RV *INVESTIGATOR*

HYDROCHEMISTRY DATA PROCESSING REPORT:

AA100 Continuous Underway Nutrients

Voyage:	IN2026_V02
Chief Scientist	Prof. Nicole Jones
Voyage title:	Quantifying the fine scale ocean dynamics of the Ningaloo Coast
Report compiled by:	Merinda McMahon, Kurt Debruille, Stephen Tibben and Julie Janssens

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Executive Summary

Voyage Objectives

1. Develop and test novel techniques to derive, with quantified uncertainty, oceanic submesoscale currents (0.1-10 km) from remotely sensed sea surface height (SSH) and/or sea surface temperature (SST) observations.
2. Optimise data assimilation techniques for improved ocean reanalysis and forecasts.
3. Investigate lateral and vertical transport processes associated with oceanic submesoscale currents and their relation to turbulent mixing within the surface mixing layer.
4. Quantify the fluxes of nutrients to Ningaloo Reef.
5. Characterise the submesoscale current fields on the Ningaloo Coast and quantify spatial variability of eddy properties including hotspots of submesoscale activity that control ocean transport.

Hydrochemistry Information

For continual underway nutrient measurements, the Auto Analyser 100 (AA100) was set up in the Underway Seawater Lab. The AA100 is a compact nutrient analyser capable of continuous measurements. The AA100 measured Nitrate + Nitrite (NOx) and phosphate from the 'instrument clean' seawater intake of RV Investigator. The 'instrument clean' seawater line was cleaned with sodium hypochlorite from the intake in the drop keel to the outlet in the underway seawater lab in March 2026, prior to the voyage.

Over 250 hours of data was measured by the AA100 over the course of the voyage. The underway measurements were made continually, but due to the nature of the method and the data processing this resulted in a calibrated data point every 108 seconds.

All the data included in the final dataset is to be considered as good data. The dataset has had a reasonable level of quality control applied to ensure there are no apparent erroneous data points. However, due to the size and sheer amount of datapoints there is a small chance there could still be some values that may be incorrect. The passing of Cyclone Narelle through the survey area caused a large disturbance to the area with a lot of sediment suspended throughout the water column noted for several days post cyclone. It was also noted that the underway lines were coated with sediment. The sediment in the water and underway line was suspected to have an impact on the phosphate analysis. Affected phosphate data has been removed from the final dataset. The sediment in the water and underway line did not have any effect on the NOx analysis.

There is a **2 minute and 35 second** delay between water entering the drop keel uptake to when it reaches the underway seawater laboratory. Nutrient analysis data points were match to the time stamps (UTC), at the time the sample was drawn from the instrument clean seawater line. This time stamp was used during data processing. A column has been added to the final dataset with a timestamp adjusted to the time (UTC) at which the sample was drawn from the drop keel. A NC file of the ship's latitude and longitude with UTC time stamps is provided to match the underway data to the ship's location.

The final data set is not corrected to the measured certified reference material. If correction to the measured certified reference material is required, per analysis measurements for the certified reference material can be found in table 7.

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	Fremantle	Fremantle
Date	17/03/2026	17/04/2026
Time	0800	0800

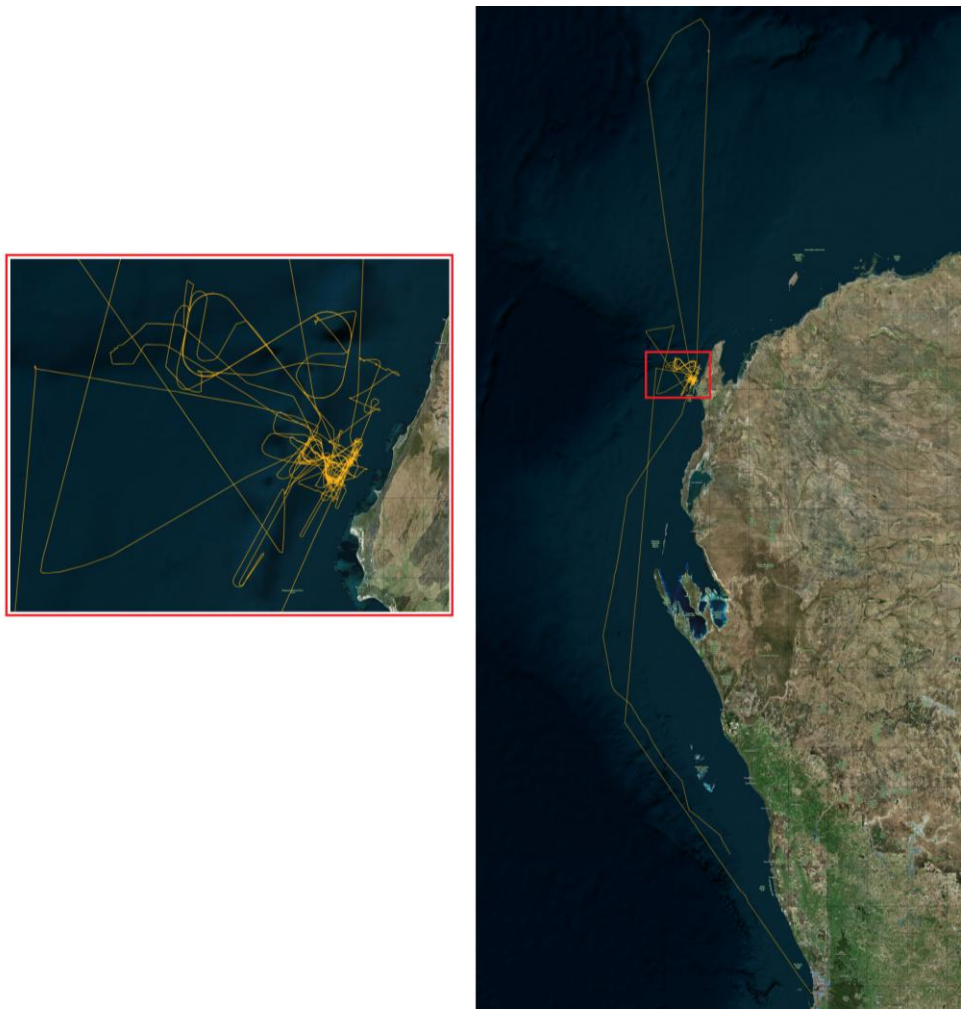

Figure 1. Voyage map

Key personnel list

Table 2: Key Personnel list

Name	Role	Organisation
Prof. Nicole Jones	Chief Scientist	UWA
Max McGuire	Voyage Manager	CSIRO
Merinda McMahon	Hydrochemist	CSIRO
Kurt Debruille	Hydrochemist	CSIRO
Stephen Tibben	Hydrochemist	CSIRO
Julie Janssens	Hydrochemist	CSIRO

Sample Summary

Sample Type and Number Assayed

Table 3: Hydrochemistry sample type and analysis summary

Analysis	Instrument	Sample source/type	Number of samples
Continuous underway nitrate	AA100	Underway (continuous)	7537
Continuous underway phosphate	AA100	Underway (continuous)	6313
Underway grab samples	AA500	Underway (discrete)	294

Data Processing Overview

The sample meta-data and the nutrient assay raw data are processed using the CSIRO-developed program HyPro2. This processing generated the final hydrology dataset.

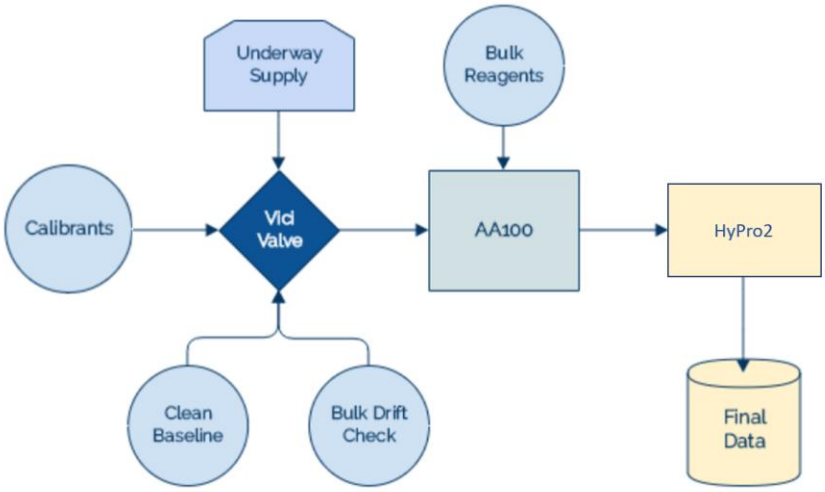

Figure 2. Underway Hydrology Data Processing Flow Diagram.

Nutrients

Nutrient Measurement Parameters

Table 4. Nutrient measurement parameters analysed with Seal AA100 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 AA100 segmented flow analyser	
Instrument operating Software	AACE 7.13 (AA100), FloZF Software (Selection valve)	
Data processing software	HyPro2 v0.70	
Hydrochemistry analysis method	AA100_SOP001	AA100_SOP002
Nutrients analysed	Phosphate	Nitrate+Nitrite
concentration range	0.0 – 3.0 (µmol L^{-1})	0.0 – 14.0 (µmol L^{-1})
Method detection limit	0.02 (µmol L^{-1})	0.02 (µmol L^{-1})
Stock standards	Made on 11th of February 2026 in 1L HDPE bottle	
Intermediate standards	Prepared every 72 hours in 30 mL polypropylene tubes. Reused after acid wash with 10% hydrochloric acid solution.	
Working standards	Prepared every 24-48 hours in 30 mL polypropylene tubes. Reused after acid wash with 10% hydrochloric acid solution.	
Reference Material	KANSO RMNS lot CU	
Analysts	Merinda McMahon and Kurt Debruille	
Comments		

Nutrient Methods

NOx and phosphate samples are assayed on a Seal AA100 segmented flow auto-analyser fitted with 1.5 cm de-bubbled flow-cells for colorimetric measurements.

Phosphate (AA100_SOP01): colourimetric, molybdenum blue method. Based on Murphy and Riley (1962) with modifications from the NIOZ-SGNOS 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 880nm.

Nitrate (AA100_SOP02): 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 reddish-purple azo complex and its absorbance is measured at 540 nm.

SOP methods can be obtained from the CSIRO NCMI Hydrochemistry Group.

As the ambient lab temperature of the underway seawater lab was unable to be controlled, both the nitrate and phosphate chemistry modules went through a heating element to ensure consistent temperature control of the chemical reaction.

Underway water was fed into the AA100 via a cup that was continually overflowing, allowing the AA100 to draw an unpressurised sample. The cup only held a volume of 20 mL, with the seawater flowrate between 3.5-4.0 L/min.

HyPro2 Processing Parameters

Table 5. HyPro2 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	Phosphate	Nitrate + Nitrite
Data Reported as	µmol L^{-1}	µmol L^{-1}
Calibration Curve fit	Linear	Linear
# of points in Calibration	6	6
Forced through zero	N	N
Matrix correction	N	N

Blank correction	N	N
Refractive Index Blank (RIB) correction	N/A	N/A
Peak window defined by	HyPro2	HyPro2
Carryover correction	Y	Y
Baseline drift correction	Y	Y
Sensitivity drift correction	Y	Y
Data Adjusted for RMNS variance	N	N
Medium of Standards	Low nutrient seawater (LNSW) collected in June 2024. Sub-lot passed through a 5-micron filter (filtered in February 2026) 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.	
Note	The reported data is not corrected to the RMNS. Per deployment RMNS data is provided in table 7	

HyPro2 Data Processing Summary

After a block of underway analysis, the raw absorbance data is exported form the instrument and processed by HyPro2. For each analyte, HyPro2 re-creates the peak traces, defines the region on the peak's plateau (peak window) used to determine the peak heights, constructs the calibration curve, applies corrections for carry-over, baseline and sensitivity drifts then, derives the nutrient concentration for each sample. The corrections are quantified using dedicated solutions included in every run.

HyPro2 is used to identify suspect calibration points, noisy peaks, method detection limits that are above the nominal limit and duplicate sample results that do not match.

With suspect calibration points, their contribution to the curve is given less weighting dependent on their distance from the final curve. The cut-off limits for good calibration data are 0.02 µmol L^{-1} for the two channels.

Grab samples (uwy001 – uwy294) were collected from the underway sampling line in the underway laboratory at various times across the AA100 underway nutrient runs. These samples were measured on the AA500 in the hydrochemistry lab for quality control purposes. The grab samples contain results for Nitrate + Nitrite, Nitrite, Phosphate, Silicate and Ammonium. Grab sample results can be found in the final hydrology data set on the CSIRO data trawler (file name: IN2026_V02_Hydro_UWY_Grab_Samples_AA500).

There are no flags provided with the final dataset as only good data points are published, all bad data points have been removed from the final dataset. HyPro2 automatically removes points that are bad based on criteria specified above. The dataset has also had a manual pass over to check the quality of the data. Any datapoints deemed bad during this manual pass over have also been removed from the final dataset. There is a small chance that there is bad data in the dataset, however this should be unlikely.

Accuracy - Reference Material for Nutrient in Seawater (RMNS)

For this voyage, Japanese KANSO certified RMNS lot CU was assayed in triplicate at the start of each analysis to monitor accuracy. The average measured CU result per analysis can be found in table 7. The certified value for RMNS lot CU can be found in table 6.

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

RMNS	Phosphate	Nitrate + Nitrite
Lot CU	0.2684 ± 0.0113	3.1753 ± 0.0922

Table 7. Measured CU result per analysis file. Units: µmol L^{-1}

Analysis File	Phosphate	Nitrate + Nitrite
001	0.2835	3.1338
002	0.2909	3.1133
003	0.2706	3.1603
004	0.2748	3.1165
005	0.2692	3.1102
006	0.2919	3.1012
007	0.2730	3.1149
008	0.2720	3.0799
009	0.2722	3.0870
010	0.2875	3.1142
011	0.2604	3.1250
012	0.2821	3.1085
013	0.2359	3.1112
014	0.2371	3.1375
015	0.2608	3.1439
016	0.2289	3.1940
017	0.2198	3.1142
018	0.2019	3.1012
019	0.2162	3.0823
020	0.2875	3.1303
021	0.2902	3.1475
022	0.2974	3.1390

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 available on CSIRO data trawler.

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

References

Murphy, J. And Riley, J.P. (1962)*"A Modified Single Solution Method for the Determination of Phosphate in Natural Waters"*, Anal. Chim. Acta, 27: p.30. doi: 10.1016/S0003-2670(00)88444-5

Wood, E.D., Armstrong, F.A.J., and Richards, F.A. (1967) *"Determination of nitrate in seawater by cadmium-copper reduction to nitrite."* Journal of the Marine Biological Association of U.K. 47: pp. 23-31.