchos, and M. Rayner. (2018) "*Methods for reproducible shipboard SFA nutrient measurement using RMNS and automated data processing*."

Limnol. Oceanogr: Methods, 17(1): pp. 25-41.

doi:10.1002/lom3.10294

If publishing ammonium data, please cite the following:

Rees, C., Janssens, J., Sherrin, K., Hughes, P., Tibben, S., McMahon, M., McDonald, J., Camac, A., Schwanger, C. and Marouchos, A., (2021*) "Method for Reproducible Shipboard Segmented Flow Analysis Ammonium Measurement Using an In-House Reference Material for Quality Control."*

Frontiers in Marine Science, 8.

doi:10.3389/fmars.2021.581901

The final hydrology dataset, data processing report, analytical methods, related log sheets and processing notes can be obtained from the CSIRO data centre. Please visit CSIRO data trawler, should there be any inquiries on hydrology data please contact CSIRO data centre at NCMI_DataLibrarians@csiro.au.

Itinerary and Voyage track

Table 1. Voyage itinerary

	Depart	**Arrive**
Port	Hobart	Hobart
Date	27/05/2025	28/06/2025
Time	0830	0800

Figure 1. Voyage map of IN2025_V04.

Key personnel list

Table 2. Key Personnel list on IN2025_V04

Name	Role	Organisation
Dr. Rich Little	Chief Scientist	CSIRO
Tegan Sime	Voyage Manager	CSIRO
Stephen Tibben	Hydrochemist	CSIRO
Pavie Nanthasurasak	Hydrochemist	CSIRO

Sample Summary

Sample Type and Number Assayed

Table 3. Hydrochemistry sample type and analysis summary for IN2025_V04

Analysis	Instrument	Sample source/type	Number of samples
Nutrients	Seal AA3HR	Conductivity-Temperature-Depth (CTD)	583
Salinity	Guidline Autosal	Conductivity-Temperature-Depth (CTD) Thermosalinograph (TSG)	372 30
Dissolved oxygen (DO)	Scripps automated titration	Conductivity-Temperature-Depth (CTD)	370

CTD sample (Conductivity, Temperature, Depth)

Table 4. CTD summary for IN2025_V04

Rosette type	36
Niskin Bottle size	12 L
Number of deployments	61
Number of deployments sampled for hydrochemistry analyses	61
CTD sampling order	Dissolved Oxygen (DO) → Dissolved Inorganic Carbon (DIC) → Total Alkalinity (TA) → Nutrients → Salinity *Note: Total Alkalinity (TA) samples are collected immediately after Dissolved Inorganic Carbon (DIC) to minimize the sampler's exposure to mercuric chloride ($HgCl_2$).*
Sample bottle	50 mL HDPE with screw cap lids
Sample log	CTD deployment paper log sheet and CAP Deployment Log Editor version 1.4.5
Sampling personnel (hydrochemistry)	Stephen Tibben and Pavie Nanthasurasak
Sampling personnel (science party)	Camila Cataldo Mendez and Frank Coman

Thermosalinograph sample (TSG)

Table 5. TSG summary for IN2025_V04

TSG source	Instrument clean seawater line supplying the pCO2 instrument in the underway laboratory
Sample bottle	200 mL volume type I (clear) borosilicate bottle with rubber liner lid and aluminium crimp cap
Sample log	TSG Samples Event Logs (available on CSIRO data trawler)
Sampling personnel (hydrochemistry)	Stephen Tibben and Pavie Nanthasurasak
Sampling personnel (science party)	N/A

Data Processing Overview

The sample meta-data, measured bottle salinity results, dissolved oxygen assay results and the nutrient assay raw data are processed using the CSIRO-developed program HyPro. This processing generates the final hydrology dataset. An overview of this process is illustrated below (fig.2).

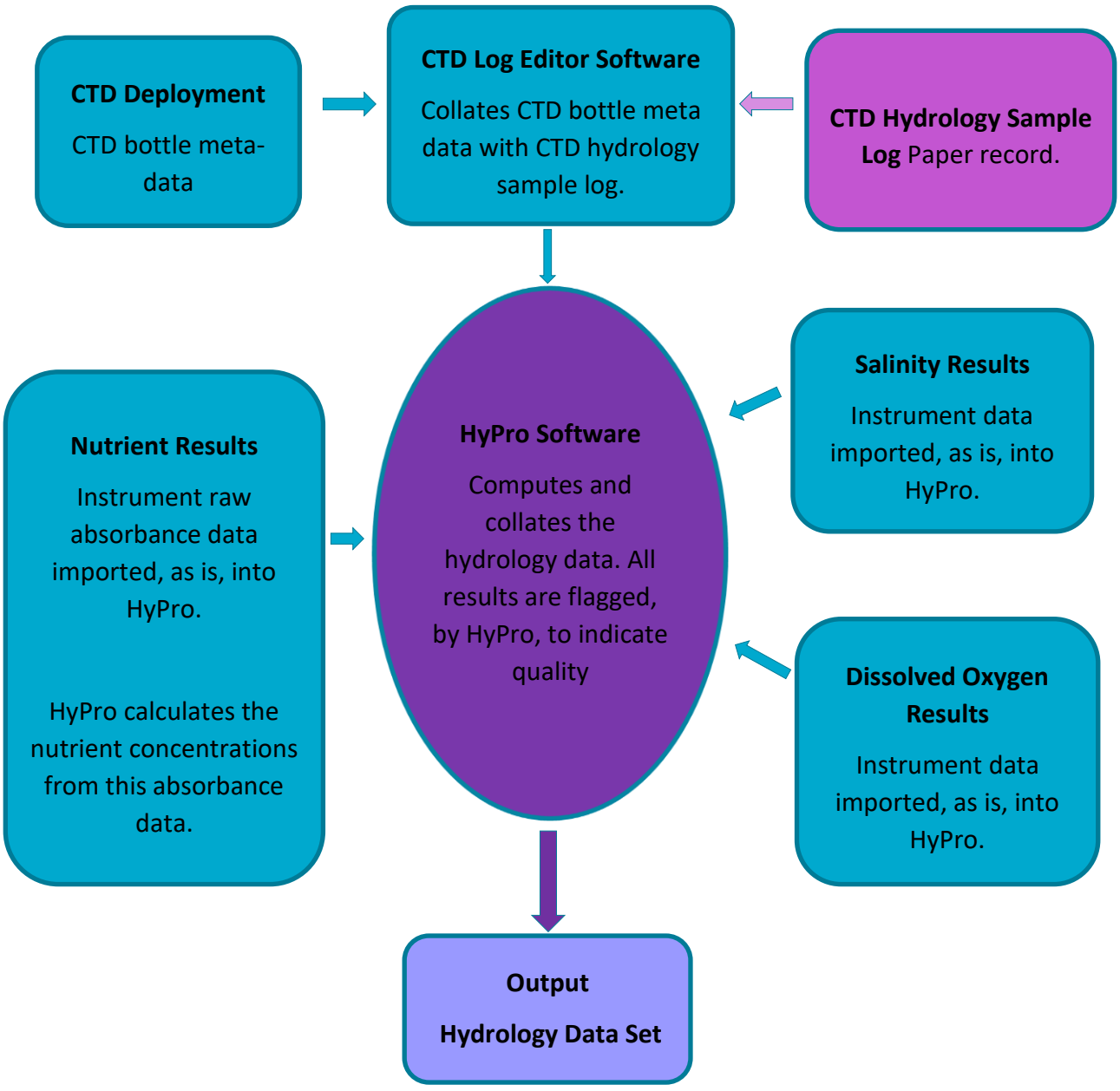

Figure 2. Conventional Hydrology Data Processing Flow Diagram.

Salinity

Salinity Measurement Parameters

Table 6. Salinity Measurement Parameters

Details	
HyPro Version	5.7
Instruments	Guildline Autosal Laboratory Salinometer 8400(B) – SN 72873 and SN 74680 (run 016-017). Bath temperature 24.0°C
Software	Ocean Scientific International Ltd (OSIL) Data Logger ver 1.2
Hydrochemistry Methods	Sampling: Salinity - WI_Sal_001, TSG – WI_Sal_004 Analysis: SOP 006
Accuracy	± 0.001 practical salinity units (PSU)
Reference Material	OSIL IAPSO – Batch P168, use by 01 December 2026, K_{15} = 0.99993
Sample Container	CTD: 200 mL volume OSIL bottles made of type II glass (clear) with disposable plastic insert and plastic screw cap. TSG: 200 mL volume type I (clear) borosilicate bottle with rubber liner lid and aluminium crimp cap.
Sample Storage	Stored in salinometer lab for minimum of 8 hrs before measurement.
Analyst	Stephen Tibben and Pavie Nanthasurasak

Salinity Method

Salinity samples were measured on a Guildline Autosal 8400B, operated in accordance with the manufacterer's technical manual. The measured value is recorded with an OSIL data logger.

Practical salinity (S) is defined as the ratio (K_{15}) of the electrical conductivity of seawater measured at 15°C, 1 atm to that of a potassium chloride (KCl) solution of mass fraction 32.4356 x 10^{-3}.

Before each lot of sample measurements, the Autosal was calibrated with standard seawater (OSIL, IAPSO) with a known K_{15} ratio. A fresh bottle of OSIL standard is used for each calibration, and calibration is performed at least once per run.

Method summary: The salinity sample is collected in a 200 mL glass bottle. The bottle is rinsed three times with sample, then filled from the bottom, via a polytetrafluoroethylene (PTFE) straw, until overflowing. The bottle is removed from the straw and the sample is decanted to allow a headspace of approximately 25 cm^3. A dry plastic insert is fitted, the bottle inverted and rinsed with ultra-pure water, wiped dry, capped and stored upside down until analysis. To measure, the salinometer cell is flushed three times with the sample and then measured after the third and fourth flush. The OSIL data logger software captures the conductivity ratio and calculates the practical salinity.

The output from the data logger is imported into HyPro and linked with the CTD deployment meta-data.

CTD Salinity vs Bottle Salinity

For this voyage, the difference between the unprocessed (uncorrected) CTD value and the measured bottle value is generally less than 0.03 PSU. The larger differences are often observed in shallow samples, where sudden changes in the thermohaline profile occurs. These discrepancies can also be attributed to mismatches between the CTD downcast and upcast profiles. CTD sensor data were recorded on the downcast, while bottle samples were collected on the upcast.

The unprocessed CTD values are adjusted (corrected) by DAP using the salinity bottle results. The corrected values are not reported in the hydrology set. Please refer to IN2025_V04 CTD data on CSIRO data trawler for corrected sensor data.

OSIL Salinity Standard

For each salinity analysis conducted on this voyage, the instrument was calibrated with OSIL standard seawater, lot P168 (PSU = 34.997).

The mean measured value for the P168 OSIL standard seawater across the voyage was:

Mean = 34.9972 PSU SD = 0.00009 n = 20

Dissolved Oxygen

Dissolved Oxygen Measurement Parameters

Table 7. Dissolved oxygen measurement parameters.

Details	
HyPro Version	5.7
Instrument	Scripps Automated Photometric Oxygen System (SIO)
Software	Scripps Institution of Oceanography (SIO)
Hydrochemistry Methods	Sampling: WI_DO_001 Analysis: SOP 005
Titrant	50 g/L Sodium Thiosulphate
Primary standard	0.0123510 N and 0.0123519 N Potassium Iodate
Accuracy	± 0.5 µmol L^{-1}
Sample Container type	140 mL glass iodine determination flasks with glass stopper
Sample Storage	Samples stored in the hydrochemistry lab until analysis. Analysis performed within 48 hours.
Analyst	Stephen Tibben and Pavie Nanthasurasak

Dissolved Oxygen Method

Scripps Institution of Oceanography (SIO) method used for dissolved oxygen analysis. The method is based on the whole bottle modified Winkler titration of Carpenter (1965) with modifications from Culberson *et al* (1991).

Method summary: The sample is collected in an iodine determination flask of known volume. To the sample, 1 mL of manganese (II) chloride solution is added, followed by 1 mL of alkaline iodide solution. The flask is then stoppered and inverted at least 30 times. Dissolved oxygen in the sample oxidizes an equivalent amount of Mn (II) to Mn (IV) which forms a precipitate. Just before titration, the sample is acidified, reducing Mn (IV) back to the divalent state and liberating an equivalent

amount of iodine. The iodine is titrated with a standardised thiosulphate solution using a Metrohm Dosimat fitted with a 1 mL burette. The titration endpoint is determined by measuring the decrease in the UV absorption at 365 nm.

The thiosulphate solution is standardised by with a 10 mL aliquot of potassium iodate primary standard. A blank correction is also determined from the difference between two titres of consecutive additions of 1 mL aliquots of potassium iodate to the same blank sample. The standardisation is conducted at least once every 24 hours, when samples are being assayed.

The output from the SIO instrument software is imported into HyPro and collated with the CTD deployment meta-data.

CTD Dissolved Oxygen vs Bottle Dissolved Oxygen

For this voyage, the difference between the unprocessed CTD value and the measured bottle value is generally less than 10 µmol L^{-1}. The larger differences are often observed in shallow samples where the sudden changes and or mixing in the dissolved oxygen profile occur.

The unprocessed CTD values are adjusted (corrected) by DAP using the dissolved oxygen bottle results. The corrected values are not reported in the hydrology set. Please refer to IN2025_V04 CTD data on CSIRO data trawler for corrected sensor data.

Dissolved Oxygen Instrument titrant: thiosulphate normality and blank correction

The variation in thiosulphate concentration remains within the QC parameter of less than 0.0005 N between standardisations. The blank correction, which accounts for oxidisable species in the reagents and in the MQ water that is added to the KIO_3 aliquot before the titration, is used in the calculation of the thiosulphate normality.

The mean normality of thiosulphate for this voyage was:

Mean: 0.201405 N SD: 0.000063 n = 32

The mean blank concentration was:

Mean: 0.00056 mL SD: 0.00010 n = 32

Nutrients

Nutrient Measurement Parameters

Table 8. Nutrient measurement parameters analysed with Seal AA3HR segmented flow analyser. All instrument parameters, reagent batches, and instrument events are logged for each analysis run. This information is available on request.

Details					
Instrument	Seal AA3HR segmented flow analyser				
HyPro version	5.7				
Operating Software	AACE 7.10				
Hydrochemistry Sampling Method	WI_Nut_001				
Hydrochemistry analysis method	SOP001	SOP002	SOP003	SOP003	SOP004
Nutrients analysed	Silicate ($SiO4^{4-}$)	Phosphate (PO_4^{3-})	Nitrate + Nitrite (NO_x)	Nitrite (NO_2^-)	Ammonia (NH_4^+)
Top concentration (µmol L^{-1})	112.0	3.0	36.4	1.4	2.0
Method detection limit (MDL) (µmol L^{-1})	0.2	0.02	0.02	0.02	0.02
Stock standards	Made on 13th of May 2025 and prepared for open ocean concentration in 1L HDPE bottle				
Intermediate standards	Prepared every 72 hours in 30 mL polypropylene tubes and refrigerated. Reused after acid wash with 10% hydrochloric acid solution.				
Working standards	Prepared every 72 hours in 30 mL polypropylene tubes and refrigerated. Reused after acid wash with 10% hydrochloric acid solution.				
Reference Material	KANSO RMNS lot CR				

Sample Container	CTD: 50 mL HDPE with screw cap lids. Reused after acid wash with 10% hydrochloric acid solution.
Sample Storage	< 4 hours at room temperature after collection or < 12 hours at 4°C after collection
Sample preparation	No filtration.
Analysts	Stephen Tibben and Pavie Nanthasurasak

Nutrient Methods

Nutrient samples are analysed using a Seal AA3HR segmented flow auto-analyser, equipped with 1 cm flow-cells for colorimetric measurements. Shimadzu RF-10AXL fluorescence detector was used for ammonium measurement.

Silicate (SOP001): colourimetric, molybdenum blue method. Based on Armstrong et al. (1967). Silicate in seawater is reacted with acidified ammonium molybdate to produce silicomolybdic acid. Tartaric acid is added to remove the phosphate molybdic acid interference. Tin (II) chloride is then added to reduce the silicomolybdic acid to silicomolybdous acid and its absorbance is measured at 660 nm.

Phosphate (SOP002): colourimetric, molybdenum blue method. Based on Murphy and Riley (1962) with modifications from the NIOZ-SGNOS[1] Practical Workshop 2012 optimizing the antimony catalyst/phosphate ratio and the reduction of silicate interferences by pH. Phosphate in seawater forms a phosphomolybdenum complex with acidified ammonium molybdate. It is then reduced by ascorbic acid and its absorbance is measured at 880 nm.

Nitrate (SOP003): colourimetric, Cu-Cd reduction – naphthylenediamine method. Based on Wood et.al (1967). Nitrate is reduced to nitrite by first adding an ammonium chloride buffer then sending it through a copper - cadmium column. Sulphanilamide is added under acidic conditions to form a diazo compound. This compound is coupled with 1-N-naphthly-ethylenediamine di-hydrochloride to produce a magenta azo complex and its absorbance is measured at 540 nm.

Nitrite (SOP003): colourimetric, naphthylenediamine method. As per nitrate method without the copper cadmium reduction column and buffer. Absorbance measured at 520 nm.

Ammonium (SOP004): fluorescence, ortho-phtaldiadehyde method. Based on Kérouel and Aminot (1997). Ammonium reacted with ortho-phtaldialdehyde and sulphite at a pH of 9.0-9.5 to produce an intensely fluorescent product. Its emission is measured at 460 nm after excitation at 370 nm.

SOP methods can be obtained from the CSIRO Oceans and Atmosphere Hydrochemistry Group.

[1] Royal Netherlands Institute for Sea Research – Study Group on Nutrient Standards.

HyPro Processing Summary for Nutrients

After a run, the raw absorbance/ fluorescence data is exported from the instrument and processed by HyPro. For each analyte, HyPro re-constructs the peak traces and defines peak window, which corresponds to the plateau region used to determine the peak heights. HyPro then constructs the calibration curve and applies corrections for carry-over, baseline, and sensitive drifts, then the nutrient concentrations for each sample are calculated. The corrections are quantified using dedicated solutions included in every run.

HyPro applies specific criteria to identify suspect calibration points, noisy peaks, method detection limits above the nominal threshold, and duplicate sample results that do not match.

Suspect calibration points are given less weight when fitting the calibration curve. The cut-off limits for acceptable calibration data are as followed:

- ±0.5% of the concentration of the top standard for silicate and nitrate+nitrite (as per WOCE[1]).
- 0.02 µmol L^{-1} for phosphate, nitrite, and ammonium.

HyPro classifies data quality as good, suspect, or bad and flags the results accordingly. The Flag key can be found in Appendix, Data Quality Flag Key. Missing or suspect nutrient data is listed in Appendix, Missing or Suspect Nutrient Data.

[1] World Ocean Circulation Experiment

Table 9. HyPro 5.7 Processing Parameters. All instrument parameters and reagent batches and operation events are logged for each analysis run. This information is available on request.

Result Details	Silicate	Phosphate	Nitrate + Nitrite	Nitrite	Ammonia
Data Reported as	µmol L^{-1}	µmol L^{-1}	µmol L^{-1}	µmol L^{-1}	µmol L^{-1}
Calibration Curve fit	Linear	Linear	Linear	Quadratic	Quadratic
# of points in Calibration	6	6	6	6	6
Forced through zero	N	N	N	N	N

Matrix correction	N	N	N	N	N
Blank correction	N	N	N	N	N
Peak window defined by	HyPro	HyPro	HyPro	HyPro	HyPro
Carryover correction	Y	Y	Y	Y	Y
Baseline drift correction	Y	Y	Y	Y	Y
Sensitivity drift correction	Y	Y	Y	Y	Y
Data Adjusted for RMNS variance	N	N	N	N	N
Medium of Standards	Low nutrient seawater (LNSW, bulk on PW1 wharf, CSIRO Hobart) collected in October 2022. Sub-lot passed through a 5-micron filter (filtered in October 2024) and stored in 20 L carboys in the hydrochemistry laboratory at 20°C.				
Medium of Baseline	18.2 MΩ water. Dispensed from the Milli-Q IQ 7010 system.				
Duplicate samples	CTD: Niskin fired at the greatest depth were analysed in duplicate. Single samples were analysed for remaining depths.				
Note	The reported data is not corrected to the RMNS. Per deployment RMNS data is provided in supporting document.				

Accuracy - Reference Material for Nutrient in Seawater (RMNS)

Descriptive statistics are used to ascertain the accuracy and precision of the analysis from the repetitive measurement of the RMNS for silicate, phosphate, NOx, nitrite and ammonia in seawater.

For this voyage, Japanese KANSO certified RMNS lot CR was assayed in triplicates in each run to monitor accuracy (Table 10). RMNS CP and CM were only analysed in the characterisation (run 001) run as additional accuracy monitoring at the start of the voyage without samples. An internal bulk quality control (BQC) was also analysed in each analysis run.

The GO-SHIP criteria (Hyde *et al*., 2010), Appendix, GO-SHIP Specifications, specifies using 1-3% of full scale (depending on the nutrient) as acceptable limits of accuracy.

KANSO publishes the RMNS nutrient values in µmol kg^{-1}. These are converted to µmol L^{-1} at 21°C. NO_x is derived by summing the NO_3 and NO_2 values.

Table 10. RMNS certified concentrations ± expanded uncertainty (U) at 21°C. Units: µmol L^{-1}

RMNS	Silicate	Phosphate	Nitrite	Nitrate + Nitrite	Ammonia
Lot CR	14.3389 ± 0.3073	0.4035 ± 0.0143	0.9935 ± 0.0717	6.5856 ± 0.2356	0.9730 ± 0.1536

Table 11. RMNS CR statistics for of this voyage. Units: µmol L^{-1}

RMNS CR	Silicate	Phosphate	Nitrite	Nitrate + Nitrite	Ammonia
Mean	14.30	0.411	1.01	6.44	0.967
Standard deviation	0.07	0.007	0.01	0.03	0.020

RMNS plots

The measured RMNS values for each nutrient analysis run on this voyage is shown in plots below. The green, pink, and red contour lines represents 1%, 2% and 3% or 1*MDL, 2*MDL and 3*MDL (MDL = 0.02 µmol L^{-1}) deviation from the RMNS certified mean value. The blue line is the manufacturer's expanded uncertainty of the certified value. The measured RMNS values per CTD deployments are provided in the supporting documents.

For this voyage, results for RMNS lot CR show high agreement with certified values, with calculated results falling within the expanded uncertainty:

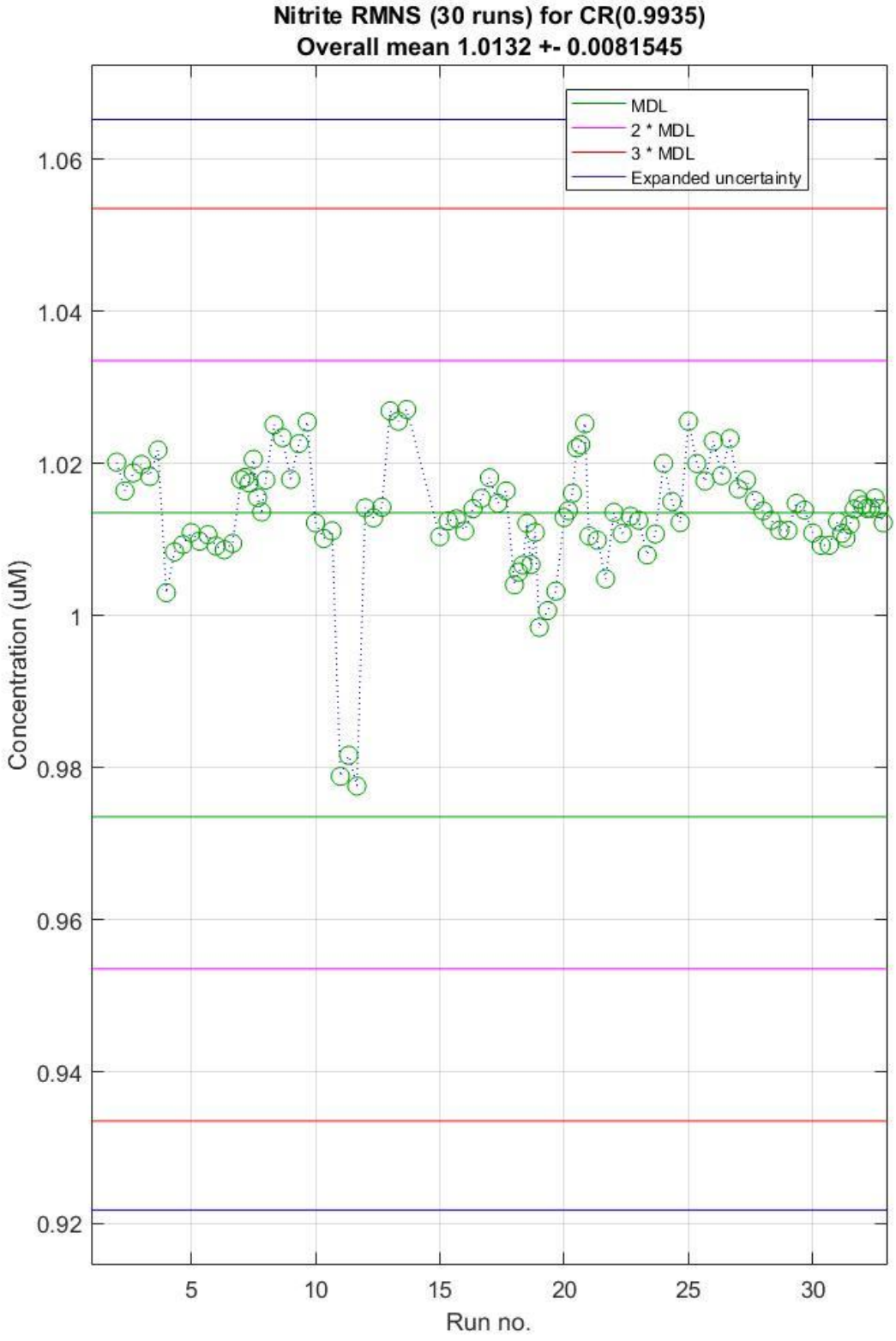

Figure 3. Nitrite RMNS lot CR plot. Units: µmol L^{-1}.

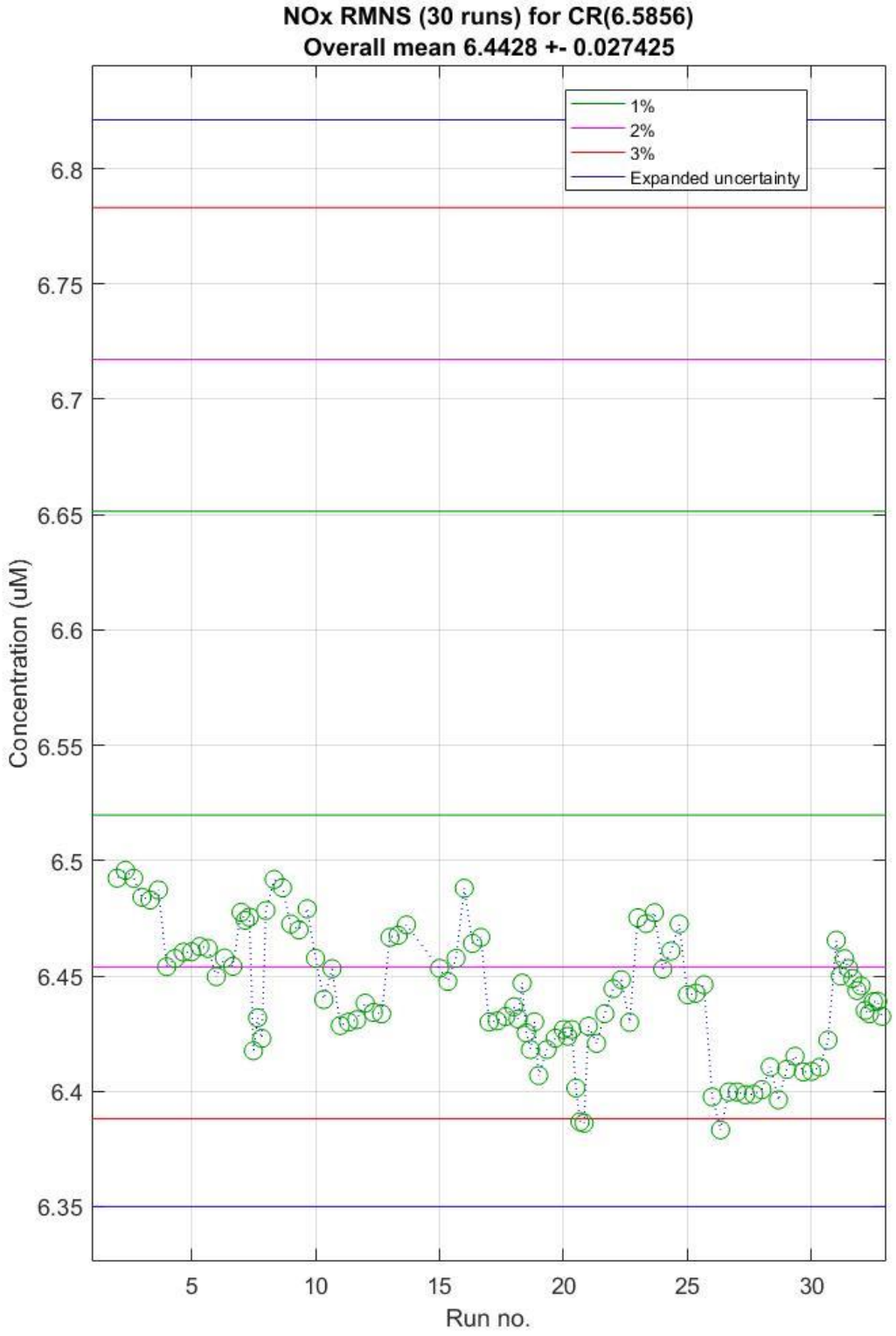

Figure 4. Nitrate + Nitrite (NOx) RMNS lot CR plot. Units: µmol L^{-1}.

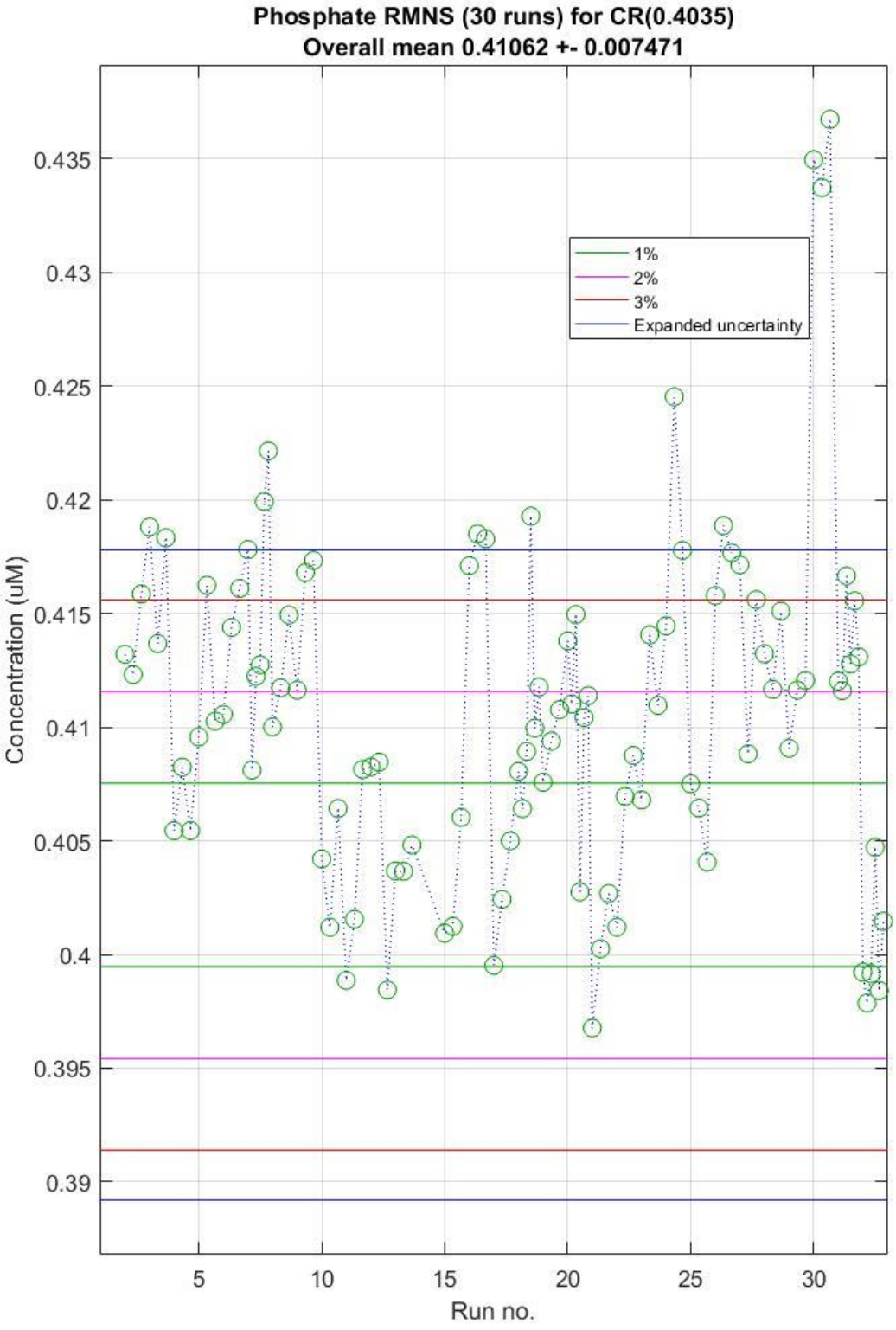

Figure 5. Phosphate RMNS lot CR plot. Units: Units: µmol L^{-1}.

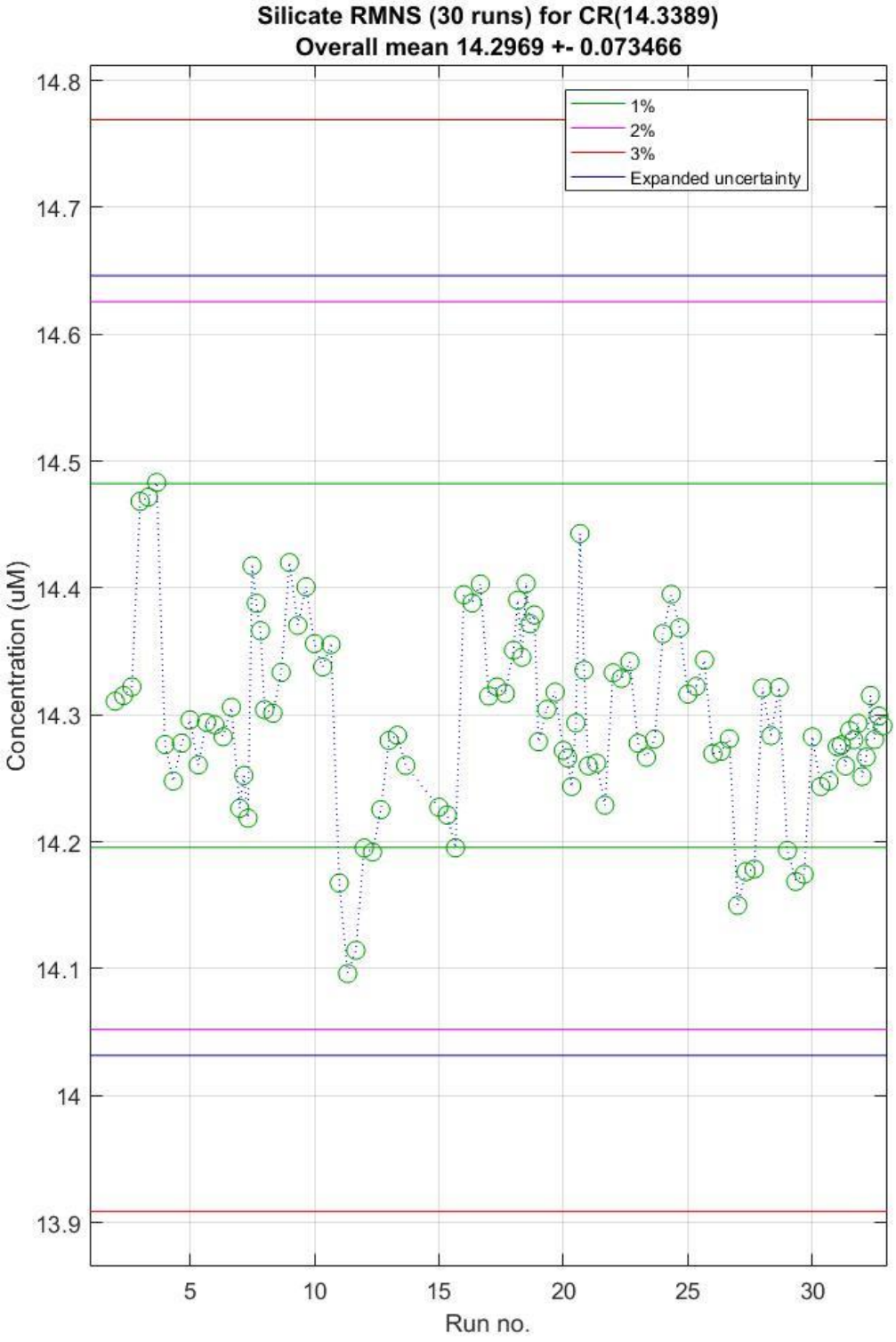

Figure 6. Silicate RMNS lot CR plot. Units: Units: µmol L^{-1}.

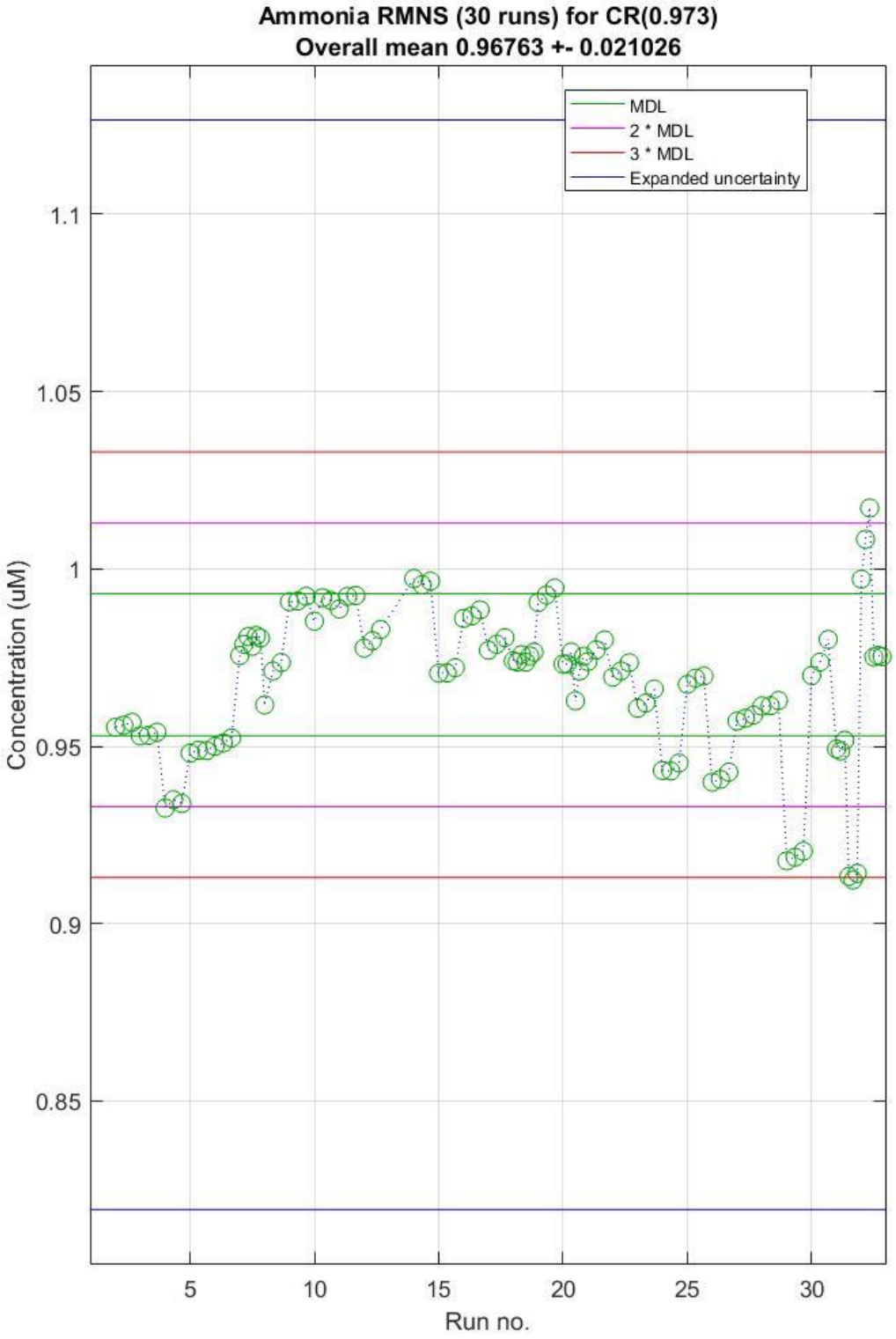

Figure 7. Ammonia RMNS lot CR plot. Units: Units: µmol L^{-1}.

Measurement Uncertainty

The CSIRO hydrochemistry method measurement uncertainty (MU) has been calculated for each nutrient based on the variation in the calibration curve, calibration standards, pipette and glassware calibration, and precision of the RMNS over time (Armishaw 2003).

Table 12. CSIRO Hydrochemistry nutrient analysis uncertainty values. Units: µmol L^{-1}

Calculated Measurement Uncertainty at 1 µmol L^{-1}				
Silicate	**Phosphate**	**Nitrite**	**Nitrate + Nitrite**	**Ammonia**
±0.017	±0.024	±0.140	±0.019	±0.30

The reported uncertainty is an expanded uncertainty using a coverage factor of 2 giving a 95% level of confidence.

Method Detection Limit for Nutrients

The method detection limit (MDL) is defined as three times the standard deviation (SD) of the LNSW results (National Association of Testing Authorities 2013). The MDL is used to assess the precision of the analysis at low nutrient concentrations.

Table 13. AA3HR auto analyser MDL statistics for this voyage. The mean and standard deviation are calculated from every analytical run performed over the voyage. Units: µmol L^{-1}.

MDL	**Silicate**	**Phosphate**	**Nitrite**	**Nitrate + Nitrite**	**Ammonia**
Nominal MDL	**0.2**	**0.02**	**0.02**	**0.02**	**0.02**
Mean	0.03	0.009	0.006	0.005	0.003
Standard deviation	0.03	0.006	0.003	0.003	0.001

Sampling Precision

Sampling precision is typically determined using the CTD test deployment (CTD 1) where multiple bottles are fired the same depth, each of which is then sampled for hydrochemistry. For

IN2025_V04, the CTD test cast was not deployed; therefore sampling precision from CTD 1 is not reported for this voyage.

Duplicate nutrient samples are also collected from the greatest depth of subsequent CTD deployments. For nutrients analysis, the sampling precision is considered good if the difference from the mean of duplicate measurements is less than the nominal method detection limit (Table 13). The exception is for NOx (nitrate+nitrite), which uses the limit of 0.06 µmol L^{-1}. Duplicate samples that exceed this limit are flagged. These are tabulated in Appendix, Data Quality Flag Key.

Temperature

Hydrochemistry lab and nutrient analyser

Ambient conditions in the hydrochemistry laboratory and on the segmented flow analyser were monitored at the following locations:

- Hydrochemistry lab temperature: positioned in close proximity to the autoanalyser
- Nutrient sample pump temperature: positioned on the pump tubes where nutrient samples and reagents are introduced into the analyser

Temperature data was measured using Ruuvi temperature logger and monitored in Grafana. A time series plot of hydrochemistry laboratory temperature plot throughout the voyage is shown below. The average analyser pump temperature of the analyser during each nutrients analysis is provided in supporting documents available on CSIRO data trawler.

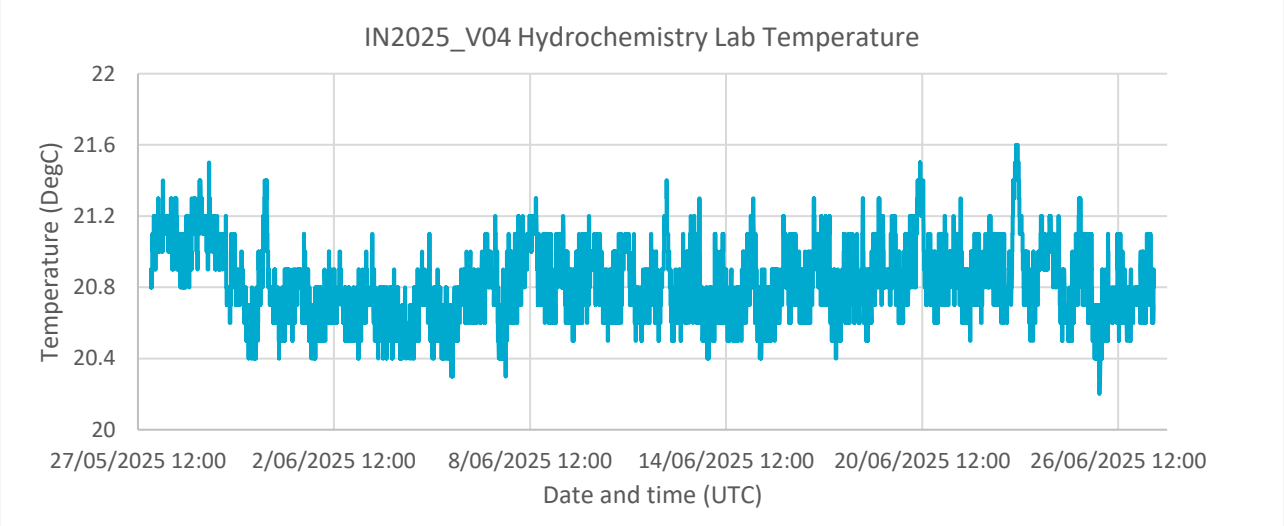

Figure 8. Hydrochemistry lab Ruuvi sensor; scale is 20°C to 22°C, mean: 20.8°C, SD: 0.2°C.

Salinity laboratory

Ambient conditions in the salinity laboratory were monitored using a Ruuvi temperature logger positioned near the area where sample crates were stored. Temperature data was recorded and visualised in Grafana. A time series plot of salinity lab temperature throughout the voyage is shown below. A complete log of salinity lab is provide in supporting documents.

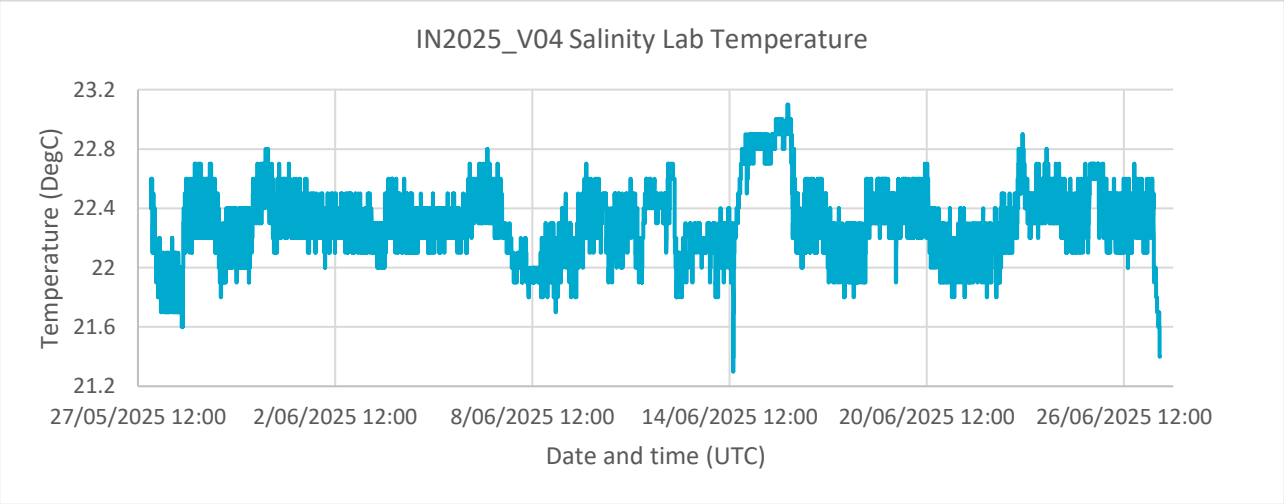

Figure 9. Salinity lab Ruuvi sensor; scale is 21.2°C to 23.2°C, mean: 22.3°C, SD: 0.2°C.

Appendix

Salinity: Reference material used

OSIL IAPSO Standard Seawater	
Batch	P168
Use by date	1 December 2026
K_{15}	0.99993
PSU	34.997

Nutrients: RMNS correction

The submitted nutrient results do NOT have RMNS corrections applied. The measured RMNS value per CTD deployment is provided in supporting document.

How to use the RMNS for correction

Ratio = Certified RMNS Concentration/Measured RMNS Concentration in each run

Corrected Concentration = Ratio x Measured Nutrient Concentration

How to use the RMNS for smoothing

Ratio = Average RMNS Concentration across voyage/Measured RMNS Concentration in each run

Corrected Concentration = Ratio x Measured Nutrient Concentration

Missing or Suspect Salinity Data

Data is flagged based on CTD sampling log notes, observations during analysis, and examination of depth profile plots (Appendix, Data Quality Flag Key).

CTD	RP	Flag	Reason for Flag
N/A	N/A	N/A	N/A

Missing or Suspect Dissolved Oxygen Data

Data is flagged based on CTD sampling log notes, observations during analysis, and examination of depth profile plots (Appendix, Data Quality Flag Key).

CTD	RP	Flag	Reason for Flag
N/A	N/A	N/A	N/A

Missing or Suspect Nutrient Data

Data is flagged based on CTD sampling log notes, observations during analysis, and examination of depth profile plots (Appendix, Data Quality Flag Key).

CTD	RP	Analyte	Flag	Reason for Flag
13	2	NH4	133	Data is bad, marked by operator. Apparent contamination since duplicate is outside of set limits.
31	2	NH4	133	Data is bad, marked by operator. Apparent contamination since duplicate is outside of set limits.
39	2	NH4	133	Data is bad, marked by operator. Apparent contamination since duplicate is outside of set limits.

Data Quality Flag Key

Flag	Description	
0	Data is GOOD	
63	Nutrients only.	Data below nominal detection limit.
65	Data is SUSPECT.	Nutrients only: Absorbance peak shape, measured by the instrument, is marginally outside set limits.
69	Data is SUSPECT.	Duplicate data is outside of set limits (software). Data point is an outlier on the depth profile plot (operator). Tagged by software or operator

79	Data is SUSPECT.	Nutrients only. Measured Method Detection Limit (MDL) for the analysis run is greater than the nominal MDL. All samples in that run tagged.
129	Data is BAD.	Nutrients Only. Absorbance peak exceeds the maximum value that can be measured by the instrument.
133	Data is BAD.	Set by operator.
134	Data is BAD.	Nutrients Only. Absorbance peak shape of calibrant, measured by the instrument, is outside of set limits (software).
141	NO Data.	Used in netcdf results file. Not used in csv results file.

GO-SHIP Specifications

Salinity

Accuracy of 0.001 is possible with Autosal™ salinometers and concomitant attention to methodology. Accuracy with respect to one particular batch of Standard Sea Water can be achieved at better than 0.001 PSS-78. A precision of approximately 0.0002 PSS-78 is possible following the methods of Kawano with great care and experience. Air temperature stability of ± 1°C is very important and should be recorded[2].

Dissolved Oxygen

Target accuracy is that 2 sigma (standard deviation) should be less than 0.5% of the highest concentration found in the ocean. Precision or reproducibility (2 sigma) is 0.08% of the highest concentration found in the ocean.

$Si(OH)_4$

Approximately 1-3% accuracy[1], 0.2% precision[3], full scale.

PO_4

Approximately 1-2% accuracy[1], 0.4% precision[3], full scale.

NO_3

Approximately 1% accuracy[1], 0.2% precision[3], full scale.

Notes

[1] If no absolute standards are available then accuracy should be taken to mean the reproducibility presently obtainable in the better laboratories.

[2] Keeping constant temperature in the room where salinities are determined greatly increases their quality. Also, room temperature during the salinity measurement should be noted for later interpretation if queries occur. Additionally, monitoring and recording the bath temperature is also recommended. The frequent use of IAPSO Standard Seawater is endorsed. To avoid the changes that occur in Standard Seawater, the use of the most recent batch is recommended. The bottles should also be used in an interleaving fashion as a consistency check within a batch and between batches.

[3] Developments of reference materials for nutrients are underway that will enable improvements in the relative accuracy of measurements and clearer definition of the performance of laboratories when used appropriately and the results are reported with the appropriate meta-data.

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