

CRUISE REPORT

HUDSON 96006

LABRADOR SEA

WOCE LINE AR7W

MAY 12 - JUNE 1, 1996

A. CRUISE NARRATIVE

1. Highlights

- a. WOCE Designation: WOCE Line AR7W
- b. Expedition Designation: Hudson 96006
- c. Chief Scientist: John R. N. Lazier
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Ocean Sciences Division
Department of Fisheries and Oceans
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- d. Ship: CSS Hudson
- e. Ports of Call: May 12 BIO, Dartmouth, NS, Canada
June 1 Sydney, NS, Canada
- f. Cruise Dates: May 12, 1996 to June 1, 1996

2. Cruise Summary Information

a. Cruise Track

A cruise track is shown in Figure 1. Ship position at midnight on each day of the cruise is indicated with an asterisk. The day of the month (May) is also given beside the asterisk.

The station positions are shown in Figures 2 and 3. Figure 2 shows the stations occupied along the Scotian Shelf and in the Gulf of St. Lawrence. Figure 3 shows stations along the WOCE line AR7W. Some station numbers are indicated for clarity.

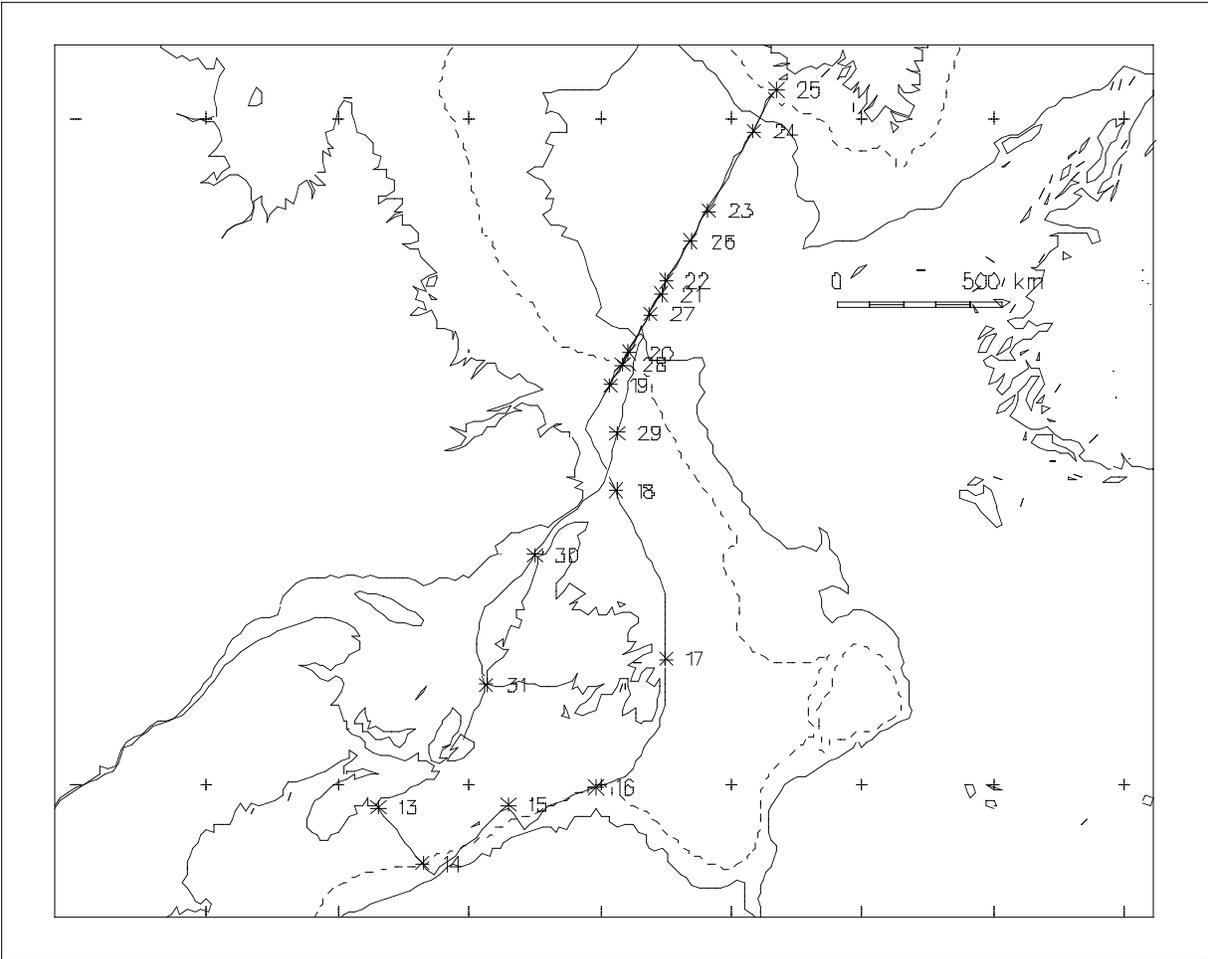


Figure 1. Ship track for 18HU96006/1; * marks Hudson's position at 0000Z each day with some day labels indicated.

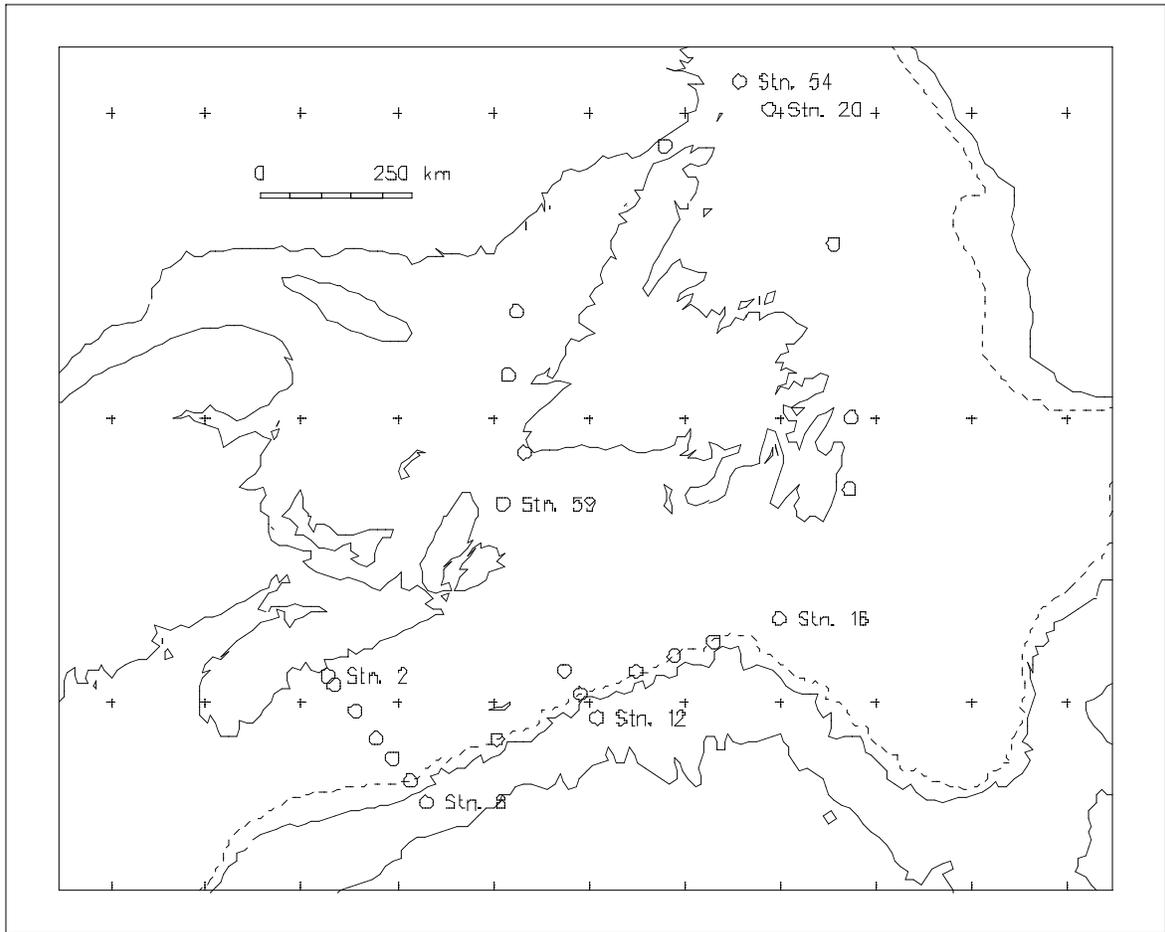


Figure 2. Station positions and numbers for 18HU96006/1 on the Scotian Shelf, Newfoundland Shelf and Gulf of St. Lawrence.

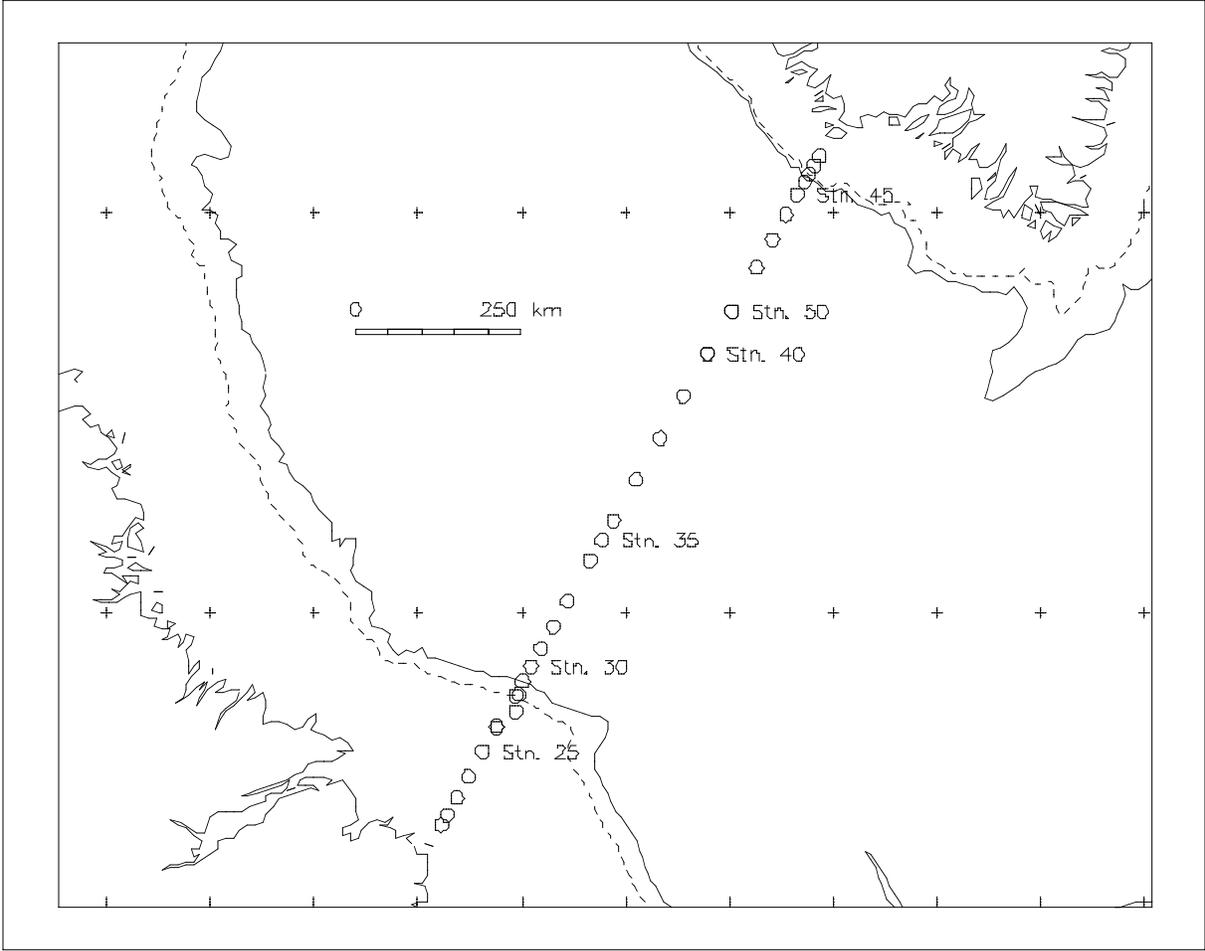


Figure 3. Station positions and numbers for 18HU96006/1 AR7W line.

b. Total Number of Stations Occupied

- 44 full depth WHP small volume CTD stations with up to 23 rosette bottles. Depending on the station, water samples were analyzed for CFCs, carbon tetrachloride, methyl chloroform, total carbonate, alkalinity, oxygen, salinity, nutrients, tritium, helium, oxygen isotopes, chlorophyll, and dissolved organic carbon.
- 1 CTD cast with no water samples
- 29 full depth velocity profiles using a lowered ADCP attached to the CTD/rosette
- 2 ALACE float deployments
- 1 current meter mooring deployed
- 2 release test moorings deployed
- 1 current meter mooring recovered
- 1 current meter mooring partially recovered

c. Floats and Drifters Deployed

A total of two floats were launched during the cruise, both on the AR7W line. The two were P-ALACE (Profiling-Autonomous Lagrangian Circulation Explorer) floats launched for Ray Schmitt of WHOI.

d. Moorings Deployed or Recovered

In 1995, a multi-instrument mooring (BIO number M1194) was deployed during the BIO cruise to AR7W (WOCE Expocode 18HU95011/1). This mooring consisted of 6 Seacat temperature /conductivity recorders, 6 Aanderaa current meters, 1 acoustic doppler current profiler (ADCP), 1 WOTAN (weather observations through ambient noise) and 1 CTD with a device for measuring the partial pressure of dissolved gas in the water. It was intended to recover this mooring and deploy a duplicate mooring in the same location. During the recovery process, however, the weather deteriorated causing delays in grappling the upper float and excessive working of the buoyancy packages in the mounting seas. This in turn caused some seizing wire on the shackles to break leading to the mooring separating into two pieces. Recovery then proceeded from the bottom end of the mooring, but high winds pushed the ship breaking the mooring wire and the remainder of the mooring sank. The recovered components consisted of 2 current meters, 1 release, the WOTAN and CTD with dissolved gas instrumentation.

A current meter mooring (BIO Number 1200) consisting of one current meter positioned 15 m off the bottom was recovered along the 1000 m isobath on the Labrador side of AR7W. This mooring was deployed during the 1995 cruise (Expocode 18HU95011/1). A duplicate mooring was deployed in the same location.

A pair of release test moorings were deployed, one on the Scotian Shelf (shallow) and one along AR7W (deep). Both consisted of a Benthos Acoustic release with a backup EG&G release. These moorings are intended as a test of the Benthos release.

3. List of Principal Investigators

Name	Affiliation	Responsibility
John R. N. Lazier	BIO LazierJ@mar.dfo-mpo.gc.ca	CTD data, shipboard ADCP data, moored instrument data, salinity
Erica Head	BIO Erica.head@maritimes.dfo.ca	biological data
Robert Houghton	LDEO Houghton@ldeo.columbia.edu	oxygen ratio
Peter Jones	BIO JonesP@mar.dfo-mpo.gc.ca	oxygen, alkalinity, carbonate, CFCs
Robert Pickart	WHOI pickart@rsp.who.edu	lowered ADCP
Peter Rhines	UW Rhines@killer.ocean.washington.edu	moored instrument data
Peter Schlosser	LDEO Peters@ldeo.columbia.edu	tritium, helium data
Peter Strain	BIO StrainP@mar.dfo-mpo.gc.ca	Nutrients

See Section 7 for addresses.

4. Scientific Programme and Methods

4.1 Physical - Chemical Program

One of the purposes of occupying the AR7W section each spring is to monitor the properties of the Labrador Sea Water (LSW) which is renewed in the central region of the sea via deep convection in winter. The depth of the convection varies with the severity of the winter and in recent years has reached 2300m in the exceptionally cold winters of the early 1990s, especially that of 1992-1993. The potential temperature and salinity (θ -S) of the water mass also vary from year to year according to the inputs of heat and salt or freshwater brought about by convection and by eddy diffusion.

The θ -S values at the core of the LSW for each of the years between 1990 and 1996 except 1991, for which we have no CTD data, are shown in Figure 4. Temperature and salinity increased between 1995 and 1996 by 0.03 °C and 0.005, while the density remained constant. We think this is likely the result of horizontal eddy diffusion in the absence of convection. This is because the LSW presents a minimum in temperature and salinity in both vertical and horizontal planes and if there is no convection θ -S must increase under eddy diffusion while the density remains unchanged.

A calculation to check this possibility was performed using the data collected in 1994. The θ and S distributions on the $\sigma_{1.5}$ surfaces within the LSW across the Labrador Sea were determined then used as initial conditions in an estimate of the heat and salt fluxes from the boundaries into the centre of the section. When the boundary values were kept constant the fluxes toward the centre raised the θ and S by 0.05 °C and 0.007 in a year. These values are close enough to the observed values to support our hypothesis and gives us some confidence in suggesting that deep convection did not extend into the previously established LSW core during the 1995-1996 winter.

Using the same argument, other years that do not show these θ -S increases in the LSW core must have been influenced by vertical convection. This is certainly true of the years between 1990 and 1993 which were very severe and which show many features of active convection in the vertical profiles. The increases in salinity in these years is thought to be due to the convection layer increasing in thickness and incorporating higher salinity water from the layer below. The increase in $\sigma_{1.5}$ over these years is also an indication of a deepening convection layer.

The θ decrease between 1993 and 1994 suggest that convection proceeded to the depth reached in the previous year but the decrease in salinity and the constancy of the $\sigma_{1.5}$ suggest it didn't penetrate any deeper than the previous year. The small changes between 1994 and 1995 suggest a

near balance between the heat and salt losses associated with convection and the heat and salt gains due to eddy diffusion.

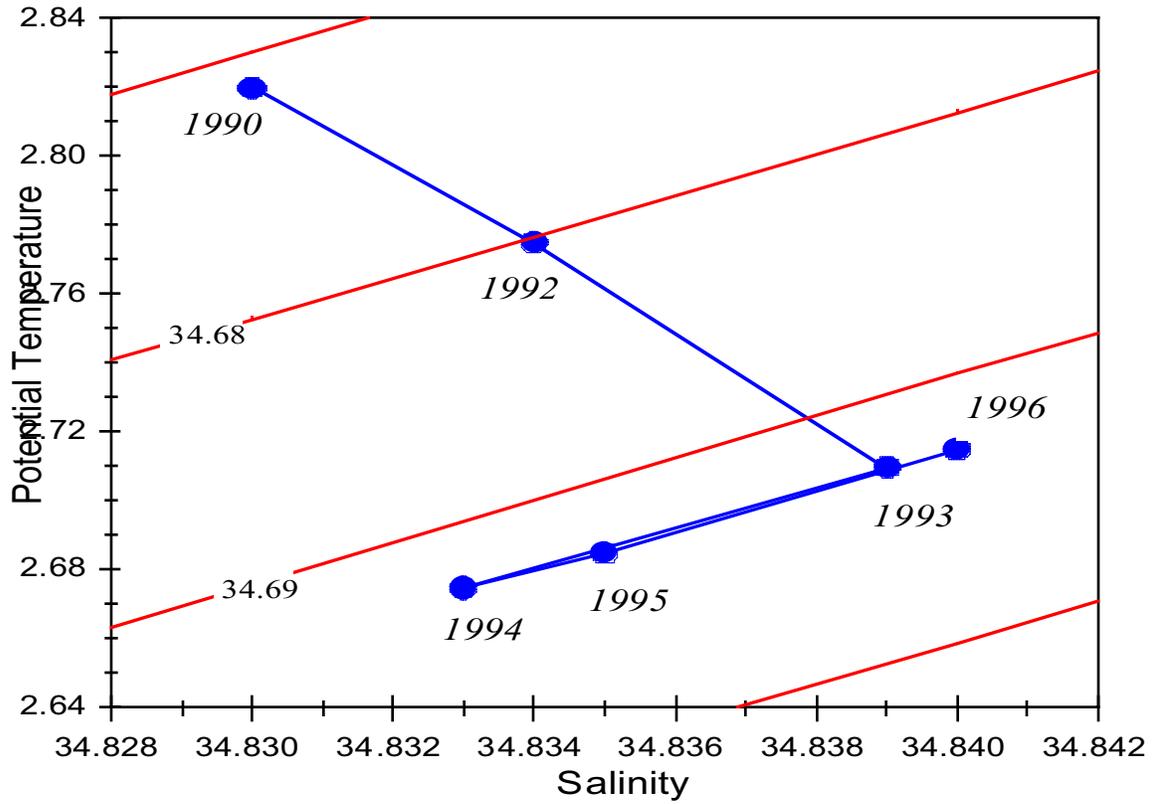


Figure 4. The θ -S values at the core of the LSW for each of the years between 1990 and 1996 except 1991.

4.2 Biological Program

4.2.1 Zooplankton Sampling and Other Experimental Programmes

E. Head / L. Harris

4.2.1.1 Estimation of the biomass and vertical distribution of zooplankton

Vertical net tows were carried out between 100 m and the surface, using a 200 µm mesh net at a total of 49 stations (see Table 1 for station positions). The optical plankton counter (OPC) was deployed in vertical drops to within 15 m of the bottom or to 200 m, at 43 stations. The vertical net tows will provide information as to the species composition and biomass of the zooplankton (primarily copepods) and the OPC will provide information as to the vertical distribution of "particles", including copepods and at some stations large coagulated masses of phytoplankton.

4.2.1.2 Assessment of the suitability of the phytoplankton as a food source for zooplankton

B. Irwin took chlorophyll profiles at many of the stations, in order to determine the biomass of phytoplankton present in the water column. In order to assess the value of this phytoplankton as food for copepods, samples were taken at the depth of the chlorophyll maximum and size fractionated at 3 mm. Particles smaller than this are unlikely to be a good food source for copepods. These samples will be analysed using high performance liquid chromatography, which will also indicate the presence of algae species thought to be noxious or toxic to zooplankton. The particulate organic carbon of the different size fractions will also be determined.

4.2.1.3 Assessment of differences between populations of *Calanus finmarchicus* occurring in the Labrador Sea, Scotian Shelf and Gulf of St. Lawrence

In previous studies it has been found that there are differences in size-at-stage between stage V *C. finmarchicus* from the Labrador Sea and Scotian Shelf. This year the study was extended and samples were collected to see if there were also differences in the amounts of the heavy natural isotopes of nitrogen (N-15) and carbon (C-13). This was performed to see if these markers could be used to trace the movements of stocks of zooplankton in the region over a yearly time scale (lifetime of the animals). Samples were taken at 9 stations for these analyses.

Samples were collected for Dr. A. Bucklin (U. of New Hampshire) for the analysis of the genetic make-up of *C. finmarchicus* females, which will allow the investigation of the movements of stocks of zooplankton over a time scale of several generations. Samples were taken at 9 stations for these analyses.

Table 1. Stations samples by E. Head and L. Harris

Biol. Stn.#	Position Lat. Deg.	Position Lat. Min.	Position Long. Deg.	Position Long. Min.	Date	Ship's Time	Zooplankton Sampling Vertical Net Tows	OPC	Water Sampling CTD	Water Sampling Pump	Chl. Max. Depth (m)	Metabolic Experiment Done	Samples For N-15 And C-13	Samples For genetic Studies
1	44	24	63	28	12.05	20.4	YES	YES	YES	-	10	-	-	-
2	44	16	63	19	13.05	0.2	YES	YES	YES	-	20	-	-	-
3	43	53	62	53	13.05	5	YES	YES	YES	-	30	-	YES	-
4	43	29	62	27	13.05	14.4	YES	YES	YES	-	40	-	-	-
5	43	11	62	6	13.05	18	YES	YES	YES	-	50	-	-	-
6	42	52	61	44	13.05	23.45	YES	YES	YES	-	30	-	YES	-
7	43	33	61	24	14.05	4.4	YES	YES	YES	-	50	-	-	-
8	43	28	59	54	14.05	13.4	YES	YES	YES	-	50	-	-	-
9	44	29	58	30	14.05	20.45	YES	YES	YES	-	40	-	-	-
10	44	8	58	11	15.05	1	YES	YES	YES	-	50	-	YES	-
11	43	47	57	50	15.05	3.2	YES	YES	YES	-	40	-	-	-
12	44	25	57	2	15.05	10.4	YES	YES	-	YES	50	-	-	-
13	44	42	56	12	15.05	15.2	YES	-	YES	-	40	-	-	-
14	44	53	55	23	15.05	20	YES	-	YES	-	30	-	-	-
15	45	13	54	0	16.05	2.2	YES	-	YES	-	50	-	-	-
16	47	3	52	33	16.05	14.15	YES	YES	-	YES	50	-	-	YES
17	48	1	52	30	16.05	19.1	YES	YES	-	-	-	-	-	-
18	50	20	52	52	17.05	8	YES	YES	-	YES	60	1	-	YES
19	52	4	54	13	17.05	19.1	YES	YES	-	-	-	-	-	-
20	53	40	55	33	18.05	7.15	YES	YES	-	YES	10	2	-	YES
21	54	13	55	2	18.05	16.05	YES	YES	-	YES	30	-	-	-
22	54	45	54	29	18.05	22.22	YES	YES	-	-	-	-	-	-
23	54	54	54	4	19.05	7.55	YES	YES	-	YES	20	3	-	YES
24	55	7	54	3	19.05	15.15	YES	YES	-	YES	10	-	YES	-
25	55	16	53	59	19.05	18.15	YES	YES	-	-	-	-	-	-
26	55	25	53	50	19.05	21.45	YES	YES	-	-	-	-	-	-
27	55	51	53	24	20.05	6.04	YES	YES	-	YES	10	4	YES	YES
28	56	7	53	7	20.05	12.2	YES	YES	-	YES	30	-	-	-
29	56	32	52	41	20.05	20.35	YES	YES	-	-	-	-	-	-
30	57	22	51	51	22.05	7	YES	YES	-	YES	10	5	-	-
31	57	48	51	20	22.05	11.3	YES	YES	-	YES	10	-	-	-
32	58	13	50	53	22.05	18.3	YES	-	-	-	-	-	-	-
33	59	29	49	29	23.05	15.15	YES	-	-	-	-	-	-	-
34	59	45	49	10	23.05	20.3	YES	-	-	-	-	-	-	-
35	60	12	48	47	24.05	7.15	YES	YES	-	YES	10	6	YES	YES
36	60	18	48	32	24.05	10.45	YES	YES	-	-	-	-	-	-
37	60	22	48	29	24.05	15.5	YES	YES	-	YES	10	-	-	-
38	60	27	48	22	24.05	19.1	YES	YES	-	-	-	-	-	-

39	60	32	48	15	24.05	21.3	YES	YES	-	-	-	-	-	-
40	59	4	49	57	25.05	7.42	YES	YES	-	YES	10	7	YES	-
41	58	39	50	25	25.05	11.4	YES	YES	-	YES	40	-	-	-
42	55	6	54	7	27.05	6.08	YES	YES	-	YES	10	8	-	-
43	54	46	54	29	27.05	14	YES	YES	-	YES	30	-	-	-
44	52	23	54	51	29.05	6.5	YES	YES	-	YES	40	9	-	-
45	51	35	56	24	29.05	15.2	YES	YES	-	YES	30	-	-	-
46	49	27	59	31	30.05	6.35	YES	YES	-	YES	60	10	-	YES
47	48	38	59	41	30.05	13.45	YES	YES	-	YES	10	-	-	-
48	47	33	59	20	30.05	21.27	YES	YES	-	-	-	-	YES	YES
49	46	41	59	48	31.05	2.1	YES	YES	-	-	-	-	YES	YES

4.2.1.4 Measurements of copepod metabolic rates

Rates of respiration, oxygen consumption and ammonia excretion were measured for communities of copepods in ten incubation experiments. Samples were also taken in five of these experiments for the determination of the rates of release of dissolved organic carbon and nitrogen.

4.2.2 Bacteria and Autofluorescent Particles

Paul Dickie

Profiles of heterotrophic bacterial activity with depth over the photic zone were estimated at 11 pump stations using radioactively labelled (³H) thymidine and leucine. These tracers were added to seawater and incubated in deck boxes cooled by surface seawater and simulating light levels roughly corresponding to the light at the depth where the seawater was obtained. Bacterial numbers will be found from DAPI stained samples of seawater from each incubation depth. Additional experiments were performed to test for the effects of predation in the incubation bottles and to measure the stimulatory effect of adding thymidine or leucine to the bacteria in the seawater samples. No results will be available until the samples can be processed at BIO.

Samples were taken at 35 stations. The samples were drawn every 10 m from the surface to either the bottom, 150 m (CTD), or 100 m (Pump), for later flow cytometric analysis of autofluorescent particles by Dr. Bill Li at BIO. The samples were preserved with 1% para-formaldehyde and frozen in liquid nitrogen. The autofluorescent particles might include prokaryotes (cyanobacteria) or eukaryotes (small phytoplankton cells). As well, the samples may be stained with a fluorescent nucleic dye to enumerate heterotrophic bacteria. Seawater of 4 different salinities was collected for use as sheath fluid in Dr. Li's flow cytometer.

Phytoplankton samples were collected at 32 stations at 10m to determine actual numbers and assemblages of phytoplankton to correlate with the flow cytometer data, with chlorophyll values and possibly with Dr. E. Head's HPLC samples from the same water.

4.2.3 Feeding Experiments with Copepods Collected during Different Stages of the Spring Bloom in the North Atlantic Ocean and Labrador Sea

Catherine J. Stevens

L. Harris, using a 200 µm mesh net collected experimental animals (natural mixtures of copepods) in vertical net tows from 100 m to the surface. The abundance and vertical distribution of phytoplankton, as determined upon deployment of the biological pump, were used to assess the stage of the spring bloom (*i.e.*, pre-bloom, mid-bloom, or post-bloom) and feeding history of the copepods. The copepods were starved for approximately 3 hours before the experiment was set up, allowing time for them to empty their guts of *in situ* food. The copepods were rinsed of adhering phytoplankton and divided into roughly equal numbers through systematic dilution with filtered seawater. They were then confined to 1 litre polycarbonate bottles (between 20 to 40

animals per bottle) and supplied with natural phytoplankton or one of two cultured diatoms, *Thalassiosira* and *Coscinosira*, over a series of five concentrations (see Table 2 for details about each experiment). At each food concentration, three experimental bottles (copepods and food) and one control bottle (food only) were set up. Initial and final samples (after about 10 hours) of control bottles were taken and frozen for HPLC analysis (high-performance liquid chromatography) and determination of total particulate chlorophyll by fluorometry. The entire contents of the experimental bottles (copepods, food and fecal pellets) were filtered for HPLC analysis.

Samples of the experimental copepods were preserved in formalin for species identification and identification of copepodite stages within individual species. When natural phytoplankton was used as a food source, samples were taken and preserved with Lugol's solution for taxonomic analysis. In addition, samples of the experimental copepods and algae were taken and frozen in cryovials for enzyme assays.

Analysis of the samples taken during the feeding experiments described above will allow the calculation of the following parameters:

1. the ingestion rates of the copepods in terms of phytoplankton pigment,
2. the percentage of the ingested pigment (chlorophylls and carotenoids) which has been converted into colorless residues (*i.e.*, destroyed), and
3. the contribution of this destruction to CBEs (chlorophyll-bleaching enzymes) in both the experimental phytoplankton and copepods.

Table 2. Feeding Experiments with Copepods from the North Atlantic and Labrador Sea

Date	Biological Station Number	Approximate Location	Stage of Spring Bloom	Food Source
14/05/96	8	off Sable Island	post-bloom	<i>Thalassiosira</i>
16/05/96	16	Laurentian Channel	post-bloom	natural phytoplankton
17/05/96	18	off St. John's, NF	post-bloom	<i>Thalassiosira</i>
18/05/96	20	beg. of WOCE line	mid-bloom	natural phytoplankton
19/05/96	23	Labrador Sea	mid-bloom	natural phytoplankton
20/05/96	27	Labrador Sea	mid-bloom	<i>Thalassiosira</i>
22/05/96	30	Labrador Sea	pre-bloom	<i>Coscinosira</i>
24/05/96	35	Labrador Sea (off Greenland)	pre-bloom	natural phytoplankton
25/05/96	40	Labrador Sea	pre-bloom	<i>Thalassiosira</i>
27/05/96	42	Labrador Sea	mid-bloom	natural phytoplankton
29/05/96	54	Strait of Belle-Isle	post-bloom	<i>Thalassiosira</i>
30/05/96	56	Gulf of St. Lawrence	post-bloom	<i>Thalassiosira</i>

4.2.4 Respiration and the Size Fractionation of P. E. Kepkay / J. B. C. Bugden Dissolved Organic Carbon (DOC)

The first direct measurements of microbial community respiration in the Labrador Sea were carried out on samples collected to depths of up to 100 m by the biological pump. Ten of the 28 sites on the WOCE line were sampled and respiration was typically measured at the three depths where phytoplankton productivity was established. Our application of the new pulsed-oxygen-electrode respirometer to these oceanic waters allowed us to carry out short-term (2 h) incubations at in-situ temperatures and minimize the artifacts generated by "bottle effects" associated with traditional long-term (1 to 5 d) incubations.

Samples taken by pump for DOC analysis were ultrafiltered to size fractionate the DOC into colloidal organic carbon (COC) and low molecular weight organic carbon (LOC). This size fractionation of surface waters was performed on the same samples taken for respiration measurements. A selection of bottles from WOCE CTD casts were also sampled for DOC analysis to establish the organic carbon signal associated with the major water masses that had been defined by salinity, temperature and tracer measurements.

Given the fact that DOC is by far the largest pool of organic carbon in the world's ocean and given the possible association of respiration with COC (the biologically-reactive component of DOC), we will use the data to establish:

- 1.** The approximate age of DOC in the main water masses.
- 2.** The contribution of DOC flux to the biological and/or physical pumps, which transport atmospheric CO₂ into deep water.
- 3.** The contribution that the respiration of COC makes to "preformed" TCO₂ and the deep flux of atmospheric CO₂ by the physical pump.

4.2.5 Primary Production Program

B. Irwin, J. Anning, A. Macdonald and J. Spry

Water samples for PI experiments were collected using the Biological Pump. Depths were selected on the basis of physical features or fluorescence structure. A total of 44 experiments were done at 21 locations.

DATE	LAT	LONG	DEPTHS
May 15	44 27N	57 01W	10,30,50
May 16	47 02N	52 32W	10,30,50
May 17	50 20N	52 53W	10,30,50
May 18	53 41N	53 41W	10,30,50
May 18	54 13N	55 02W	10
May 19	54 55N	54 06W	10,20,30
May 19	55 07N	54 03W	10
May 20	55 51N	53 23W	10,20,40
May 20	56 07N	53 08W	30
May 22	57 22N	51 51W	10,20,40
May 22	57 47N	51 21W	10
May 24	60 12N	48 46W	10,30,50
May 24	60 22N	48 27W	10
May 25	59 04N	49 57W	10,30,50
May 25	58 38N	50 25W	40
May 27	55 06N	54 07W	10,20,30
May 27	54 46N	54 28W	30
May 29	52 23N	54 51W	10,30,50
May 29	51 35N	56 25W	30
May 30	49 27N	59 31W	10,20,30
May 30	48 37N	59 41W	10

At each of the sampled depths water was filtered for chlorophyll concentration, HPLC, Particulate Organic Carbon and Nitrogen.

Pump profiles were from the surface to 100m or the bottom at shallow stations. Samples were collected at 10 m intervals for inorganic nutrients, chlorophyll concentration and total dissolved inorganic carbon.

4.2.6 Surface Water Continuous Monitoring System

**B. Irwin, J. Anning, A. Macdonald
and J. Spry**

Water from approximately 4 m was pumped continuously up to the forward lab. The temperature, conductivity and fluorescence of this flow was continuously measured and logged every 30 seconds. The temperature and conductivity were measured with Seabird sensors and the fluorescence by a Wet Labs Inc. flow-through fluorometer. Incident Photosynthetically Active Radiation (PAR) was measured with a Biospherical PAR sensor and the data merged with the seawater parameters. Exact positions were logged at the same time from a Raytheon GPS.

Discrete water samples were collected every 10 minutes by an auto sampler for later analysis for phosphate, nitrate and silicate.

A NAS 2 nitrate analyzer, on loan from WS Ocean Systems for evaluation, was incorporated into the flowthrough system. Nitrate concentration was measured every 10 minutes. This data will be compared with the concentrations found in the discrete samples.

5. Major Problems and Goals Not Achieved

The failed recovery of 70% of the mooring along AR7W is a major disappointment. The component of the mooring that sunk still contains a functioning release mechanism, thus enabling us to locate the end of the mooring line. An unsuccessful dragging attempt was made to recover the mooring line. We hope to attempt recovery of the mooring again in October 1996.

Due to poor weather, the replacement mooring along AR7W at ca. 3500 m was not deployed.

6. Other Incidents of Note

During equipment trials in Bedford Basin on Friday May 10, the CTD, LADCP and rosette were lost. A combination of mechanical failure and incorrect winch operation resulted in the package breaking free of the winch cable and falling to the bottom of Bedford Basin, in about 70 m of water. The package was recovered on Saturday May 11 using an underwater remotely operated vehicle, which was used to attach a line to the rosette frame. The package was found in an upright position on the bottom. The package was retrieved with minor damage, this being several broken spigots on the Niskin bottles. The duct system was flushed and cable was re-terminated.

CTD equipment tests on Sunday May 12 showed problems with the pump power cable Y-splice. This Y-splice is required because of the dual system configuration on the package. The power cable is spliced to supply power to both pumps. A new splice corrected the problem.

7. List of Cruise Participants

Name	Responsibility	Affiliation
Jeff Anning	Underway Sampling	BIO
Rick Boyce	CTD/Watchkeeper	BIO
Jay Bugden	"DOC levels, Respiration"	JSE
Paul Dickie	Bacterial Abundance and activity	BIO
Bob Gershey	CFC/Alkalinity/Carbonate	BDR Research
Les Harris	Zooplankton	BIO
Albert Hartling	Moorings/Watchkeeper	BIO
Erica Head	Zooplankton	BIO
Mike Hingston	CFC/Alkalinity/Carbonate	BDR Research
Brian Irwin	"Phytoplankton, CO2"	BIO
Anthony Isenor	Data Quality/Computers	BIO
Paul Kepkay	"DOC levels, Respiration"	BIO
Samar Khatiwala	Helium/Tritium Sampling	LDEO
John Lazier	Chief Scientist	BIO
Al MacDonald	Chlorophylls/Oxygens	BIO
Manon Poliquin	Salinometer/Oxygens	
Murray Scotney	Moorings/Watchkeeper	BIO
Jeff Spry	Pump Sampling	BIO
Catherine Stevens	Zooplankton	Dal
Igor Yashayaev	Scientist/Watchkeeper	Shirshov
Frank Zemlyak	CFC/Alkalinity/Carbonate	BIO

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Dal Dalhousie University
Halifax, Nova Scotia

JSE J and S Envirotech
Dartmouth, Nova Scotia

LDEO Lamont-Doherty Earth Observatory of Columbia University
Palisades, NY, 10964, USA

B. UNDERWAY MEASUREMENTS

1. Navigation and Bathymetry

Anthony W. Isenor

The navigation system onboard CSS Hudson consisted of a Differential GPS receiver and AGCNAV. The system also broadcasts navigation NMEA strings throughout the ship's network about 1 Hz. The navigation data are then logged at one-minute intervals on a PC. This PC was running the AGCNAV software package; a PC based display, and waypoint setting software package developed at the Atlantic Geoscience Centre at BIO. This software graphically displayed ship position, waypoints, course, speed, etc.

The echo sounder system consisted of a Raytheon Line Scan Recorder, Model LSR 1811-2 (serial number A117) connected to a hull mounted 12kHz transducer. The transducer beam width was 15 degrees. The sweep rate of the recorder was adjusted throughout the course of data collection to aid in identifying the bottom signal. The recorder was also linked to a clock, and thus could indicate 5 minute intervals on the sounder paper. The system was used to collect soundings at 5 minute intervals while underway for most of the cruise.

2. Acoustic Doppler Current Profiler

Murray Scotney

The Hudson was equipped with a hull mounted RDI Acoustic Doppler Current Profiler (ADCP). The transducer (serial number 177) had SC ADCP electronics (serial number 607) converted for ship board use. Logging, using Transect software on a 386 PC, was started on May 12, 1996 at 2221 Z along the Scotian Shelf. The configuration of the equipment resulted in a bin length of 4 metres and a total of 128 bins. The raw data were stored to disk and backed up every few days. The data was also averaged in real-time over 1 minute intervals. ADCP logging was stopped on June 1, 1996 at 1021 Z in Halifax Harbour.

3. XBT and XCTD

No probes were used

4. Meteorological observations

The ship's crew carried out routine reporting of meteorological variables.

5. Atmospheric Chemistry

There was no atmospheric chemistry programme.

**C. HYDROGRAPHIC MEASUREMENTS -
DESCRIPTIONS, TECHNIQUES AND CALIBRATIONS**

1. CTD Measurements

Igor Yashayaev and Anthony W. Isenor

a. Description of the Equipment and Technique

The CTD measurements were made with a standard SEABIRD model 9Plus CTD (S/N 09P 7356-0299, BIO System #4, deck unit S/N 11P9984-0353). This CTD was equipped with two model 3-02/F temperature sensors, two model 4-02/0 conductivity sensors, a paroscientific digiquartz model 410K-105 pressure sensor and two model 13-02 dissolved oxygen sensors. All but the pressure sensor were mounted in one of two ducts through which separate pumps pulled seawater. Hence the water flow past the actual sensors was independent of the lowering rate.

The dual sensors used in the configuration consisted of the BIO System #4 as the primary set and BIO System #3 or #2 as secondary. Each set of sensors had a separate duct system for flowing water past the sensors. The sensors used for each System and the Systems used for each station are listed below.

BIO System Number	Sensor	Serial Number
System #4 (Primary)	Temperature	031422
	Conductivity	041124
	Oxygen	130284
	Pressure	53355
System #3 (Secondary)	Temperature	031376
	Conductivity	041076
System #2 (Secondary)	Temperature	031205
	Conductivity	040996
Secondary Oxygen (both Systems #3 and #2)	Oxygen	130265

Station Number	System Pairing (Primary, Secondary)
1-7	4,3
8-16	4,2
21-33	4,3
34-39	4,2
40-49	4,3

The Seabird CTD was mounted vertically within a custom designed and built CTD/Rosette frame. This frame was square rather than round to better accommodate the restricted space of Hudson's winch room and winch room door. All the pressure cases as well as the sample bottles

were mounted vertically to improve the package's stability as it descended through the water column. In the centre of the frame was a 10 inch diameter aluminum tube, which contained at its upper end a General Oceanics Model 1015-24 bottle rosette unit (BIO rosette #3, S/N 1185). The bottom of this tube was designed to hold an RDI 150 kHz Broadband ADCP in a shortened pressure case. On another side was clamped the pressure case for the Seabird CTD. The CTD sensors and pump were mounted on the third side and on the fourth was clamped a rechargeable battery pack for the ADCP and below it a General Oceanics model 6000 12 kHz pinger unit.

The rosette bottles were produced by the Physical and Chemical Oceanographic Data Facility located at the Scripps Institution of Oceanography. Six bottles were mounted to each side of the rosette frame. Each bottle collected 10 litres of water.

A fluorometer was also attached to the CTD for measuring chlorophyll concentrations.

b. Sampling Procedure and Data Processing Techniques

The CTD was deployed with a lowering rate of 60 metres/min (40 metres/min in the upper 200 metres or deeper if the conditions were rough). It was recovered at a rate of 60 metres/min.

The CTD data was recorded onto the disk of a 486 PC running SEABIRD SEASOFT Version 4.216 software. A screen display of temperature, oxygen and salinity profiles vs pressure were used to decide the depths at which bottles were to be tripped on the up cast. The bottles were tripped using the enable and fire buttons on the SEABIRD deck unit.

At the end of each station, the SEASAVE software was used to create 1 and 2 dbar processed data files, an inflection point file and a processed rosette trip file. All the raw and processed data files associated with the station were then transferred to the ship's MicroVAX computer for archive and subsequent access and distribution to various users on the vessel.

The data processing takes the following steps:

DATCNV	Converted the raw data to physical parameters.
SPLIT	Split the data into DOWN and UP cast.
WILDEDIT	This program took consecutive blocks of 12 scans and flagged all scans whose pressure, temperature and conductivity values differed from the mean by more than 2 standard deviations. Then the mean and standard deviation were recomputed using the unflagged data and all scans exceeding 4 standard deviations from this new mean were marked as bad.
FILTER	Low pass filtered pressure and conductivity channels. Time constant used for conductivity was 0.045 seconds, for pressure 0.150 seconds.
LOOPEDIT	Marked as bad, all cycles on the down trace for which the vertical velocity of the CTD unit was less than 0.1 meters/sec.
ALIGNCTD	Aligned the temperature, conductivity and oxygen values relative to the pressure values to account for the time delays in the system. The time offsets for the primary sensors were 0.010 seconds for conductivity, 0.000 seconds for temperature and 3.000 seconds for oxygen. The time offsets for the secondary sensors were 0.083 seconds for conductivity, 0.000 seconds for temperature and 3.000 seconds for oxygen (NOTE: the primary conductivity was adjusted by 0.073 seconds in the Deck unit while the secondary conductivity was not adjusted in the Deck unit.).
CELLTM	A recursive filter was used to remove the thermal mass effects from the conductivity data. Thermal anomaly amplitude and time constants of 0.0300 and 9.0000 were used.
DERIVE	Computed oxygen values.
BINAVG	Averaged the down cast into 1 and 2 dbar pressure bins.
DERIVE	Computed salinity, potential temperature and sigma-theta.
ROSSUM	Averaged 3 seconds of CTD data after every bottle trip. Used in comparison with water sample data.

c. Calibration Data

After considering the CTD temperature measurements as compared to the digital thermometers (see Reversing Thermometer Replicate Analysis section), we noted that the interthermometer comparison indicated differences of 0.002°C. The differences between the thermometers and the CTD were also about 0.002°C. Thus, we did not apply any temperature calibration to the CTD.

However, oxygen and salinity calibrations were necessary. A calibration summary is presented in Table C1.

Sensor Information		24 Hz Data		1 and 2 dbar data
Parameter	System of Sensors	Shipboard Processing	First Calibration	Second Calibration
Pressure	System #4	1-16 21-49		
Temperature	System #2	8-16 34-39	8-16 ⁽¹⁾ 34-39 ⁽¹⁾ I, II	
	System #3	1-7 21-33 40-49	1-7 ⁽²⁾ 21-33 ⁽²⁾ 40-49 ⁽²⁾ I, II	
	System #4	1-16 21-49	1-16 ⁽³⁾ 21-49 ⁽³⁾ I, II	
Conductivity	System #2	8-16 34-39	8-16 ⁽⁴⁾ 34-39 ⁽⁴⁾ I, II	
	System #3	1-7 21-33 40-49	1-7 ⁽⁵⁾ 21-33 ⁽⁵⁾ 40-49 ⁽⁵⁾ I, II	
	System #4	1-16 21-49	1-16 ⁽⁶⁾ 21-49 ⁽⁶⁾ I, II	
Salinity	System #2	8-16 34-39		8-16 ⁽⁹⁾ 34-39 ⁽⁹⁾ I, IV
	System #3	1-7 21-33 40-49		1-7 ⁽¹⁰⁾ 21-33 ⁽¹⁰⁾ 40-49 ⁽¹⁰⁾ I, IV
	System #4	1-16 21-49		1-16 ⁽¹¹⁾ 21-49 ⁽¹¹⁾ I, IV
Oxygen	Systems #2	1-16 21-49	1-16 ⁽⁷⁾ 21-49 ⁽⁷⁾ I, III	
	System #4	1-16 21-49	1-16 ⁽⁸⁾ 21-49 ⁽⁸⁾ I, III	

Table C1. CTD Calibration Summary. Shipboard Processing, First Calibration and Second Calibration represent sections in the text. The numerals I, II, III and IV represent procedures that were followed to determine the applied coefficients. These procedures are described in section (iv) Calibration Procedure. The numerics (e.g. 8 - 20) represent station numbers. Superscripts represent equation numbers in sections (ii) and (iii).

i. Shipboard Processing

The CTD calibrations used during this cruise were supplied by Seabird Electronics. The slope and offset applied to the various sensors was based on calibrations determined at BIO. The applied calibrations are as follows:

BIO SEABIRD CTD System #4

During the cruise the temperature sensor for System #4 used two different sets of slope and offset pairings. The most recent BIO calibration slope and offset were specified for the System #4 temperature sensor when the system pair (4,3) was being used. However, the slope and offset for the System #4 temperature sensor were slightly different when the system pair (4,2) was being used. During the reprocessing of the CTD data, both system pairs used the most recent temperature sensor coefficients originally specified for the (4,2) system pair.

Temperature Sensor (031422)

$$T = 1/\{a + b[\ln(f_0/f)] + c[\ln^2[f_0/f] + d[\ln^3(f_0/f)]]\} - 273.15$$

where

ln indicates a natural logarithm,

f is the frequency

a = 3.68096068 E-03

b = 5.98528033 E-04

c = 1.47933699 E-05

d = 2.18572143 E-06

f₀ = 6142.890

slope = 1.00013300, offset = 0.0044 (Calibration dated Feb. 13, 1996) {used by the (4,3) system pairing}

slope = 1.00013650, offset = 0.0043 {used by the system (4,2) pairing}

Pressure Sensor (53355)

$$\text{pressure} = c (1 - T_0^2/T^2) (1 - d[1 - T_0^2/T^2])$$

where

T is the pressure period

c = c₁ + c₂ U + c₃ U²

d = d₁ + d₂ U

T₀ = T₁ + T₂ U + T₃ U² + T₄ U³ + T₅ U⁴

U is the temperature

c₁ = -4.290243 E+04 psia

c₂ = 5.13724 E-01 psia/°C

c₃ = 1.33407 E-02 psia/°C²

d₁ = 4.0395 E-02

d₂ = 0

T₁ = 2.993058 E+01 μsec

T₂ = -8.85537 E-05 μsec/°C

T₃ = 3.59773 E-06 μsec/°C²

T₄ = 5.58385 E-09 μsec/°C³

T₅ = 0

AD590M = 1.146000 E-02
 AD590B = -8.11354 E+00
 slope = 1, offset = 0 (Seabird calibration, Feb. 2, 1993)

Conductivity Sensor (041124)

$$\text{conductivity} = (af^m + bf^2 + c + dt) / [10(1 - \{CPcor\} p)]$$

where

f is the frequency,
 p is pressure in dbar,
 t is the temperature
 m = 4.2
 a = 1.35924955 E-05
 b = 4.87959496 E-01
 c = -4.19483432 E+00
 d = -1.04684736 E-04
 CPcor = -9.5700 E-08
 Slope = 1.000560 E+00, Offset = -9.60 E-04 (Calibration dated Feb. 15, 1996)

Oxygen Sensor (130284)

$$\text{Oxygen} = [Soc \leftrightarrow (oc + \tau \frac{doc}{dt}) + Boc] \leftrightarrow \text{OXSAT}(T, S) \leftrightarrow e^{\{tcor \leftrightarrow [T + wt \leftrightarrow (T_o - T)] + pcor \leftrightarrow P\}}$$

where

Soc = 2.5328
 oc is the oxygen sensor current (µamps)
 oc = mV + b
 m = 2.4528 E-07
 V is the oxygen temperature sensor voltage signal
 b = -3.9245 E-09
 tau = 2.0
 doc
 $\frac{doc}{dt}$ is the time derivative of oc
 Boc = -0.0322
 OXSAT is the oxygen saturation value dependent on T and S
 T is the water temperature (°C)
 S is salinity (psu)
 e is natural log base
 tcor = -0.033
 wt = 0.670
 T_o oxygen sensor internal temperature (°C)
 T_o = kV + c
 k = 8.9625
 c = -6.9161
 pcor = 1.5 E-04
 P is the pressure (psia)

BIO SEABIRD CTD System #3

Temperature Sensor (031376)

$$T = 1/\{a + b[\ln(f_0/f)] + c[\ln^2[f_0/f] + d[\ln^3(f_0/f)]]\} - 273.15$$

where

ln indicates a natural logarithm,

f is the frequency

a = 3.68093833 E-03

b = 6.00726775 E-04

c = 1.51819564 E-05

d = 2.19535579 E-06

f₀ = 6482.310

slope = 1.000148, offset = -0.000800 (Calibration dated Jan. 23-24, 1996)

Conductivity Sensor (041076)

$$\text{conductivity} = (af^m + bf^2 + c + dt)/[10(1-\{CPcor p\})]$$

where

f is the frequency

p is pressure in dbar

t is the temperature

m = 4.1

a = 2.21442246 E-05

b = 5.67193159 E-01

c = -4.19781901 E+00

d = -1.23661793 E-04

CPcor = -9.5700 E-08

Slope = 1.000524 E+00, Offset = -1.130 E-03 (Calibration dated Jan. 26, 1996)

BIO SEABIRD CTD System #2

Temperature Sensor (031205)

$$T = 1/\{a + b[\ln(f_0/f)] + c[\ln^2[f_0/f] + d[\ln^3(f_0/f)]]\} - 273.15$$

where

ln indicates a natural logarithm

f is the frequency

a = 3.68701470 E-03

b = 6.04767412 E-04

c = 1.60190147 E-05

d = 2.56736249 E-06

f₀ = 6167.520

slope = 1.000150, offset = 6.100 E-03 (Calibration dated Jan. 23-24, 1996)

Conductivity Sensor (040996)

$$\text{conductivity} = (af^m + bf^2 + c + dt) / [10(1 - \{CPcor p\})]$$

where

f is the frequency

p is pressure in dbar

t is the temperature

m = 4.1

a = 2.53328870 E-05

b = 5.95111155 E-01

c = -4.22225011 E+00

d = -2.08943055 E-04

CPcor = -9.5700 E-08

Slope = 1.00078920, Offset = -1.330 E-03 (Calibration dated Jan. 26, 1996)

Oxygen Sensor (130265)

$$\text{Oxygen} = [Soc \leftrightarrow (oc + \tau \frac{doc}{dt}) + Boc] \leftrightarrow \text{OXSAT}(T, S) \leftrightarrow e^{\{tcor \leftrightarrow [T + wt \leftrightarrow (T_o - T)] + pcor \leftrightarrow P\}}$$

where

Soc = 2.4323

oc is the oxygen sensor current (μ amps)

oc = mV + b

m = 2.4608 E-07

V is the oxygen temperature sensor voltage signal

b = -4.9216 E-10

tau = 2.0

doc

$\frac{doc}{dt}$ is the time derivative of oc

Boc = -0.0397

OXSAT is the oxygen saturation value dependent on T and S

T is the water temperature ($^{\circ}$ C)

S is salinity (psu)

e is natural log base

tcor = -0.033

wt = 0.670

T_o oxygen sensor internal temperature ($^{\circ}$ C)

T_o = kV + c

k = 8.9939

c = -6.8210

pcor = 1.5 E-04

P is the pressure (psia)

ii. First Calibration

The generated shipboard 1dbar downcast ODF (Ocean Data Format, specific to BIO) data and the water sample data were used to determine calibrations (given below) for all primary and secondary sensors. All of these calibrations were applied on June 1, 1996. Only the slope and offset changed for the temperature and conductivity sensors. Only the coefficients SOC, BOC, tcor and pcor changed for the oxygen sensors. These new calibrations were then applied to the raw 24 Hz data.

- a) Temperature sensor coefficients for System #2 were changed according to Eqn. 1 below.
- b) Temperature sensor coefficients for System #3 were changed according to Eqn. 2 below.
- c) Temperature sensor coefficients for System #4 in the con file for the (4,3) system pair were changed to the ones used for (4,2) system pair according to Eqn. 3 below.
- d) Conductivity sensor coefficients for System #2 were changed according to Eqn. 4 below.
- e) Conductivity sensor coefficients for System #3 were changed according to Eqn. 5 below.
- f) Conductivity sensor coefficients for System #4 were changed according to Eqn. 6 below.
- g) Secondary oxygen sensor coefficients for System #2 were changed according to Eqn. 7 below.
- h) Primary oxygen sensor coefficients for System #4 were changed according to Eqn. 8 below.

a) Temperature Sensor #2 (031205)

$$T = 1/\{a + b[\ln(f_o/f)] + c[\ln^2[f_o/f] + d[\ln^3(f_o/f)]]\} - 273.15 \quad \text{Eqn. 1}$$

where

ln indicates a natural logarithm
f is the frequency
a = 3.68701470 E-03
b = 6.04767412 E-04
c = 1.60190147 E-05
d = 2.56736249 E-06
f_o = 6167.520
slope = 1.00016000, offset = 5.600 E-03

b) Temperature Sensor #3 (031376)

$$T = 1/\{a + b[\ln(f_o/f)] + c[\ln^2[f_o/f] + d[\ln^3(f_o/f)]]\} - 273.15 \quad \text{Eqn. 2}$$

where

ln indicates a natural logarithm,
f is the frequency
a = 3.68093833 E-03
b = 6.00726775 E-04
c = 1.51819564 E-05
d = 2.19535579 E-06
f_o = 6482.310
slope = 1.000141, offset = 0 (Calibration dated June 1, 1996)

c) Temperature Sensor #4 (031422)

$$T = 1/\{a + b[\ln(f_0/f)] + c[\ln^2[f_0/f] + d[\ln^3(f_0/f)]]\} - 273.15 \quad \text{Eqn. 3}$$

where

ln indicates a natural logarithm,

f is the frequency

a = 3.68096068 E-03

b = 5.98528033 E-04

c = 1.47933699 E-05

d = 2.18572143 E-06

f₀ = 6142.890

slope = 1.000137, offset = 0.004300 (Seabird calibration dated February 13, 1996)

d) Conductivity Sensor #2 (040996)

$$\text{conductivity} = (af^m + bf^2 + c + dt)/[10(1-\{CPcor p\})] \quad \text{Eqn. 4}$$

where

f is the frequency

p is pressure in dbar

t is the temperature

m = 4.1

a = 2.53328870 E-05

b = 5.95111155 E-01

c = -4.22225011 E+00

d = -2.08943055 E-04

CPcor = -9.5700 E-08

Slope = 1.000780, Offset = -5.60 E-04

e) Conductivity Sensor #3 (041076)

$$\text{conductivity} = (af^m + bf^2 + c + dt)/[10(1-\{CPcor p\})] \quad \text{Eqn. 5}$$

where

f is the frequency

p is pressure in dbar

t is the temperature

m = 4.1

a = 2.21442246 E-05

b = 5.67193159 E-01

c = -4.19781901 E+00

d = -1.23661793 E-04

CPcor = -9.5700 E-08

Slope = 1.000550, Offset = -1.310 E-03

f) Conductivity Sensor #4 (041124)

$$\text{conductivity} = (af^m + bf^2 + c + dt)/[10(1 - \{CPcor\}p)] \quad \text{Eqn. 6}$$

where

f is the frequency,
 p is pressure in dbar,
 t is the temperature
 m = 4.2
 a = 1.35924955 E-05
 b = 4.87959496 E-01
 c = -4.19483432 E+00
 d = -1.04684736 E-04
 CPcor = -9.5700 E-08
 Slope = 1.000563, Offset = -8.300 E-04

g) Oxygen Sensor #2 (130265)

$$\text{Oxygen} = [Soc \leftrightarrow (oc + \tau \frac{doc}{dt}) + Boc] \leftrightarrow \text{OXSAT}(T, S) \leftrightarrow e^{\{tcor \leftrightarrow T + wt \leftrightarrow (T_o - T)\} + pcor \leftrightarrow P} \quad \text{Eqn. 7}$$

where

Soc = 1.33
 oc is the oxygen sensor current (μ amps)
 $oc = mV + b$
 m = 2.4608 E-07
 V is the oxygen temperature sensor voltage signal
 b = -4.9216 E-10
 tau = 2.0
 $\frac{doc}{dt}$ is the time derivative of oc
 Boc = 0.446
 OXSAT is the oxygen saturation value dependent on T and S
 T is the water temperature ($^{\circ}$ C)
 S is salinity (psu)
 e is natural log base
 tcor = -5.00 E-03
 wt = 0.670
 T_o oxygen sensor internal temperature ($^{\circ}$ C)
 $T_o = kV + c$
 k = 8.9939
 c = -6.8210
 pcor = 5.35 E-05
 P is the pressure (psia)

h) Oxygen Sensor #4 (130284)

$$\text{Oxygen} = [S_{oc} \leftarrow (oc + \tau \frac{doc}{dt}) + B_{oc}] \leftrightarrow \text{OXSAT}(T, S) \leftrightarrow e^{\{t_{cor} \leftarrow T + wt \leftarrow (T_o - T)\} + p_{cor} \leftarrow P} \quad \text{Eqn. 8}$$

where

$$S_{oc} = 2.29$$

oc is the oxygen sensor current (μ amps)

$$oc = mV + b$$

$$m = 2.4528 \text{ E-07}$$

V is the oxygen temperature sensor voltage signal

$$b = -3.9245 \text{ E-09}$$

$$\tau = 2.0$$

$$\frac{doc}{dt}$$

is the time derivative of oc

$$B_{oc} = 0.322$$

OXSAT is the oxygen saturation value dependent on T and S

T is the water temperature ($^{\circ}$ C)

S is salinity (psu)

e is natural log base

$$t_{cor} = -6.00 \text{ E-03}$$

$$wt = 0.670$$

T_o oxygen sensor internal temperature ($^{\circ}$ C)

$$T_o = kV + c$$

$$k = 8.9625$$

$$c = -6.9161$$

$$p_{cor} = 8.00 \text{ E-05}$$

P is the pressure (psia)

iii. Second Calibration

The second calibration was applied to the 1 and 2 dbar data sets that resulted from the first calibration, section (ii). The second calibration is represented in Eqns. 9 - 11.

System #2 Sensor (secondary sensor for stations 8 – 16 and 34 – 39)

$$S_{CAL} = S_{UN} - 0.000318 \quad \text{Eqn. 9}$$

System #3 Sensor (secondary sensor for stations 1 – 7, 21 – 33 and 40 – 49)

$$S_{CAL} = S_{UN} + 0.00051 - 2.827\text{E-07} * P \quad \text{Eqn. 10}$$

System #4 Sensor (primary sensor for all stations)

$$S_{\text{CAL}} = S_{\text{UN}} + 0.000554 + 7.9841\text{E-}07 * P - 8.2712\text{E-}10 * P^2 + 1.34\text{E-}13 * P^3 \quad \text{Eqn. 11}$$

where

S_{CAL} : Salinity Calibrated
 S_{UN} : Salinity Uncalibrated
P : Pressure

iv. Calibration Procedure

The calibration procedures for calibrating the CTD conductivity (see equations 4 – 6), CTD oxygen data (see equations 7 – 8) and CTD salinity data (see equations 9 – 11) are listed below. The CTD conductivity sensors only required modified offsets to be calculated. The CTD Oxygen sensors required new non-linear ‘hardware’ coefficients to be computed. The CTD salinity data required corrections based on CTD Pressure. The calibration parameters for the CTD oxygen data and the CTD salinity data were based on down trace CTD data and measurements of water sample oxygen concentration from bottles tripped on the uptrace. Although these data sets are inconsistent (to some degree) in time and spatial location, they were considered the only reliable source of information for calibration of CTD oxygen and CTD salinity data.

The procedure for finding the calibrations to be applied to the CTD data were divided into four stages. Stage I applied only to the CTD conductivity data, stages II and III applied to the downcast CTD oxygen and stages II and IV applied to the downcast CTD salinity. Both stages II and III were iterative procedures.

- I. Creating a calibration file,**
- II. Compute new offsets,**
- III. Computing non-linear ‘hardware’ coefficients,**
- IV. Computing corrections of residual effects of pressure, temperature and salinity**
(secondary correction).

I. Creating a Calibration File

- 1) The *calibration file* is used for finding and testing calibrations (set of coefficients) later applied to the CTD data, while computing CTD Oxygen. A base for this file consisted of discrete CTD readings of temperature, pressure, salinity, etc.; averaged over three seconds at the depth and time of bottle tripping. The *calibration file* creation steps are outlined below;
- 2) Water sample salinity and oxygen concentration determined onboard were added to the *calibration file*;

- 3) For initial ‘indirect’ check of quality, the differences between water sample and calibrated CTD salinity were computed. If the absolute difference exceeded 0.004 the point (record) containing this data was considered unreliable and discarded from further analysis;
- 4) Next, a search and selection was performed for each record of the *calibration file*. The goal is to find a point in a downtrace profile in the same general water type.
 - data from a downtrace profile were restricted to a certain pressure (or/and) density (or/and) temperature (or/and) salinity vicinity of the uptrace point (the *calibration file*). This defines a *group*. Typical criteria (definition of vicinity): differences between uptrace and downtrace pressure 25 dbar, potential temperature 0.5K, and salinity 0.02. [Note: For some upcast data points, no downcast point was found within the defined criteria. In these cases, the CTD oxygen in the SEA file is indicated with a null value of -9.0 and a quality flag of 9, not sampled.]
 - find a point in the *group* which is closest to the uptrace data point (from the *calibration file*) in multidimensional space, where dimensions are normalized (weighted or rescaled) pressure, potential temperature, salinity and density. Normalization for each axis was done according to expected variability within a water type. In ultimate cases only one or two dimensions were chosen. The found point was identified as being “closest” to the upcast CTD data point at the time of bottle trip.

At this point, the downtrace CTD data has been added to the calibration file.

- 5) Next the data set was split into *sets* based on distinct changes in the sensors behavior. The *set* represented quasi-steady periods of oxygen sensor behavior. This avoided extreme temporal drifts in any of the *sets* and allowed the use of the same non-linear coefficients for each *set*.

II. Compute new offsets

Temperature Sensor Calibration

Using the calibration file, the median temperature difference between the two temperature sensors was computed and used for each deep station. The computed medians were then used to determine the adjustment to the temperature sensor’s coefficients.

Note: At this point the CTD data was reprocessed using the new temperature coefficients.

Conductivity Sensor Calibration

The calibration file was used to compare the conductivity acquired by the CTD with the water sample conductivity. The water sample salinities were converted to conductivities using the temperature measured by the CTD at the time of the bottle firing. In computing the new coefficients for the three conductivity sensors used on the cruise, the slopes changed only slightly from the original values, while the offsets changed more significantly.

Note: At this point the CTD data was reprocessed using the new conductivity coefficients.

III. Computing Non-linear ‘Hardware’ Coefficients

- 1) A nonlinear multiparametric least square technique was used to determine the oxygen sensor processing coefficients (soc , boc , $tcor$, and $bcor$) using $oxygen_{ws}$ vs. downcast $temperature_{ctd}$, $salinity_{ctd}$, $pressure_{ctd}$, $oxygen\ current_{ctd}$ and $oxygen\ temperature_{ctd}$ (where the ws/ctd subscripts represents water sample/CTD data).
- 2) Applying the results of step III.1, the $oxygen_{ctd}$ was derived.
- 3) Compute $oxygen_{ws} - oxygen_{ctd}$. Statistics of the difference were computed and the records that produced outliers (no matter if the outliers were produced by $oxygen_{ws}$ or $oxygen_{ctd}$) were marked or deleted from the *calibration file*.
- 4) Checking the $oxygen_{ws} - oxygen_{ctd}$ distributions:
 - if the differences ($oxygen_{ws} - oxygen_{ctd}$) are randomly distributed versus all parameters (temperature, pressure, oxygen current, and oxygen temperature) and there are no evident outliers, proceed to stage IV,
 - otherwise, using the cleaned *calibration file* (derived in stage I and cleaned according to III.3) repeat all the steps of stage III until the first part of the check III.4 is true (typically, it requires 10 to 15 iterations to clean the *calibration file* and determine the oxygen sensor processing coefficients soc , boc , $tcor$, and $bcor$).

Note: After stage III the CTD data was reprocessed using the Seabird software and the new oxygen coefficients.

IV. Computing corrections of residual effects of pressure and salinity

- 1) Use the *set* of stations (as defined in I.5) to compute a polynomial fit of the differences (residuals) between the CTD salinity and water sample salinity given in the calibration file (*first iteration on this stage*) or IV.2 (*second and higher iteration*), individually for pressure and then salinity.
- 2) Subtract the polynomial correction, derived in IV.1, from the differences computed in IV.1. Check if there are any outliers.
 - If these (*new IV.2*) residuals don't depend on pressure, salinity or time and their statistics is not improving with any sequential iteration (distribution getting tighter) advance to IV.3.
 - Otherwise, use the results of step IV.2 and repeat step IV.1 until the first bulleted part of IV.2 is true. This iteration typically requires 7 to 14 repetitions.
- 3) Finalize calibration coefficients.

v. CTD Quality Flagging and Data Delivery

The processed 2 dbar CTD was quality flagged by applying “bad” flags to the near-surface data. These data would have been collected before the system pump was activated, and thus do not represent measurements from a properly operating system. This typically meant that the temperature, salinity and oxygen data above 10 dbar were flagged using WOCE flag “4”. As well, some at-depth points were flagged as either questionable or bad, depending on subjective assessment of the density profile.

Only the CTD data from the primary sensors are reported to the WOCE DAC. BIO archives data from both sensors. The Marine Environmental Data Service, MEDS, (Canada's NODC) will receive data from all sensors.

2. Salinity

Manon Poliquin

a. Description of Equipment and Technique

Salinity samples were analyzed on one of two Guildline Autosal model 8400 salinometers, serial numbers 61083 and 60968. Samples were drawn in 150 ml medicine bottles. New caps, equipped with plastic liners, were placed on the sample bottles for each use.

The salinometer cell was filled and rinsed three times with sample water before readings were recorded. Three readings of the salinometer were recorded for every sample and standardization.

The last two readings were averaged and entered into the water sample database as the conductivity of the water sample.

b. Sampling Procedure and Data Processing Technique

Salinity samples were drawn into 150 ml medicine bottles after three rinses. The bottles were filled up to the shoulders and then capped with new caps with plastic liners.

One conductivity file for the entire cruise was prepared. The file consisted of a sequential record number, the bath temperature, sample ID number, average conductivity ratio and a quality flag. A PC based program running under a commercial DBMS computed the salinity using the average conductivity ratio and the standard IAPSO formula. Any changes in the salinometer readings between successive standardizations were assumed to have occurred as a linear drift of the instrument. Thus, the program applied a correction to the ratios, which varied linearly with the samples analyzed. The salinity data was then placed in the water sample database. A total of 594 salinity values were obtained for this cruise.

c. Laboratory and Sample Temperatures

Full cases of samples were taken from the winch room to the GP lab where they were left for a period of at least 10 hours to equilibrate to laboratory temperature before being analyzed.

The baths in both salinometers were kept at 24°C for all stations.

d. Replicate Analysis

A duplicate salinity sample was drawn from one of the rosette bottles on most casts. A total of 24 duplicate salinity samples were drawn and statistically analyzed. Statistics of the duplicate differences follow. Only acceptable values were used in calculating the duplicate differences. All of the duplicate sample values and their quality flags are listed in Table C.2 below.

Statistic	Value
Number of Points	23
Minimum	0.0000
Maximum	0.0024
Mean	0.0006
Median	0.0004
Standard Deviation	0.0006

e. Standards Used

The salinometer was standardized on May 14, 1996 using IAPSO standard water, Batch P124, prepared on January 18, 1994. A check on the standardization using a new ampoule was carried out at the beginning and end of every 32 bottle case and at intermediate points during a case if instrument drift was suspected.

Table C.2 Replicate water sample salinity values with their quality flags.

Sample ID Number	Salinity	WOCE QF	Sample ID Number	Salinity	WOCE QF
158186	32.8470	2	158368	34.8872	2
158186	32.8462	2	158368	34.8869	2
158190	33.0984	2	158391	34.8893	2
158190	33.0990	2	158391	34.8893	2
158194	33.2849	2	158413	34.8721	2
158194	33.2858	2	158413	34.8733	2
158204	33.5019	2	158438	34.9003	2
158204	33.5020	2	158438	34.9004	2
158211	33.0533	2	158472	34.8470	2
158211	33.0534	2	158472	34.8471	2
158217	34.2151	2	158483	34.8921	2
158217	34.2140	2	158483	34.8917	2
158225	34.8606	2	158518	34.8319	2
158225	34.8608	2	158518	34.8322	2
158237	34.8868	2	158529	34.8815	2
158237	34.8874	2	158529	34.8821	2
158254	34.8919	2	158552	34.8970	2
158254	34.8932	2	158552	34.8976	2
158292	34.8648	3	158595	34.9035	2
158292	34.8690	3	158595	34.9035	2
158316	34.8771	2	158614	34.8996	2
158316	34.8775	2	158614	34.9020	2
158340	34.8929	2	158630	32.8430	2
158340	34.8930	2	158630	32.8422	2

3. Oxygen

Manon Poliquin

a. Description of Equipment and Technique

The oxygen samples were analyzed using an automated procedure developed by the Ocean Sciences Division (OSD) of the Bedford Institute of Oceanography (BIO) from a manual titration system (Levy et al. 1977). The OSD procedure was a modified Winkler titration from Carritt and Carpenter (1966), using a whole bottle titration. In this method there was no starch indicator and a wetting agent (Wetting Agent A, BDR) was introduced to reduce bubble formation. The automated titration system consisted of an IBM PC linked to a Brinkmann PC800 colorimeter and a Metrohm 665 Multi-Dosimat Automatic Titrator. A full description of the system and method can be found in Jones, et al. (1992) with the following exception: Pages 2-4, section 2.3 Method - Sample titration should read, *'The stopper is not replaced and the acid rinsed down the stopper's end into the flask. The end is then rinsed into the flask with deionized water. One drop of wetting agent and the magnetic stirring bar are then added.'*

b. Sampling Procedure and Data Processing Technique

The sampling bottles were 125ml Iodine flasks with custom ground stoppers (Levy et al. 1977). The flask volumes were determined gravimetrically. The matched flasks and stoppers were etched with Identification numbers and entered into the Oxygen program database.

For this cruise 10 litre rosette bottles were used to obtain the original sample. The oxygen subsamples were drawn immediately following the drawing of the CFC, DOC and helium subsamples. The oxygen subsamples were drawn through the bottle's spigot with a latex or silicone tube attached so as to introduce the water to the bottom of the flask. The flask and its stopper were thoroughly rinsed and filled to overflowing. The flow was allowed to continue until at least two to three flask volumes overflowed. The flask was then slowly retracted with continuous low flow to ensure that no air got trapped in the flask. The flask was then brought to the reagent station and one ml each of the Alkaline Iodide and Manganous Chloride Reagents were added. The stoppers were then carefully inserted; again ensuring that no air got into the flasks. The flasks were thoroughly shaken then carried to the lab for analysis.

Some problems were encountered with the processing software. In particular, the oxygen program initially used to compute the end point and titrant volume failed. No immediate reason for the failure could be determined. The software would not load and resulted in the PC being hung. Reloading the software did not solve the problem. A second, newer version of the software was then loaded and functioned properly. The problem resulted in samples 158423 and 158424 being lost. The first sample used for the second version of the software was sample ID number 158425. It is unclear why the PC initially had the older version of the software.

Due to the processing software problem noted above, we recommend upgrading the IBM PC-2000 (XT) to a newer model. This change would involve adapting the database program to run on a 486 model. With a newer version of the computer it would be easier to switch to another

computer in case of a malfunction. With the XT it is almost impossible to do so because of the scarcity of such models. Furthermore, having a complete backup copy of the database program on floppy disk is recommended for future missions. More complete version control tracking of the software is also required to allow traceability in the data processing.

c. Replicate Analysis

There were 657 unique sample id numbers that were analyzed for dissolved oxygen, of which 546 had one sample value, 35 had two sample values, 75 had three sample values and one had four sample values. At least a single replicate oxygen sample was drawn from one of the rosette bottles on every cast. On one cast, duplicate samples were drawn from five rosette bottles. All sample id numbers that had oxygen samples for stations two through eight had triplicate oxygen samples drawn.

Statistics of the replicate differences follow. Only acceptable values were used in calculating the replicate differences. The calculated replicate statistics used the absolute value of the replicate differences. All of the replicate sample values and their quality flags are listed in Table C.3 below.

Number of replicate differences

$$\begin{aligned}
 &= (34) \text{ sample id numbers having one replicate} * (1) \text{ possible difference} \\
 &+ (77) \text{ sample id numbers having two replicates} * (3) \text{ possible differences} \\
 &= 265
 \end{aligned}$$

$$\text{Median of } [(\text{absolute difference} / \text{sample mean concentration of all samples}) * 100\%] = 0.38 \%$$

Statistic	Value (μmoles/kg)
Minimum	0.0
Maximum	20.6
Mean	1.9
Median	1.0
Standard Deviation	2.6

Cumulative Frequency	Oxygen Difference (μmoles/kg)
50 %	≤ 1.0
68 %	≤ 1.9
95 %	≤ 6.5

Table C.3 Replicate water sample oxygen values in $\mu\text{moles/kg}$, along with their quality flags.

Sample ID Number	Oxygen	WOCE QF	Sample ID Number	Oxygen	WOCE QF
158001	327.3	2	158020	343.8	2
158001	327.8	2	158020	344.1	2
158001	326.7	2	158020	346.8	2
158003	336.0	2	158021	346.3	2
158003	336.7	2	158021	346.4	2
158003	336.7	2	158021	347.7	2
158004	345.7	2	158022	357.6	2
158004	344.4	2	158022	358.2	2
158004	344.9	2	158022	358.3	2
158005	350.1	2	158023	355.8	2
158005	349.4	2	158023	356.8	2
158005	349.4	2	158023	357.6	2
158006	357.6	2	158024	357.0	2
158006	358.1	2	158024	357.1	2
158006	358.3	2	158024	358.8	2
158007	361.5	2	158025	354.7	2
158007	360.9	2	158025	358.8	2
158007	361.2	2	158025	357.0	2
158008	361.5	2	158026	148.4	2
158008	356.0	2	158026	150.0	2
158008	354.1	2	158026	150.8	2
158009	351.4	2	158027	150.9	2
158009	351.5	2	158027	152.0	2
158009	357.8	2	158027	152.0	2
158010	204.5	2	158028	150.1	2
158010	207.3	2	158028	155.8	2
158010	209.2	2	158028	156.5	2
158013	287.4	2	158029	150.8	2
158013	288.8	2	158029	152.7	2
158013	308.0	2	158029	152.9	2
158015	305.0	2	158030	155.4	2
158015	306.0	2	158030	157.5	2
158015	306.2	2	158030	157.7	2
158017	311.2	2	158032	166.2	2
158017	311.7	2	158032	162.1	2
158017	315.2	2	158032	160.6	2
158019	338.9	2	158034	184.2	2
158019	340.8	2	158034	192.1	2
158019	339.6	2	158034	182.5	2
158036	184.5	2	158044	344.6	2
158036	183.3	2	158044	339.8	2
158036	184.8	2	158044	337.6	2
158038	204.6	2	158045	335.6	2
158038	205.0	2	158045	335.7	2
158038	206.2	2	158045	339.4	2
158040	238.7	2	158046	335.9	2
158040	238.1	2	158046	337.7	2
158040	238.5	2	158046	338.0	2
158042	314.8	2	158047	209.7	2
158042	315.3	2	158047	210.5	2
158042	316.2	2	158047	211.2	2
158043	335.7	2	158048	256.8	2
158043	334.0	2	158048	256.9	2
158043	335.7	2			

Table C.3 Replicate water sample oxygen values in $\mu\text{moles/kg}$, along with their quality flags.

Sample ID Number	Oxygen	WOCE QF	Sample ID Number	Oxygen	WOCE QF
158048	259.0	2	158066	213.0	2
158049	314.5	2	158066	213.6	2
158049	313.7	2	158066	214.4	2
158049	313.8	2	158067	227.1	2
158050	335.9	2	158067	226.4	2
158050	334.8	2	158067	226.5	2
158050	334.0	2	158070	241.5	2
158051	323.9	2	158070	238.2	2
158051	326.2	2	158070	239.2	2
158051	330.5	2	158072	245.0	2
158052	325.3	2	158072	245.6	2
158052	326.4	2	158072	246.0	2
158052	327.7	2	158074	259.6	2
158053	323.6	2	158074	259.2	2
158053	324.4	2	158074	259.2	2
158053	328.3	2	158076	293.9	2
158054	325.5	2	158076	293.9	2
158054	326.1	2	158076	293.4	2
158054	328.6	2	158077	304.2	2
158056	259.9	2	158077	300.2	2
158056	262.6	2	158077	300.6	2
158056	263.4	2	158078	321.7	2
158058	305.5	2	158078	322.1	2
158058	306.5	2	158078	324.6	2
158058	305.5	2	158079	335.0	2
158059	315.8	2	158079	335.3	2
158059	316.3	2	158079	337.2	2
158059	316.7	2	158080	331.4	2
158060	334.8	2	158080	332.7	2
158060	335.3	2	158080	334.8	2
158060	339.4	2	158081	328.2	2
158061	338.2	2	158081	326.5	2
158061	338.5	2	158081	328.1	2
158061	339.8	2	158082	327.8	2
158062	322.0	2	158082	327.6	2
158062	324.9	2	158082	327.5	2
158062	325.7	2	158083	179.9	2
158063	324.2	2	158083	182.2	2
158063	324.2	2	158083	185.1	2
158063	326.5	2	158084	184.2	2
158064	325.1	2	158084	184.3	2
158064	323.9	2	158084	185.0	2
158064	324.7	2	158085	223.7	2
158065	172.5	2	158085	223.8	2
158065	174.4	2	158085	226.1	2
158065	174.7	2	158088	243.0	2
			158088	243.3	2
			158088	244.1	2
			158090	227.7	2
			158090	230.2	2
			158090	234.7	2

Table C.3 Replicate water sample oxygen values in $\mu\text{moles/kg}$, along with their quality flags.

Sample ID Number	Oxygen	WOCE QF	Sample ID Number	Oxygen	WOCE QF
158092	233.4	2	158337	291.2	2
158092	234.8	2	158337	303.9	2
158092	234.4	2			
			158360	300.7	2
158094	266.0	2	158360	300.9	2
158094	266.6	2			
158094	266.7	2	158374	295.7	2
			158374	298.7	2
158095	293.5	2			
158095	293.7	2	158388	297.2	2
158095	294.0	2	158388	304.8	2
158096	314.3	2	158412	303.1	2
158096	316.4	2	158412	304.0	2
158096	316.6	2	158412	304.9	2
158097	313.5	2	158414	298.4	2
158097	313.5	2	158414	298.6	2
158097	316.9	2			
			158421	299.7	2
158098	312.9	2	158421	299.8	2
158098	314.1	2			
158098	314.7	2	158434	303.3	2
			158434	303.3	2
158099	311.4	2			
158099	313.2	2	158440	282.6	2
158099	311.3	2	158440	281.9	2
158100	312.0	2	158442	282.0	2
158100	312.6	2	158442	285.4	2
158100	313.3	2			
			158444	298.6	2
158185	336.3	2	158444	298.9	2
158185	339.1	2			
			158446	298.8	2
158189	318.5	2	158446	299.0	2
158189	319.2	2			
			158457	305.1	2
158196	401.7	2	158457	305.3	2
158196	402.3	2			
			158480	296.1	2
158198	322.5	2	158480	303.1	2
158198	317.6	2			
			158505	300.4	2
158206	341.1	2	158505	300.5	2
158206	341.4	2			
			158526	303.3	2
158208	306.5	2	158526	303.5	2
158208	317.6	2			
			158553	288.0	2
158214	291.5	2	158553	287.3	2
158214	288.7	2			
			158572	294.0	2
158224	290.9	2	158572	294.5	2
158224	290.8	2			
			158596	286.2	2
158234	286.6	2	158596	287.4	2
158234	286.9	2			
			158613	285.0	2
158251	292.0	2	158613	285.5	2
158251	293.7	2			
			158627	340.8	2
158271	302.5	2	158627	341.5	2
158271	302.7	2			
			158631	355.7	2
158296	275.6	2	158631	355.5	2
158296	286.2	2			
158318	285.5	2			
158318	275.6	2			

4. Nutrients

a. Description of Equipment and Technique

Nutrient samples for this cruise were analyzed at the Bedford Institute of Oceanography. The samples were drawn and stored as described below.

b. Sampling Procedure and Data Processing Technique

Duplicate nutrient subsamples were drawn into 30 ml HDPE (Nalge) wide mouth sample bottles from 10 L Niskins. The bottles were 10% HCl washed, rinsed once with tap water, three times with Super-Q and oven dried at >100 °F.

Within about 30 minutes of drawing, the samples were placed in a deep freezer and stored at -13 °C.

c. Replicate Analysis

A total of 1234 seawater samples were analyzed for silicate, phosphate and NO₂+NO₃. Included in these samples were a total of 615 duplicate samples and 1 quadruplicate samples. Statistics relating to the precision of the sample values follow. All values are given in µmoles/kg. Only the samples that had acceptable replicate values were included in the statistics. All replicate values and their quality flags are given in Table C.4.

Precision is a measure of the variability of individual measurements and in the following analysis two categories of precision were determined: field and analytical precision. Analytical precision is based on the pooled estimate of the standard deviation of the check standards over the course of a complete autoanalyzer run and is a measure of the greatest precision possible for a particular analysis. Field precision is based on the analysis of two or more water samples taken from a single Niskin sampling bottle and has an added component of variance due to subsampling, storage and natural sample variability.

Both categories of precision were determined by computing the variance, σ_i^2 , of each replicate set, where "i" is the index of the replicate set. In the case of analytical (field) precision, a replicate set consisted of all the check standards (duplicate samples). Given p replicate sets and n samples within any replicate set, the mean standard deviation, $\bar{\sigma}$, was determined from

$$\bar{\sigma} = \sqrt{\frac{\sum_{i=1}^p (n-1)_i \sigma_i^2}{p}}$$

The precision expressed in percent was based on the mean concentration (M) of the check standards (analytical precision) or water samples (field precision) and was given by

$$P_{\%} = \frac{\sigma}{M} \times 100\%$$

The following table indicates the analytical and field precision obtained for this cruise.

Statistic	Silicate	Phosphate	NO₂+NO₃
Number of Samples	1234	2068	1231
Number of Replicates	577	577	574
Mean concentration (μmoles/kg)	7.59	0.90	11.34
Field Precision (μmoles/kg)	0.81	0.07	1.08
Field Precision (%)	10.73	7.72	9.48
Analytical Precision (μmoles/kg)	0.32	0.05	0.20
Analytical Precision (%)	0.88	3.26	1.07
Detection Limit (μmoles/kg)	0.30	0.02	0.10

The laboratory temperature during all analyses was between 21 and 23 °C.

The conversion to mass units for the analytical precision and detection limits used a standard density of 1.02443 kg/litre corresponding to 33 ppt and 15°C. The conversion of individual sample values from volume to mass units used a potential density with a fixed temperature of 15°C.

Duplicate samples were drawn from each rosette bottle for the determination of silicate, phosphate and nitrate concentrations.

The nutrient detection limits noted in the above table were applied to the dataset. All values at or below the detection limits were set to zero.

Table C.4 Replicate nutrient water sample values in $\mu\text{moles/kg}$, along with their quality flags.

ID	SiO2	PO4	NO2+NO3	QF	ID	SiO2	PO4	NO2+NO3	QF
158001	2.38	0.76	1.18	2 2 2	158026	17.34	1.29	20.29	2 2 2
158001	2.29	0.73	1.23	2 2 2	158026	17.38	1.34	20.27	2 2 2
158002	1.94	0.70	1.12	2 2 2	158027	15.78	1.46	19.75	2 2 2
158002	1.99	0.71	1.12	2 2 2	158027	15.83	1.30	19.69	2 2 2
158003	1.44	0.66	0.88	2 2 2	158028	14.40	1.24	19.16	2 2 2
158003	1.49	0.67	0.92	2 2 2	158028	14.43	1.24	19.42	2 2 2
158004	0.98	0.65	0.75	2 2 2	158029	13.13	1.25	18.55	2 2 2
158004	1.00	0.61	0.74	2 2 2	158029	14.16	1.30	20.90	2 2 2
158005	0.88	0.61	0.70	2 2 2	158030	12.36	1.22	18.06	2 2 2
158005	0.88	0.62	0.75	2 2 2	158030	12.45	1.22	18.36	2 2 2
158006	0.78	0.60	0.67	2 2 2	158031	11.78	1.19	17.59	2 2 2
158006	0.78	0.59	0.65	2 2 2	158031	11.78	1.21	17.80	2 2 2
158007	0.60	0.53	0.30	2 2 2	158032	11.86	1.15	17.12	2 2 2
158007	0.62	0.52	0.32	2 2 2	158032	11.87	1.17	17.12	2 2 2
158008	0.79	0.50	0.18	2 2 2	158033	10.61	1.08	15.64	2 2 2
158008	0.80	0.51	0.19	2 2 2	158033	10.62	1.06	15.56	2 2 2
158009	0.81	0.52	0.17	2 2 2	158034	10.09	1.03	14.90	2 2 2
158009	0.84	0.51	0.17	2 2 2	158034	10.16	1.00	15.13	2 2 2
158010	12.82	1.21	12.91	2 2 2	158035	8.80	0.98	13.59	2 2 2
158010	12.85	1.22	13.09	2 2 2	158035	8.77	0.99	13.59	2 2 2
158011	11.98	1.20	12.50	2 2 2	158036	9.66	1.03	15.08	2 2 2
158011	11.98	1.20	12.42	2 2 2	158036	9.68	1.02	15.21	2 2 2
158012	9.48	1.11	10.30	2 2 2	158037	9.64	0.92	13.72	2 2 2
158012	9.53	1.11	10.21	2 2 2	158037	9.65	0.95	13.66	2 2 2
158013	6.65	1.03	6.58	2 2 2	158038	8.90	0.97	12.95	2 2 2
158013	6.65	1.01	6.53	2 2 2	158038	8.92	0.98	12.85	2 2 2
158014	5.35	0.88	4.89	2 2 2	158039	8.02	1.01	11.55	2 2 2
158014	5.26	0.88	4.88	2 2 2	158039	8.07	0.98	11.54	2 2 2
158015	4.89	0.82	4.67	2 2 2	158040	7.24	0.96	10.60	2 2 2
158015	4.94	0.80	4.74	2 2 2	158040	7.24	0.96	10.57	2 2 2
158016	4.59	0.88	4.56	2 2 2	158041	3.70	0.72	4.44	2 2 2
158016	4.66	0.92	4.68	2 2 2	158041	3.71	0.70	4.48	2 2 2
158017	4.29	0.81	4.16	2 2 2	158042	2.90	0.67	3.07	2 2 2
158017	4.32	0.79	4.19	2 2 2	158042	2.91	0.64	3.03	2 2 2
158018	3.02	0.76	2.94	2 2 2	158043	2.33	0.53	0.43	2 2 2
158018	3.03	0.75	2.89	2 2 2	158043	2.36	0.53		2 2 9
158019	1.29	0.61	0.81	2 2 2	158044	0.65	0.32	0.26	2 2 2
158019	1.28	0.60	0.83	2 2 2	158044	0.69	0.30	0.28	2 2 2
158020	0.81	0.54	0.29	2 2 2	158045	0.62	0.30	0.26	2 2 2
158020	0.76	0.53	0.30	2 2 2	158045	0.62	0.30	0.23	2 2 2
158021	1.02	0.56	0.83	2 2 2	158046	0.60	0.12	0.19	2 2 2
158021	1.04	0.55	0.83	2 2 2	158046	0.63	0.04	0.21	2 2 2
158022	0.50	0.48	0.18	2 2 2	158047	10.10	0.13	12.36	2 2 2
158022	0.51	0.50	0.21	2 2 2	158047	10.21	0.99	12.64	2 2 2
158023	0.33	0.36	0.00	2 2 2	158048	4.73	0.22	7.12	2 2 2
158023	0.35	0.39	0.00	2 2 2	158048	4.66	0.22	7.22	2 2 2
158024	0.33	0.37	0.00	2 2 2	158049	1.65	0.18	1.66	2 2 2
158024	0.34	0.36	0.00	2 2 2	158049	1.64	0.21	1.64	2 2 2
158025	0.40	0.39	0.00	2 2 2					
158025	0.39	0.38	0.00	2 2 2					

Table C.4 Replicate nutrient water sample values in $\mu\text{moles/kg}$, along with their quality flags.

ID	SiO2	PO4	NO2+NO3	QF	ID	SiO2	PO4	NO2+NO3	QF
158050	0.87	0.39	0.00	2 2 2	158075	4.22	0.71	6.55	2 2 2
158050	0.89	0.39	0.00	2 2 2	158075	4.25	0.72	6.78	2 2 2
158050	0.97	0.41	0.00	2 2 2					
158050	0.99	0.35	0.00	2 2 2	158076	4.61	0.75	5.72	2 2 2
158051	0.66	0.14	0.31	2 2 2	158076	4.56	0.73	5.63	2 2 2
158051	0.75	0.22	0.40	2 2 2	158077	4.42	0.80	5.43	2 2 2
158052	0.82	0.40	0.15	2 2 2	158077	4.22	0.80	5.04	2 2 2
158052	0.83	0.40	0.24	2 2 2	158078	1.37	0.50	1.45	2 2 2
158053	0.46	0.32	0.16	2 2 2	158078	1.38	0.50	1.62	2 2 2
158053	0.44	0.31		2 2 9	158079	0.55	0.46	0.50	2 2 2
158054	0.62	0.12	0.21	2 2 2	158079	0.56	0.43	0.54	2 2 2
158054	0.68	0.13	0.22	2 2 2	158080	0.41	0.40	0.18	2 2 2
158055	5.26	0.14	6.99	2 2 2	158080	0.47	0.39	0.18	2 2 2
158055	5.58	0.18	7.48	2 2 2	158081	0.00	0.38	0.18	2 2 2
158056	5.87	0.20	7.95	2 2 2	158081	0.31	0.40	0.23	2 2 2
158056	5.93	0.18	8.05	2 2 2	158082	0.29	0.39	0.16	2 2 2
158057	3.81	0.22	5.49	2 2 2	158082	0.00	0.37	0.16	2 2 2
158057	3.86	0.22	5.46	2 2 2	158083	11.35	1.31	19.31	2 2 2
158058	2.49	0.69	3.20	2 2 2	158083	11.37	1.28	19.41	2 2 2
158058	2.50	0.66	3.46	2 2 2					
158059	1.79	0.67	2.11	2 2 2	158084	10.62	1.27	19.51	2 2 2
158059	1.80	0.63	2.09	2 2 2	158084	10.62	1.31	19.77	2 2 2
158060	0.66	0.49	0.58	2 2 2	158085	8.71	1.04	15.05	2 2 2
158060	0.69	0.53	0.62	2 2 2	158085	8.73	1.02	14.90	2 2 2
158061	0.54	0.40	0.18	2 2 2	158086	7.55	0.93	13.69	2 2 2
158061	0.49	0.41	0.18	2 2 2	158086	7.58	0.96	13.79	2 2 2
158062	0.56	0.35	0.14	2 2 2	158087	7.62	0.95	13.67	2 2 2
158062	0.57	0.30	0.13	2 2 2	158087	7.63	0.92	13.61	2 2 2
					158088	6.97	0.89	12.59	2 2 2
158063	0.59	0.39		2 2 9	158088	7.00	0.88	12.48	2 2 2
158063	0.59	0.37	0.13	2 2 2	158089	4.91	0.68	8.49	2 2 2
158064	0.62	0.38	0.13	2 2 2	158089	4.98	0.70	8.55	2 2 2
158064	0.63	0.38	0.15	2 2 2	158090	6.36	0.83	11.67	2 2 2
158065	10.28	1.24	17.92	2 2 2	158090	6.28	0.82	11.74	2 2 2
158065	10.33	1.23	18.01	2 2 2	158091	6.21	0.80	11.48	2 2 2
158066	9.54	1.09	15.47	2 2 2	158091	6.27	0.82	11.67	2 2 2
158066	9.52	1.07	15.31	2 2 2	158092	5.60	1.25	9.71	2 2 2
158067	7.81	0.99	13.26	2 2 2	158092	5.60	1.26	9.69	2 2 2
158067	7.78	1.01	13.29	2 2 2	158093	5.55	0.79	9.65	2 2 2
158068	8.02	0.91	12.41	2 2 2	158093	5.59	0.77	9.63	2 2 2
158068	8.06	0.92	12.48	2 2 2	158094	3.97	0.75	7.35	2 2 2
158069	7.48	0.89	11.77	2 2 2	158094	3.99	0.77	7.41	2 2 2
158069	7.49	0.88	11.81	2 2 2	158095	2.00	0.65	3.44	2 2 2
158070	6.93	0.86	11.04	2 2 2	158095	1.96	0.60	3.47	2 2 2
158070	6.97	0.86	11.14	2 2 2	158096	1.14	0.46	1.01	2 2 2
158071	7.26	0.83	11.56	2 2 2	158096	1.10	0.45	0.97	2 2 2
158071	7.25	0.86	11.71	2 2 2	158097	0.82	0.28	0.15	2 2 2
158072	6.50	0.80	10.52	2 2 2	158097	0.89	0.32	0.24	2 2 2
158072	6.53	0.83	10.65	2 2 2	158098	0.75	0.30	0.19	2 2 2
158073	5.77	0.75	9.12	2 2 2	158098	0.78	0.30	0.27	2 2 2
158073	5.83	0.76	9.11	2 2 2	158099	0.68	0.34	0.23	2 2 2
158074	5.76	0.82	9.23	2 2 2	158099	0.70	0.33	0.12	2 2 2
158074	5.77	0.79	9.18	2 2 2	158100	0.61	0.31	0.12	2 2 2
					158100	0.69	0.34	0.24	2 2 2

Table C.4 Replicate nutrient water sample values in $\mu\text{moles/kg}$, along with their quality flags.

ID	SiO2	PO4	NO2+NO3	QF	ID	SiO2	PO4	NO2+NO3	QF
158101	5.70	0.87	5.96	2 2 2	158127	0.00	0.44	0.00	2 2 2
158101	5.64	0.86	5.98	2 2 2	158127	0.00	0.38	0.00	2 2 2
158102	5.66	0.85	5.97	2 2 2	158128	0.00	0.38	0.00	2 2 2
158102	5.68	0.87	5.95	2 2 2	158128	0.00	0.36	0.00	2 2 2
158103	5.23	0.87	5.67	2 2 2	158129	0.00	0.39	0.00	2 2 2
158103	5.28	0.87	5.67	2 2 2	158129	0.00	0.39	0.00	2 2 2
158104	4.02	0.85	4.55	2 2 2	158130	4.11	0.66	8.43	2 2 2
158104	4.22	0.82	4.80	2 2 2	158130	4.08	0.63	8.45	2 2 2
158105	3.16	0.96	4.05	2 2 2	158131	4.24	0.71	8.48	2 2 2
158105	3.18	0.96	3.97	2 2 2	158131	4.30	0.69	8.95	2 2 2
158106	1.13	0.73	1.57	2 2 2	158132	3.64	0.66	7.19	2 2 2
158106	1.13	0.75	1.64	2 2 2	158132	3.69	0.66	7.37	2 2 2
158107	0.85	0.61	0.69	2 2 2	158133	3.42	0.63	6.81	2 2 2
158107	0.87	0.61	0.73	2 2 2	158133	3.49	0.65	6.91	2 2 2
158108	0.58	0.45	0.16	2 2 2	158134	2.03	0.49	3.47	2 2 2
158108	0.59	0.46	0.18	2 2 2	158134	2.05	0.50	3.38	2 2 2
158109	0.45	0.39	0.00	2 2 2	158135	1.43	0.50	1.66	2 2 2
158109	0.47	0.37	0.00	2 2 2	158135	1.52	0.51	1.66	2 2 2
158110	0.51	0.39	0.00	2 2 2	158136	1.31	0.44	0.83	2 2 2
158110	0.54	0.40	0.00	2 2 2	158136	1.34	0.43	0.83	2 2 2
158111	0.52	0.40	0.00	2 2 2	158137	0.54	0.35	0.00	2 2 2
158111	0.46	0.38	0.00	2 2 2	158137	0.54	0.32	0.00	2 2 2
158112	1.69	0.61	0.18	2 2 2	158138	0.00	0.32	0.00	2 2 2
158112	1.76	0.60	0.18	2 2 2	158138	0.00	0.27	0.00	2 2 2
158113	1.73	0.63	0.19	2 2 2	158139	0.00	0.31	0.00	2 2 2
158113	1.74	0.64	0.17	2 2 2	158139	0.00	0.28	0.00	2 2 2
158114	1.86	0.64	0.10	2 2 2	158140	0.00	0.35	0.00	2 2 2
158114	1.90	0.63	0.15	2 2 2	158140	0.00	0.33	0.00	2 2 2
158115	1.44	0.59	0.00	2 2 2	158141	6.95	0.89	7.80	2 2 2
158115	1.60	0.57	0.00	2 2 2	158141	6.97	0.89	7.81	2 2 2
158116	0.36	0.43	0.00	2 2 2	158142	4.86	0.79	5.46	2 2 2
158116	0.57	0.45	0.00	2 2 2	158142	4.90	0.77	5.45	2 2 2
158117	0.44	0.40	0.00	2 2 2	158143	4.22	0.79	5.13	2 2 2
158117	0.45	0.42	0.00	2 2 2	158143	4.18	0.81	5.14	2 2 2
158118	0.00	0.41	0.31	2 2 2	158144	3.05	0.78	4.13	2 2 2
158118	0.30	0.39	0.31	2 2 2	158144	2.75	0.76	3.86	2 2 2
158119	6.18	0.84	6.06	2 2 2	158145	5.30	0.81	7.94	2 2 2
158119	6.14	0.84	5.74	2 2 2	158145	5.41	0.84	7.84	2 2 2
158120	7.43	0.94	6.71	2 2 2	158146	2.02	0.86	4.35	2 2 2
158120	7.55	0.92	6.77	2 2 2	158146	2.02	0.83	4.41	2 2 2
158121	8.14	1.00	7.82	2 2 2	158147	0.00	0.42	0.17	2 2 2
158121	8.17	1.00	7.76	2 2 2	158147	0.00	0.42	0.15	2 2 2
158122	4.18	0.89	5.03	2 2 2	158148	0.00	0.36	0.00	2 2 2
158122	4.24	0.92	5.12	2 2 2	158148	0.00	0.35	0.00	2 2 2
158123	2.97	0.91	4.73	2 2 2	158149	0.00	0.41	0.00	2 2 2
158123	2.99	0.92	4.74	2 2 2	158149	0.00	0.42	0.00	2 2 2
158124	1.42	0.81	2.85	2 2 2	158150	0.00	0.43	0.00	2 2 2
158124	1.39	0.79	2.78	2 2 2	158150	0.00	0.43	0.00	2 2 2
158125	0.50	0.52	0.56	2 2 2	158151	0.00	0.40	0.00	2 2 2
158125	0.44	0.51	0.60	2 2 2	158151	0.00	0.40	0.00	2 2 2
158126	0.00	0.45	0.00	2 2 2	158152	8.62	0.40	11.49	2 2 2
158126	0.00	0.44	0.00	2 2 2	158152	8.69	0.99	11.44	2 2 2

Table C.4 Replicate nutrient water sample values in $\mu\text{moles/kg}$, along with their quality flags.

ID	SiO2	PO4	NO2+NO3	QF	ID	SiO2	PO4	NO2+NO3	QF
158153	6.12	0.87	9.46	2 2 2	158180	0.00	0.46	0.00	2 2 2
158153	6.06	0.88	9.36	2 2 2	158180	0.00	0.44	0.00	2 2 2
158154	6.83	0.89	8.39	2 2 2	158185	10.98	1.13	8.50	2 2 2
158154	6.79	0.94	8.44	2 2 2	158185	11.27	0.95	8.93	2 2 2
158155	4.94	0.80	6.68	2 2 2	158186	8.30	0.79	6.41	3 3 3
158155	4.99	0.79	6.71	2 2 2	158186	10.30	0.94	8.05	3 3 3
158156	4.66	0.44	5.41	2 2 2	158187	6.59	0.73	3.86	2 2 2
158156	4.70	0.72	5.40	2 2 2	158187	6.67	0.76	3.50	2 2 2
158157	3.26	0.37	3.37	2 2 2	158188	1.55	0.48	0.10	3 3 3
158157	3.30	0.64	3.51	2 2 2	158188	2.60	0.46	0.11	3 3 3
158158	0.56	0.48	0.34	2 2 2	158189	9.62	0.92	8.29	3 3 3
158158	0.56	0.81	0.35	2 2 2	158189	11.64	0.99	10.11	3 3 3
158159	0.37	0.47	0.13	2 2 2	158190	10.67	0.95	9.21	3 3 3
158159	0.00	0.46	0.13	2 2 2	158190	13.79	0.94	9.59	3 3 3
158160	0.00	0.55	0.17	2 2 2	158191	10.81	0.97	8.38	3 3 3
158160	0.00	0.36	0.17	2 2 2	158191	17.14	0.98	8.29	3 3 3
158161	0.00	0.31	0.28	2 2 2	158192	3.29	0.51	1.25	2 2 2
158161	0.30	0.42	0.30	2 2 2	158192	4.35	0.65	1.41	2 2 2
158162	0.00	0.33	0.00	2 2 2	158193	6.47	0.47	0.08	3 3 3
158162	0.00	0.34	0.00	2 2 2	158193	2.41	0.53	0.54	3 3 3
158163	5.75	0.32	10.30	2 2 2	158194	9.99	0.81	7.69	3 3 3
158163	5.76	0.72	10.21	2 2 2	158194	13.01	1.05	10.60	3 3 3
158164	4.56	0.71	8.88	2 2 2	158195	8.49	0.83	7.24	3 3 3
158164	4.60	0.68	8.80	2 2 2	158195	10.16	0.80	7.24	3 3 3
158165	4.08	0.64	8.43	2 2 2	158196	2.72	0.51	0.67	3 3 3
158165	4.10	0.66	8.44	2 2 2	158196	3.07	0.57	0.42	3 3 3
158166	3.74	0.55	7.31	2 2 2	158197	3.62	0.52	0.23	2 2 2
158166	3.79	0.64	7.30	2 2 2	158197	3.65	0.54	0.10	2 2 2
158167	3.60	0.56	6.09	2 2 2	158198	11.18	0.97	9.47	2 2 2
158167	3.59	0.60	6.13	2 2 2	158198	11.56	0.92	9.83	2 2 2
158168	4.09	0.69	4.97	2 2 2	158199	8.61	0.81	7.16	2 2 2
158168	4.13	0.62	4.99	2 2 2	158199	10.20	0.88	8.70	2 2 2
158169	1.44	0.57	1.88	2 2 2	158200	3.04	0.65	0.90	2 2 2
158169	1.52	0.55	1.89	2 2 2	158200	3.70	0.54	0.87	2 2 2
158170	0.33	0.45	0.18	2 2 2	158201	2.33	0.41	0.27	2 2 2
158170	0.33	0.45	0.20	2 2 2	158201	2.18	0.53	0.00	2 2 2
158171	0.00	1.21	0.00	2 3 2	158203	11.21	0.93	11.22	2 2 2
158171	0.00	1.17	0.00	2 3 2	158203	11.60	1.01	11.22	2 2 2
158172	0.00	0.39	0.00	2 2 2	158204	9.89	0.83	9.77	2 2 2
158172	0.00	0.37	0.00	2 2 2	158204	10.28	0.86	9.73	2 2 2
158173	0.00	0.40	0.00	2 2 2	158205	9.08	0.80	7.53	3 3 3
158173	0.00	0.42	0.00	2 2 2	158205	10.43	0.96	8.71	3 3 3
158175	1.62	0.64	1.86	2 2 2	158206	9.80	0.89	7.79	2 2 2
158175	1.63	0.68	1.88	2 2 2	158206	10.66	0.98	8.34	2 2 2
158176	0.59	0.53	0.73	2 2 2	158207	2.70	0.57	0.00	2 2 2
158176	0.64	0.52	0.77	2 2 2	158207	1.96	0.49	0.27	2 2 2
158177	0.42	0.64	0.32	2 2 2	158208	8.98	0.82	9.84	2 2 2
158177	0.43	0.47	0.30	2 2 2	158208	7.25	0.74	8.55	2 2 2
158178	0.00	0.42	0.00	2 2 2	158209	10.24	0.91	10.74	2 2 2
158178	0.00	0.40	0.00	2 2 2	158209	10.65	1.00	10.85	2 2 2
158179	0.00	0.40	0.00	2 2 2					
158179	0.00	0.38	0.00	2 2 2					

Table C.4 Replicate nutrient water sample values in $\mu\text{moles/kg}$, along with their quality flags.

ID	SiO2	PO4	NO2+NO3	QF	ID	SiO2	PO4	NO2+NO3	QF
158210	9.07	0.77	9.20	2 2 2	158235	11.21	1.04	16.28	2 2 2
158210	10.16	0.85	10.63	2 2 2	158235	11.28	1.05	16.16	2 2 2
158211	7.58	0.77	6.81	3 3 3	158236	11.23	1.05	16.70	2 2 2
158211	12.06	0.97	9.13	3 3 3	158236	10.95	1.05	16.56	2 2 2
158212	8.72	0.77	6.75	3 3 3	158237	10.98	1.06	16.78	2 2 2
158212	10.75	0.96	7.87	3 3 3	158237	10.86	1.06	16.27	2 2 2
158213	2.23	0.48	0.16	2 2 2	158238	10.59	1.07	16.63	2 2 2
158213	2.02	0.45	0.32	2 2 2	158238	10.81	1.08	16.76	2 2 2
158214	9.13	0.88	12.11	3 3 3	158239	10.07	0.89	16.78	2 2 2
158214	9.97	1.03	13.25	3 3 3	158239	10.29	1.08	16.80	2 2 2
158215	10.00	1.03	12.99	2 2 2	158240	9.84	0.87	16.75	2 2 2
158215	10.14	0.93	12.63	2 2 2	158240	10.00	1.08	16.58	2 2 2
158216	7.24	0.77	9.86	3 3 3	158241	9.94	1.09	17.02	2 2 2
158216	10.81	0.90	14.29	3 3 3	158241	10.01	1.05	16.66	2 2 2
158217	8.23	0.76	10.40	3 3 3	158242	9.94	1.02	16.65	2 2 2
158217	10.61	0.92	12.20	3 3 3	158242	9.74	1.05	17.03	2 2 2
158218	9.69	0.91	11.17	2 2 2	158243	9.66	1.08	16.83	2 2 2
158218	9.97	0.92	11.60	2 2 2	158243	9.73	1.02	17.14	2 2 2
158219	7.90	0.78	8.70	3 3 3	158244	9.50	1.08	16.91	2 2 2
158219	10.35	0.94	10.90	3 3 3	158244	9.57	1.04	16.82	2 2 2
158220	7.45	0.75	7.76	3 3 3	158245	9.32	1.09	16.66	2 4 2
158220	10.60	0.99	11.28	3 3 3	158245	9.40	1.03	16.73	2 2 2
158221	10.19	0.97	8.26	2 2 2	158246	9.07	0.94	16.08	2 2 2
158221	9.11	0.86	6.96	2 2 2	158246	9.27	1.05	16.59	2 2 2
158222	3.50	0.58	0.61	2 2 2	158247	8.59	1.03	15.85	2 2 2
158222	3.77	0.50	0.50	2 2 2	158247	8.67	1.00	15.94	2 2 2
158223	7.68	0.99	12.53	3 3 3	158248	8.28	0.98	15.91	2 2 2
158223	13.28	1.04	16.34	3 3 3	158248	8.36	1.05	15.44	2 2 2
158224	7.48	0.85	12.59	3 2 3	158249	8.09	0.95	14.65	2 2 2
158224	8.08	0.90	13.50	3 2 3	158249	8.09	0.85	14.63	2 2 2
158225	10.02	1.11	16.65	3 3 3	158250	2.66	0.61	6.68	2 2 2
158225	13.30	0.91	14.98	3 3 3	158250	2.62	0.58	6.75	2 2 2
158226	9.76	1.08	16.84	3 3 3	158251	10.16	0.90	14.01	3 3 3
158226	8.28	0.96	13.87	3 3 3	158251	11.28	0.82	15.77	3 3 3
158227	9.65	1.06	16.11	2 2 2	158252	11.59	1.02	15.72	2 2 2
158227	9.11	1.03	16.09	2 2 2	158252	11.64	1.00	15.72	2 2 2
158228	8.91	0.97	15.46	2 2 2	158253	11.57	0.99	15.76	2 2 2
158228	9.02	1.06	15.86	2 2 2	158253	11.77	0.97	15.99	2 2 2
158229	9.69	1.05	15.93	2 2 2	158254	11.55	1.02	16.14	2 2 2
158229	9.91	0.98	14.89	2 2 2	158254	11.66	1.04	15.87	2 2 2
158230	7.39	0.85	12.63	2 2 2	158255	11.61	1.03	15.93	2 2 2
158230	8.26	0.89	13.00	2 2 2	158255	11.53	1.00	16.32	2 2 2
158231	11.74	0.77	10.28	3 3 3	158256	11.42	0.98	16.32	2 2 2
158231	10.20	1.10	13.59	3 3 3	158256	11.38	1.05	16.24	2 2 2
158232	8.70	0.90	11.78	2 2 2	158257	10.89	1.06	16.54	2 2 2
158232	10.36	0.94	12.24	2 2 2	158257	11.02	1.00	16.47	2 2 2
158233	7.93	0.74	7.04	2 2 2	158258	10.46	1.04	16.71	2 2 2
158233	8.07	0.82	7.56	2 2 2	158258	10.58	1.04	16.61	2 2 2
158234	11.08	1.05	16.14	2 2 2	158259	9.88	1.08	16.75	2 2 2
158234	11.22	1.04	16.26	2 2 2	158259	9.94	1.06	16.79	2 2 2
					158260	9.26	1.03	15.35	2 2 3
					158260	10.76	0.97	15.19	2 2 3

Table C.4 Replicate nutrient water sample values in $\mu\text{moles/kg}$, along with their quality flags.

ID	SiO2	PO4	NO2+NO3	QF	ID	SiO2	PO4	NO2+NO3	QF
158261	9.00	1.01	15.32	3 3 3	158287	8.91	1.17	15.55	2 2 2
158261	7.97	0.93	13.61	3 3 3	158287	8.94	1.18	15.33	2 2 2
158262	9.68	1.07	17.03	2 2 2	158288	8.88	1.16	14.83	2 2 2
158262	9.94	1.11	17.01	2 2 2	158288	10.74	1.17	15.25	2 2 2
158263	9.21	1.07	16.45	2 2 2	158289	8.10	1.07	13.37	3 3 3
158263	9.24	1.08	16.51	2 2 2	158289	8.07	0.98	11.33	3 3 3
158264	9.13	1.07	16.60	2 2 2	158290	7.33	0.93	11.04	2 2 2
158264	9.16	1.06	16.76	2 2 2	158290	9.23	0.93	10.56	2 2 2
158265	9.40	1.09	16.84	2 2 2	158291	10.85	1.12	14.46	2 2 2
158265	9.42	1.09	16.66	2 2 2	158291	10.88	1.12	14.72	2 2 2
158266	8.37	0.92	16.02	2 2 2	158292	9.30	1.06	12.91	3 3 3
158266	8.55	1.01	15.68	2 2 2	158292	10.49	1.06	14.34	3 3 3
158267	8.60	0.92	16.02	2 2 2	158293	9.72	1.10	13.70	2 4 2
158267	8.66	1.03	15.68	2 2 2	158293	9.95	1.07	13.81	2 2 2
158268	8.98	1.01	15.95	2 2 2	158294	11.37	1.15	15.50	2 2 2
158268	9.10	1.02	15.84	2 2 2	158294	10.25	1.06	13.54	2 2 2
158269	8.30	0.85	14.64	2 2 2	158295	11.85	1.21	15.63	2 2 2
158269	8.33	1.00	14.73	2 2 2	158295	11.46	1.17	14.97	2 2 2
158270	3.25	0.69	8.43	2 2 2	158296	10.39	1.14	14.09	2 2 2
158270	3.33	0.66	8.16	2 2 2	158296	11.99	1.22	15.67	2 2 2
158271	10.98	0.98	14.86	2 2 2	158297	9.47	1.05	12.71	3 3 3
158271	10.60	0.97	14.77	2 2 2	158297	11.78	1.19	15.91	3 3 3
158272	10.42	0.99	15.35	2 2 2	158298	11.06	1.18	15.84	2 2 2
158272	10.71	1.01	15.22	2 2 2	158298	11.24	1.20	16.10	2 2 2
158273	10.65	0.96	15.15	2 2 2	158299	10.23	1.12	15.08	3 3 3
158273	10.88	0.99	14.87	2 2 2	158299	11.23	1.24	16.47	3 3 3
158274	10.80	0.99	15.30	2 2 2	158300	10.79	1.25	17.05	2 2 2
158274	10.86	1.03	15.00	2 2 2	158300	10.47	1.23	16.17	2 2 2
158275	11.83	1.03	15.97	2 2 2	158301	8.36	1.13	14.16	3 3 3
158275	11.96	1.03	15.81	2 2 2	158301	12.15	1.25	16.93	3 3 3
158276	11.56	1.11	16.19	2 4 2	158302	8.21	1.08	13.41	3 3 3
158276	11.67	0.96	16.14	2 2 2	158302	9.96	1.28	17.01	3 3 3
158277	10.99	1.06	16.53	2 2 2	158303	10.10	1.25	16.67	2 2 2
158277	11.19	1.09	16.55	2 2 2	158303	10.63	1.28	16.82	2 2 2
158278	8.10	0.92	12.69	3 3 3	158304	9.33	1.21	15.79	2 2 2
158278	10.48	1.08	17.00	3 3 3	158304	9.72	1.23	16.35	2 2 2
158279	10.28	1.10	16.66	2 2 2	158305	8.24	1.08	13.66	3 3 3
158279	10.23	1.12	17.04	2 2 2	158305	11.93	1.28	17.04	3 3 3
158280	9.91	1.12	16.97	2 2 2	158306	5.29	0.67	6.63	3 3 3
158280	10.01	1.13	16.88	2 2 2	158306	10.12	1.24	16.86	3 3 3
158281	9.76	1.12	16.87	2 2 2	158307	8.61	1.04	14.31	2 2 2
158281	10.42	1.14	17.23	2 2 2	158307	9.62	1.10	14.88	2 2 2
158282	10.02	1.23	16.73	2 2 2	158308	8.97	1.19	16.16	2 2 2
158282	10.22	1.22	16.67	2 2 2	158308	9.38	1.13	14.73	2 2 2
158283	9.87	1.23	16.87	2 2 2	158309	7.87	1.09	13.90	3 3 3
158283	9.98	1.25	17.08	2 2 2	158309	9.14	1.22	16.86	3 3 3
158284	10.22	1.25	16.45	2 2 2	158310	8.11	1.13	14.79	2 2 2
158284	10.04	1.24	16.93	2 2 2	158310	7.96	1.14	14.79	2 2 2
158285	9.83	1.23	16.55	2 2 2	158311	8.55	1.07	15.80	3 2 2
158285	9.77	1.14	16.72	2 2 2	158311	10.84	1.17	15.21	3 2 2
158286	8.79	1.19	15.89	2 2 2	158312	7.10	1.00	12.20	3 3 3
158286	8.88	1.19	15.92	2 2 2	158312	8.10	1.16	14.37	3 3 3

Table C.4 Replicate nutrient water sample values in $\mu\text{moles/kg}$, along with their quality flags.

ID	SiO2	PO4	NO2+NO3	QF	ID	SiO2	PO4	NO2+NO3	QF
158313	3.31	0.69	6.84	2 2 2	158339	11.34	1.10	15.11	2 2 2
158313	3.37	0.73	7.41	2 2 2	158339	11.43	1.08	15.30	2 2 2
158314	12.77	1.00	12.64	2 2 2	158340	12.94	1.15	15.69	2 2 2
158314	9.62	0.99	13.06	2 2 2	158340	13.03	1.14	15.91	2 2 2
158315	9.71	1.00	13.08	2 2 2	158341	13.34	1.16	16.33	2 2 2
158315	10.65	1.13	14.70	2 2 2	158341	13.65	1.17	16.30	2 2 2
158316	10.74	1.15	15.08	2 2 2	158342	12.92	1.19	16.22	3 3 3
158316	11.03	1.14	14.79	2 2 2	158342	11.84	1.14	15.03	3 3 3
158317	11.47	1.12	14.81	2 2 2	158343	12.84	1.34	16.50	2 2 2
158317	11.91	1.15	15.44	2 2 2	158343	12.55	1.18	16.52	2 2 2
158318	12.02	1.18	15.54	2 2 2	158344	11.55	1.18	15.54	3 3 3
158318	11.49	1.13	15.07	2 2 2	158344	12.06	1.20	16.67	3 3 3
158319	11.17	1.13	14.52	2 2 2	158345	11.27	1.19	16.62	2 2 2
158319	13.05	1.19	15.81	2 2 2	158345	11.52	1.23	16.95	2 2 2
158320	11.75	1.21	15.91	2 2 2	158346	10.06	1.18	16.58	2 2 2
158320	12.22	1.23	16.30	2 2 2	158346	10.17	1.21	16.95	2 2 2
158321	8.79	1.00	12.05	3 3 3	158347	10.10	1.19	17.06	2 2 2
158321	11.25	1.21	16.42	3 3 3	158347	9.57	1.18	16.16	2 2 2
158322	9.34	1.04	13.86	3 3 3	158348	9.41	1.15	15.75	3 3 3
158322	11.13	1.24	16.49	3 3 3	158348	9.97	1.20	16.99	3 3 3
158323	12.03	1.16	15.28	2 2 2	158349	9.93	1.18	16.53	2 2 2
158323	9.45	1.05	13.61	2 2 2	158349	10.00	1.18	16.70	2 2 2
158324	9.68	1.18	17.13	2 2 2	158350	9.98	1.20	16.70	2 2 2
158324	8.60	1.15	14.96	2 2 2	158350	10.04	1.20	16.88	2 2 2
158325	8.01	1.08	14.10	3 3 3	158351	9.94	1.19	16.66	2 2 2
158325	9.12	1.16	15.75	3 3 3	158351	10.00	1.22	17.09	2 2 2
158326	8.54	1.13	14.70	3 3 3	158352	10.29	1.20	17.03	3 3 3
158326	9.85	1.25	17.01	3 3 3	158352	9.25	1.15	15.78	3 3 3
158327	9.53	0.94	12.85	3 3 3	158353	9.62	1.19	16.44	2 2 2
158327	10.26	1.23	17.25	3 3 3	158353	9.48	1.18	16.35	2 2 2
158328	10.02	1.26	16.99	2 2 2	158354	9.15	1.12	15.95	2 2 2
158328	10.58	1.24	16.61	2 2 2	158354	9.20	1.16	16.32	2 2 2
158329	22.02	1.24	16.95	4 2 2	158355	8.96	1.16	16.17	2 2 2
158329	12.13	1.19	16.11	4 2 2	158355	9.11	1.14	16.32	2 2 2
158330	9.04	1.11	15.47	2 2 2	158356	8.83	1.14	15.99	2 2 2
158330	9.54	1.19	16.19	2 2 2	158356	8.86	1.17	15.97	2 2 2
158331	7.06	0.95	12.13	2 2 2	158357	7.04	1.02	12.61	3 3 3
158331	8.22	1.06	13.46	2 2 2	158357	8.79	1.11	15.68	3 3 3
158332	7.71	1.03	13.18	2 2 2	158358	7.21	0.95	11.96	3 3 3
158332	9.76	1.22	16.54	2 2 2	158358	6.23	0.87	9.71	3 3 3
158333	10.11	1.16	15.97	3 2 2	158359	5.21	0.81	8.51	2 2 2
158333	12.12	1.16	15.38	3 2 2	158359	5.39	0.78	8.86	2 2 2
158334	6.32	0.93	10.94	3 3 3	158365	10.81	1.05	14.85	2 2 2
158334	8.97	1.14	15.90	3 3 3	158365	10.95	1.04	14.96	2 2 2
158335	7.94	1.08	14.24	2 2 2	158366	10.74	1.08	14.86	2 2 2
158335	9.26	1.16	15.40	2 2 2	158366	10.89	1.06	14.89	2 2 2
158336	6.12	0.81	9.06	3 2 2	158367	10.32	1.05	14.38	2 2 2
158336	8.05	0.81	9.14	3 2 2	158367	10.71	1.05	15.01	2 2 2
158337	11.48	1.11	14.92	2 2 2	158368	11.88	1.11	15.41	2 2 2
158337	11.26	1.07	14.52	2 2 2	158368	11.89	1.10	15.67	2 2 2
158338	10.96	1.07	14.56	2 2 2	158369	12.50	1.12	15.98	2 2 2
158338	11.00	1.07	14.98	2 2 2	158369	12.79	1.13	15.89	2 2 2

Table C.4 Replicate nutrient water sample values in $\mu\text{moles/kg}$, along with their quality flags.

ID	SiO2	PO4	NO2+NO3	QF	ID	SiO2	PO4	NO2+NO3	QF
158370	12.49	1.15	16.37	2 2 2	158396	10.89	1.20	17.06	2 2 2
158370	12.63	1.14	16.26	2 2 2	158396	10.92	1.06	17.23	2 2 2
158371	12.03	1.18	16.41	2 2 2	158397	9.75	1.13	15.97	3 3 3
158371	12.00	1.15	16.57	2 2 2	158397	10.40	1.20	16.88	3 3 3
158372	7.84	1.04	13.77	2 2 2	158398	8.38	1.08	15.09	3 3 3
158372	7.89	1.02	13.88	2 2 2	158398	9.34	1.16	16.65	3 3 3
158373	9.66	1.11	15.18	3 3 3	158399	8.82	1.12	16.33	2 2 2
158373	10.91	1.17	16.59	3 3 3	158399	9.24	1.02	16.94	2 2 2
158374	9.98	1.17	16.61	2 2 2	158400	9.22	1.15	16.91	2 2 2
158374	10.01	1.18	16.83	2 2 2	158400	9.21	1.15	16.93	2 2 2
158375	9.66	1.14	16.80	2 2 2	158401	9.39	1.18	16.84	2 2 2
158375	9.89	1.13	16.52	2 2 2	158401	9.48	1.18	16.98	2 2 2
158376	9.91	1.16	16.71	2 2 2	158402	9.46	1.20	17.17	2 2 2
158376	9.71	1.17	16.73	2 2 2	158402	9.49	1.19	16.96	2 2 2
158377	9.72	1.16	16.80	2 2 2	158403	9.41	1.17	17.41	2 2 2
158377	9.33	1.08	16.25	2 2 2	158403	9.53	1.16	17.31	2 2 2
158378	8.67	1.07	15.37	2 2 2	158404	8.95	1.15	16.86	2 2 2
158378	9.68	1.17	16.93	2 2 2	158404	9.07	1.16	17.13	2 2 2
158379	9.08	1.13	15.98	2 2 2	158405	8.85	1.16	16.68	2 2 2
158379	9.14	1.14	16.29	2 2 2	158405	8.61	1.14	16.72	2 2 2
158380	9.36	1.15	16.57	2 2 2	158406	8.93	1.17	16.67	2 2 2
158380	9.87	1.16	16.75	2 2 2	158406	8.83	1.17	16.59	2 2 2
158381	9.15	1.14	16.42	2 2 2	158407	8.56	1.14	16.63	2 2 2
158381	9.15	1.15	16.31	2 2 2	158407	8.63	1.17	16.62	2 2 2
158382	9.22	1.16	16.70	2 2 2	158408	7.84	1.08	15.62	2 2 2
158382	9.11	1.15	16.71	2 2 2	158408	7.99	1.09	15.47	2 2 2
158383	8.66	1.18	16.58	2 2 2	158409	7.38	1.04	14.20	2 2 2
158383	8.67	1.22	16.53	2 2 2	158409	7.42	1.06	14.17	2 2 2
158384	8.18	1.12	15.93	2 2 2	158410	5.70	0.84	10.53	2 2 2
158384	8.26	1.13	15.65	2 2 2	158410	5.84	0.82	10.42	2 2 2
158385	8.17	1.12	15.34	2 2 2	158411	9.78	1.05	14.90	2 2 2
158385	8.32	1.13	15.68	2 2 2	158411	9.71	1.03	14.90	2 2 2
158386	6.43	0.94	11.15	2 2 2	158412	9.81	1.04	14.78	2 2 2
158386	6.44	0.90	11.22	2 2 2	158412	9.89	1.04	14.42	2 2 2
158387	6.00	0.86	10.61	2 2 2	158413	9.51	1.05	14.61	3 3 3
158387	6.15	0.85	11.01	2 2 2	158413	9.58	1.03	12.74	3 3 3
158388	9.96	1.09	14.86	2 2 2	158414	10.02	1.07	14.80	3 3 3
158388	10.04	1.07	14.88	2 2 2	158414	10.44	0.97	11.71	3 3 3
158389	8.81	1.15	16.05	2 2 2	158415	11.66	1.06	15.64	2 2 2
158389	9.08	1.18	15.98	2 2 2	158415	11.75	1.12	15.68	2 2 2
158390	10.59	1.07	15.15	2 2 2	158416	11.56	1.05	14.25	3 3 3
158390	10.61	1.10	15.07	2 2 2	158416	12.51	1.13	16.24	3 3 3
158391	11.77	1.12	15.78	2 2 2	158417	11.76	1.14	16.03	3 3 3
158391	11.78	1.18	15.70	2 2 2	158417	12.88	1.16	14.15	3 3 3
158392	12.64	1.16	16.16	2 2 2	158418	10.73	1.11	15.83	2 2 2
158392	12.40	1.16	16.28	2 2 2	158418	10.83	1.06	15.71	2 2 2
158393	12.18	1.15	16.19	2 2 2	158419	10.46	1.15	16.73	2 2 2
158393	12.19	1.16	16.28	2 2 2	158419	9.25	1.01	14.63	2 2 2
158394	11.73	1.17	16.29	2 2 2	158420	9.22	1.09	14.55	2 2 2
158394	11.75	1.15	16.53	2 2 2	158420	9.87	1.13	16.89	2 2 2
158395	11.51	1.17	16.99	2 2 2	158421	7.04	0.80	12.09	3 3 3
158395	11.52	1.17	16.91	2 2 2	158421	9.21	1.14	16.84	3 3 3

Table C.4 Replicate nutrient water sample values in $\mu\text{moles/kg}$, along with their quality flags.

ID	SiO2	PO4	NO2+NO3	QF	ID	SiO2	PO4	NO2+NO3	QF
158422	9.31	1.18	16.56	3 3 3	158448	10.07	1.13	16.60	3 3 3
158422	9.32	1.14	16.60	3 3 3	158448	9.67	1.15	16.88	3 3 3
158423	7.43	0.95	13.28	3 3 3	158449	9.71	1.16	16.79	3 3 3
158423	9.38	1.13	16.90	3 3 3	158449	9.77	1.13	16.56	3 3 3
158424	9.63	1.14	16.93	2 2 2	158450	9.01	1.10	15.70	2 2 2
158424	9.42	1.14	16.77	2 2 2	158450	9.04	1.12	15.93	2 2 2
158425	9.33	1.12	16.55	3 3 3	158451	8.77	1.09	15.25	3 3 3
158425	5.72	0.76	10.23	3 3 3	158451	9.44	1.16	16.83	3 3 3
158426	7.29	0.89	11.95	3 3 3	158452	7.96	1.06	14.91	2 2 2
158426	9.11	1.14	16.78	3 3 3	158452	8.63	1.12	15.71	2 2 2
158427	6.86	0.91	13.52	3 3 3	158453	8.54	1.09	15.74	2 2 2
158427	8.79	1.11	16.61	3 3 3	158453	8.26	1.09	15.71	2 2 2
158428	5.64	0.74	9.30	3 3 3	158454	8.36	1.08	15.42	2 2 2
158428	8.73	1.11	16.61	3 3 3	158454	8.15	1.09	15.56	2 2 2
158429	7.54	1.00	14.10	3 3 3	158455	7.52	0.95	13.27	3 3 3
158429	6.41	0.86	12.17	3 3 3	158455	7.98	0.98	13.89	3 3 3
158430	7.22	0.94	13.76	3 3 3	158456	6.62	0.84	10.80	2 2 2
158430	8.24	1.10	15.63	3 3 3	158456	6.77	0.84	10.72	2 2 2
158431	6.39	0.86	12.03	3 3 3	158457	9.43	0.97	14.67	2 2 2
158431	8.48	1.06	15.27	3 3 3	158457	9.53	0.97	14.52	2 2 2
158432	7.85	0.94	13.18	2 2 2	158458	10.65	1.04	14.68	2 2 2
158432	7.94	0.95	12.94	2 2 2	158458	10.77	1.03	14.68	2 2 2
158433	4.85	0.70	7.96	3 3 3	158459	10.74	1.07	15.26	2 2 2
158433	6.09	0.81	10.10	3 3 3	158459	10.44	1.05	14.90	2 2 2
158434	10.10	1.01	14.36	2 2 2	158460	12.62	1.10	15.62	2 2 2
158434	9.92	1.01	14.76	2 2 2	158460	12.74	1.12	15.68	2 2 2
158435	9.92	1.07	15.28	2 2 2	158461	12.59	1.10	15.97	2 2 2
158435	9.83	1.07	15.24	2 2 2	158461	12.68	1.12	15.75	2 2 2
158436	9.83	1.03	14.71	2 2 2	158462	11.05	0.99	13.05	3 3 3
158436	10.02	1.04	14.83	2 2 2	158462	13.02	1.12	15.79	3 3 3
158437	11.48	1.06	15.01	3 3 3	158463	9.61	0.96	12.29	3 3 3
158437	11.93	1.10	15.41	3 3 3	158463	10.97	0.99	14.52	3 3 3
158438	13.27	1.12	15.79	2 2 2	158464	11.52	1.12	15.80	2 2 2
158438	13.27	1.24	15.97	2 4 2	158464	11.58	1.09	16.07	2 2 2
158439	12.61	1.05	15.70	3 3 3	158465	10.87	1.14	16.85	2 2 2
158439	13.07	1.11	16.02	3 3 3	158465	11.01	1.15	16.75	2 2 2
158440	12.37	1.15	16.07	2 2 2	158466	8.97	1.08	15.52	2 2 2
158440	12.22	1.13	16.26	2 2 2	158466	9.10	1.11	16.06	2 2 2
158441	8.70	1.07	15.20	3 3 3	158467	6.41	0.87	11.07	3 3 3
158441	9.16	1.10	15.97	3 3 3	158467	9.74	1.13	16.68	3 3 3
158442	11.59	1.16	16.45	3 3 3	158468	9.59	1.14	16.72	2 2 2
158442	11.86	1.21	16.93	3 3 3	158468	9.65	1.16	16.27	2 2 2
158443	8.98	1.04	14.22	3 3 3	158469	9.59	1.15	16.87	3 3 3
158443	10.38	1.15	16.26	3 3 3	158469	6.82	0.94	11.82	3 3 3
158444	8.50	1.03	14.62	3 3 3	158470	7.09	0.95	12.26	3 3 3
158444	10.08	1.15	16.64	3 3 3	158470	8.51	1.04	14.57	3 3 3
158445	9.17	1.10	15.38	3 3 3	158471	9.39	1.14	16.66	2 2 2
158445	9.93	1.16	16.69	3 3 3	158471	9.66	1.13	16.72	2 2 2
158446	9.78	1.20	16.77	2 2 2	158472	7.40	0.96	12.91	3 3 3
158446	9.93	1.14	16.70	2 2 2	158472	9.31	1.08	16.34	3 3 3
158447	9.82	1.12	16.58	2 2 2	158473	8.74	1.10	16.03	2 2 2
158447	9.88	1.10	16.49	2 2 2	158473	8.80	1.09	16.40	2 2 2

Table C.4 Replicate nutrient water sample values in $\mu\text{moles/kg}$, along with their quality flags.

ID	SiO2	PO4	NO2+NO3	QF	ID	SiO2	PO4	NO2+NO3	QF
158474	8.68	1.10	16.23	2 2 2	158505	9.51	1.00	14.47	2 2 2
158474	8.77	1.10	15.71	2 2 2	158505	10.15	1.00	15.08	2 2 2
158480	9.38	1.00	14.46	2 2 2	158506	11.11	1.05	15.30	2 2 2
158480	9.53	1.03	14.78	2 2 2	158506	6.42	0.76	8.94	2 2 2
158481	8.57	0.91	12.37	2 2 2	158507	12.33	1.06	15.77	3 3 3
158481	8.63	0.96	12.48	2 2 2	158507	10.61	0.92	13.29	3 3 3
158482	10.74	1.04	15.21	2 2 2	158508	11.65	1.04	15.54	2 2 2
158482	10.26	1.04	14.28	2 2 2	158508	11.89	1.01	15.65	2 2 2
158483	11.83	1.08	15.54	2 2 2	158509	11.15	1.07	15.58	2 2 2
158483	12.01	1.09	15.40	2 2 2	158509	11.32	1.13	15.87	2 2 2
158484	12.68	1.03	15.27	2 2 2	158510	10.88	1.10	16.37	2 2 2
158484	12.86	1.04	15.83	2 2 2	158510	11.00	1.12	16.09	2 2 2
158485	9.64	0.89	12.18	3 3 3	158511	10.46	1.13	15.89	2 2 2
158485	13.02	1.07	16.21	3 3 3	158511	9.89	1.13	16.03	2 2 2
158486	9.16	0.93	12.74	3 3 3	158512	10.11	1.12	16.51	2 2 2
158486	11.70	1.06	16.03	3 3 3	158512	10.20	1.12	16.64	2 2 2
158487	11.28	1.06	16.40	2 2 2	158513	8.32	1.05	13.46	3 3 3
158487	10.74	1.05	15.46	2 2 2	158513	9.79	1.12	16.39	3 3 3
158488	10.62	1.06	16.03	2 2 2	158514	9.55	1.13	16.82	2 2 2
158488	9.57	1.03	14.74	2 2 2	158514	10.33	1.14	16.19	2 2 2
158489	6.48	0.86	10.58	3 3 3	158515	8.62	1.07	15.24	2 2 2
158489	10.12	1.11	16.72	3 3 3	158515	9.55	1.15	16.45	2 2 2
158490	8.38	1.02	14.19	3 3 3	158516	9.77	1.14	16.81	3 3 3
158490	9.70	1.08	16.76	3 3 3	158516	8.30	1.05	13.98	3 3 3
158491	9.68	1.10	16.58	2 2 2	158517	9.46	1.11	16.51	2 2 2
158491	9.77	1.08	16.95	2 2 2	158517	9.27	1.12	16.79	2 2 2
158492	6.20	0.76	10.85	3 3 3	158518	9.07	1.12	16.55	2 2 2
158492	7.14	0.88	12.48	3 3 3	158518	9.10	1.10	16.27	2 2 2
158493	7.98	0.94	13.88	3 3 3	158519	8.71	1.10	16.29	2 2 2
158493	6.06	0.84	10.79	3 3 3	158519	8.87	1.10	16.39	2 2 2
158494	8.56	1.01	15.19	2 2 2	158520	8.18	1.06	15.44	2 2 2
158494	9.35	1.08	16.78	2 2 2	158520	8.45	1.11	16.00	2 2 2
158495	6.70	0.88	11.75	3 3 3	158521	8.18	1.07	15.17	2 2 2
158495	9.23	1.08	16.35	3 3 3	158521	8.48	1.07	15.18	2 2 2
158496	5.75	0.81	10.59	3 3 3	158522	8.40	1.09	15.62	2 2 2
158496	9.03	1.07	16.49	3 3 3	158522	8.10	1.07	15.72	2 2 2
158497	8.73	1.06	16.39	2 2 2	158523	8.11	1.06	15.48	2 2 2
158497	8.88	1.08	16.25	2 2 2	158523	8.77	1.09	15.13	2 2 2
158498	8.49	1.06	16.12	2 2 2	158524	6.53	0.86	11.23	2 2 2
158498	8.62	1.08	15.92	2 2 2	158524	7.07	0.87	12.01	2 2 2
158499	7.81	1.05	14.68	2 2 2	158525	7.08	0.92	11.88	2 2 2
158499	8.38	1.06	16.12	2 2 2	158525	7.25	0.90	12.20	2 2 2
158500	7.98	1.01	15.39	2 2 2	158526	9.64	1.00	14.63	2 2 2
158500	8.13	1.03	15.73	2 2 2	158526	10.12	1.00	14.04	2 2 2
158501	7.80	0.95	13.82	3 3 3	158527	9.31	0.97	13.64	2 2 2
158501	7.26	0.94	12.61	3 3 3	158527	9.49	1.01	14.39	2 2 2
158502	7.30	0.90	12.69	2 2 2	158528	9.86	0.97	13.92	2 2 2
158502	7.42	0.92	12.69	2 2 2	158528	10.20	1.03	14.79	2 2 2
158503	9.89	0.98	14.53	2 2 2	158529	11.08	1.05	15.17	2 2 2
158503	10.13	1.01	14.53	2 2 2	158529	11.86	1.00	14.33	2 2 2
158504	9.48	0.97	13.74	2 2 2	158530	12.59	1.10	15.57	2 2 2
158504	9.81	1.00	14.74	2 2 2	158530	11.96	1.06	15.13	2 2 2

Table C.4 Replicate nutrient water sample values in $\mu\text{moles/kg}$, along with their quality flags.

ID	SiO2	PO4	NO2+NO3	QF	ID	SiO2	PO4	NO2+NO3	QF
158531	12.87	1.11	16.27	2 2 2	158557	9.84	1.00	14.89	2 2 2
158531	12.89	1.10	15.91	2 2 2	158557	10.20	1.05	15.71	2 2 2
158532	11.78	1.00	15.65	2 2 2	158558	10.15	1.06	16.34	2 2 2
158532	12.51	1.15	16.02	2 2 2	158558	10.19	1.09	16.22	2 2 2
158533	11.46	1.07	15.96	2 2 2	158559	9.99	1.08	16.56	2 2 2
158533	11.55	1.06	16.08	2 2 2	158559	9.78	1.09	16.54	2 2 2
158534	7.93	0.84	12.04	3 3 3	158560	9.55	1.09	16.39	2 2 2
158534	9.46	0.97	14.08	3 3 3	158560	9.59	1.09	16.45	2 2 2
158535	10.27	1.06	16.28	2 2 2	158561	9.78	1.12	16.95	2 2 2
158535	10.09	1.07	16.60	2 2 2	158561	10.08	1.09	16.47	2 2 2
158536	9.59	1.05	16.36	3 3 3					
158536	8.09	0.97	13.95	3 3 3	158562	8.21	0.98	14.22	3 3 3
					158562	9.77	1.11	16.68	3 3 3
158537	9.47	1.07	16.43	2 2 2					
158537	9.51	1.08	16.59	2 2 2	158563	9.54	1.10	16.32	2 2 2
					158563	9.96	1.13	17.04	2 2 2
158538	8.85	1.16	16.23	2 2 2					
158538	9.42	1.07	16.37	2 2 2	158564	8.72	1.02	15.02	3 3 3
					158564	7.25	0.86	12.62	3 3 3
158539	9.45	1.08	16.02	2 2 2					
158539	9.55	1.08	16.70	2 2 2	158565	9.36	1.07	16.07	2 2 2
					158565	8.54	1.03	15.15	2 2 2
158540	8.32	0.93	14.43	2 2 2					
158540	8.40	0.92	14.99	2 2 2	158566	7.61	0.97	13.66	3 3 3
					158566	8.80	1.07	15.77	3 3 3
158541	9.49	1.07	16.66	2 2 2					
158541	9.17	1.06	15.84	2 2 2	158567	8.01	0.99	14.58	2 2 2
					158567	8.39	1.05	15.44	2 2 2
158542	8.62	1.05	15.75	2 2 2					
158542	8.85	1.06	16.43	2 2 2	158568	7.33	0.97	13.85	3 3 3
					158568	8.04	1.04	15.24	3 3 3
158543	6.57	0.88	12.23	3 3 3					
158543	8.61	1.03	15.75	3 3 3	158569	5.50	0.80	10.09	3 3 3
					158569	7.85	1.00	14.54	3 3 3
158544	6.21	0.84	11.76	3 3 3					
158544	7.96	1.00	14.79	3 3 3	158570	7.74	0.93	12.81	2 2 2
					158570	7.72	0.94	13.19	2 2 2
158545	8.20	1.01	15.36	2 2 2					
158545	8.37	1.03	15.60	2 2 2	158571	7.10	0.86	11.47	2 2 2
					158571	7.39	0.90	11.97	2 2 2
158546	7.82	0.97	13.98	2 2 2					
158546	8.07	0.86	14.67	2 2 2	158572	8.95	0.87	13.01	3 3 3
					158572	10.44	1.02	15.24	3 3 3
158547	5.19	0.69	7.96	2 2 2					
158547	6.43	0.78	9.99	2 2 2	158573	6.34	0.76	9.04	3 3 3
					158573	9.02	0.95	13.08	3 3 3
158548	5.81	0.70	9.00	2 2 2					
158548	6.22	0.75	9.79	2 2 2	158574	9.62	0.95	13.48	3 3 3
					158574	10.35	1.02	14.72	3 3 3
158549	8.33	0.87	12.88	3 3 3					
158549	9.87	0.97	14.89	3 3 3	158575	9.05	0.94	12.84	3 3 3
					158575	10.83	1.05	15.33	3 3 3
158550	9.92	0.98	14.64	2 2 2					
158550	10.13	1.00	15.04	2 2 2	158576	8.04	0.84	11.41	3 3 3
					158576	9.56	0.97	13.28	3 3 3
158551	10.78	1.01	15.21	2 2 2					
158551	10.77	1.03	15.06	2 2 2	158577	7.99	0.86	11.52	3 3 3
					158577	9.28	0.91	12.59	3 3 3
158552	12.14	1.03	15.13	2 2 2					
158552	12.43	1.05	15.31	2 2 2	158578	8.87	0.92	12.55	3 3 3
					158578	7.38	0.78	10.32	3 3 3
158553	10.60	0.98	14.18	2 2 2					
158553	11.16	1.01	14.84	2 2 2	158579	5.61	0.70	8.31	3 3 3
					158579	8.29	0.85	12.29	3 3 3
158554	11.66	1.05	15.66	2 2 2					
158554	11.92	1.06	16.10	2 2 2	158580	8.43	0.87	13.33	3 3 3
					158580	10.42	1.01	16.26	3 3 3
158555	10.06	0.98	13.75	2 2 2					
158555	11.97	1.06	16.33	2 2 2	158581	7.57	0.88	12.79	2 2 2
					158581	8.58	0.93	14.53	2 2 2
158556	9.73	0.98	14.59	2 2 2					
158556	10.70	1.07	16.03	2 2 2	158582	6.33	0.79	10.78	2 2 2
					158582	8.53	0.92	14.35	2 2 2

Table C.4 Replicate nutrient water sample values in $\mu\text{moles/kg}$, along with their quality flags.

ID	SiO2	PO4	NO2+NO3	QF	ID	SiO2	PO4	NO2+NO3	QF
158583	7.92	1.04	12.94	2 2 2	158609	7.84	0.89	14.43	2 2 2
158583	6.85	0.81	11.63	2 2 2	158609	7.81	0.89	14.83	2 2 2
158584	9.94	1.01	16.87	2 2 2	158610	7.65	0.82	12.75	2 2 2
158584	8.17	0.89	13.99	2 2 2	158610	7.68	0.83	12.90	2 2 2
158585	5.34	0.71	9.27	3 3 3	158611	7.29	0.71	10.14	2 2 2
158585	8.11	0.92	14.13	3 3 3	158611	7.32	0.71	10.08	2 2 2
158586	8.16	0.98	14.50	2 2 2	158612	3.56	0.43	4.76	3 3 3
158586	9.11	1.04	16.25	2 2 2	158612	6.07	0.61	7.94	3 3 3
158587	7.57	0.89	13.51	2 2 2	158613	5.39	0.62	8.53	3 3 3
158587	8.01	0.91	14.22	2 2 2	158613	8.90	0.91	15.40	3 3 3
158588	7.46	0.87	13.96	3 3 3	158614	9.57	0.93	16.35	2 2 2
158588	5.71	0.69	10.94	3 3 3	158614	9.72	0.93	16.16	2 2 2
158589	6.93	0.82	12.24	2 2 2	158615	8.60	0.90	14.54	2 2 2
158589	7.71	0.90	13.74	2 2 2	158615	9.52	0.95	16.18	2 2 2
158590	7.36	0.80	12.04	2 2 2	158616	7.33	0.82	12.61	3 3 3
158590	7.46	0.82	11.81	2 2 2	158616	9.00	0.92	15.93	3 3 3
158591	7.02	0.75	10.52	2 2 2	158617	8.83	0.92	15.82	2 2 2
158591	7.13	0.76	10.73	2 2 2	158617	7.97	0.87	14.15	2 2 2
158592	6.43	0.71	9.31	2 2 2	158618	6.17	0.66	8.36	2 2 2
158592	6.45	0.70	9.07	2 2 2	158618	6.55	0.66	8.99	2 2 2
158593	11.12	0.95	15.70	2 2 2	158619	4.99	0.65	9.40	3 3 3
158593	10.99	0.93	14.89	2 2 2	158619	6.29	0.72	11.33	3 3 3
158594	11.23	0.95	15.18	2 2 2	158620	6.85	0.72	11.66	2 2 2
158594	11.10	0.95	14.95	2 2 2	158620	7.34	0.79	12.87	2 2 2
158595	10.30	0.93	14.91	2 2 2	158621	6.08	0.65	9.41	2 2 2
158595	11.08	0.97	15.63	2 2 2	158621	6.28	0.66	9.33	2 2 2
158596	6.60	0.67	9.79	3 3 3	158622	6.56	0.70	9.84	2 2 2
158596	10.52	0.89	15.43	3 3 3	158622	6.34	0.66	9.12	2 2 2
158597	9.14	0.86	13.46	3 3 3	158623	6.04	0.62	7.87	2 2 2
158597	11.07	0.95	16.07	3 3 3	158623	5.07	0.57	6.83	2 2 2
158598	6.94	0.71	10.84	3 3 3	158624	4.71	0.43	3.85	2 2 2
158598	9.68	0.92	14.74	3 3 3	158624	5.11	0.46	4.19	2 2 2
158599	10.61	1.02	16.41	3 3 3	158627	5.30	0.57	6.97	2 2 2
158599	7.33	0.77	11.06	3 3 3	158627	5.86	0.60	7.93	2 2 2
158600	8.17	0.84	13.16	3 3 3	158628	4.47	0.48	4.95	2 2 2
158600	9.80	0.94	15.79	3 3 3	158628	4.81	0.50	5.23	2 2 2
158601	9.56	0.94	15.75	2 2 2	158629	3.89	0.41	4.48	2 2 2
158601	10.01	0.96	16.47	2 2 2	158629	3.73	0.39	2.91	2 2 2
158602	7.72	0.78	11.91	3 3 3	158630	2.55	0.30	0.73	2 2 2
158602	9.92	0.99	16.41	3 3 3	158630	2.59	0.29	0.71	2 2 2
158603	9.92	1.00	16.68	2 2 2	158631	3.97	0.46	4.73	2 2 2
158603	9.98	0.97	16.28	2 2 2	158631	4.71	0.52	5.69	2 2 2
158604	7.33	0.77	12.24	2 2 2	158632	4.76	0.54	5.76	2 2 2
158604	7.84	0.77	13.86	2 2 2	158632	4.81	0.54	5.80	2 2 2
158605	7.35	0.77	12.95	2 2 2	158633	3.55	0.34	1.71	2 2 2
158605	7.92	0.85	14.05	2 2 2	158633	3.65	0.36	1.74	2 2 2
158606	6.42	0.72	11.40	2 2 2	158634	2.21	0.23	0.10	2 2 2
158606	7.34	0.80	12.26	2 2 2	158634	2.15	0.22	0.12	2 2 2
158607	6.95	0.80	12.82	2 2 2					
158607	7.34	0.84	13.49	2 2 2					
158608	6.55	0.77	12.39	2 2 2					
158608	6.86	0.82	12.84	2 2 2					

5. Dissolved Inorganic Carbon in Seawater

Bob Gershey

a. Description of Equipment and Technique

The total dissolved inorganic carbon content of seawater is defined as the total concentration of carbonate ion, bicarbonate ion and unionized species of carbon dioxide. Before analysis, the sample was treated with acid to convert all ionized species to the unionized form, which was then separated from the liquid phase and subsequently measured using a coulometric titration technique. This involved the reaction of carbon dioxide gas with a dimethylsulfoxide solution of ethanolamine to produce hydroxyethylcarbamic acid. The acidic solution was titrated with hydroxide ions formed by the electrolytic decomposition of water. The progress of the titration was followed through colorimetric measurement of the absorbance of a pH indicator dye (thymolphthalein) in the ethanolamine solution.

A known volume of seawater was dispensed into a stripping chamber from a pipet of known volume and temperature controlled to within 0.4 °C. It was then acidified with ten percent of its volume of a 10% solution of carbon dioxide-free phosphoric acid. The solution was stripped of carbon dioxide gas by bubbling with a stream of nitrogen gas directed through a glass frit. The carrier gas exiting the stripper passed through a magnesium perchlorate trap that removed water vapour and acidic water droplets.

The gas stream was then directed into the coulometric titrator where the total amount of carbon dioxide gas was quantified. The coulometer was calibrated in two ways. Calibration using gas loops was accomplished by filling stainless steel sample loops (1.5, 2.5 ml) with 99.995% carbon dioxide gas and injecting these into the coulometer. The temperature and pressure of the gas within the loops must be known to within 0.05 °C and 20 Pa respectively. The system was also calibrated using Certified Reference Materials obtained from the Scripps Institute of Oceanography. These samples were treated in the same manner as a seawater sample.

Values will be reported in units of $\mu\text{mol/kg}$. The overall precision of the analysis should be at least 1.5 $\mu\text{mol/kg}$ for samples with concentrations in the range of 1800-2300 $\mu\text{mol/kg}$.

b. Sampling Procedure and Data Processing Technique

Water samples were initially collected using a 10 litre rosette bottle. Samples for analysis of total inorganic carbon were drawn immediately following the drawing of the salinity samples in order to minimize exchange of carbon dioxide gas with the headspace in the sampler. This exchange will typically result in a loss of carbon dioxide. It is desirable that the samples be drawn before half the sampler is emptied and within ten minutes of recovery. Clean borosilicate glass bottles are rinsed twice with 30 - 50 ml of the sample. The bottle is then filled from the bottom using a length of vinyl tubing attached to the spigot of the sampler. The sample is overflowed by at least a half of the volume of the bottle (typically 250 ml). A headspace of 1% is left to allow for expansion without leakage. If samples are not to be analyzed within four to five hours, the sample is poisoned with 100 $\mu\text{l}/250\text{ ml}$ of 50%

saturated mercuric chloride solution. The bottle is tightly sealed and stored preferably at the temperature of collection in the dark.

c. Replicate Analysis

The precision of this data was estimated as 4.2 $\mu\text{mol/kg}$. In total, 25 replicate carbonate measurements were obtained for 24 sample id numbers; 23 sample id numbers had one replicate, while one sample id number had three replicates. But two of the sample id numbers having one replicate, had data that was questionable. The following is a statistical summary of the absolute value of the replicate differences; only acceptable values were used in calculating the statistics. Table C.5 lists all replicate measurements.

Number of Replicate Differences = 1 id had two replicates * 3 possible differences
+ 21 ids had one replicate * 1 possible difference = 3 + 21 = 24

Statistic	Value
Number of Replicate Differences	24
Minimum ($\mu\text{moles/kg}$)	0.1
Maximum ($\mu\text{moles/kg}$)	4.1
Mean ($\mu\text{moles/kg}$)	1.7
Median ($\mu\text{moles/kg}$)	1.2
Standard Deviation ($\mu\text{moles/kg}$)	1.2

Table C.5 Replicate water sample total carbon values in $\mu\text{moles/kg}$.

Sample ID Number	Total Carbon	WOCE QF	Sample ID Number	Total Carbon	WOCE QF
158186	2109.5	2	158272	2150.3	2
158186	2106.7	2	158272	2152.3	2
158192	2056.0	2	158284	2151.8	2
158192	2057.8	2	158284	2153.2	2
158195	2107.3	2	158338	2147.5	2
158195	2107.9	2	158338	2148.3	2
158197	2014.3	2	158366	2146.7	2
158197	2015.5	2	158366	2147.7	2
158197	2018.5	2	158389	2146.0	3
158200	2048.1	2	158389	2148.6	3
158200	2051.0	2	158418	2149.5	2
158205	2109.6	2	158418	2150.6	2
158205	2110.5	2	158482	2151.8	2
158206	2111.2	2	158482	2148.6	2
158206	2109.0	2			
158209	2109.6	2	158520	2144.4	3
158209	2110.1	2	158520	2147.5	3
158215	2139.2	2	158594	2152.1	2
158215	2140.4	2	158594	2155.7	2
158227	2145.8	2	158615	2148.0	2
158227	2146.2	2	158615	2148.1	2
158235	2150.7	2	158628	2073.3	2
158235	2151.9	2	158628	2073.9	2
158252	2154.2	2	158632	2075.3	2
158252	2151.1	2	158632	2074.9	2

a. Description of Equipment and Technique

The total alkalinity of seawater is defined as the number of moles of hydrogen ion equivalent to the excess of proton acceptors (bases formed from weak acids with dissociation constants of less than $K=10^{-4.5}$) over proton donors (acids with $K>10^{-4.5}$) in a one kilogram sample. An automated potentiometric titration system is used to determine this quantity. During the course of the titration the pH is measured using a Ross combination electrode standardized using a Hansson seawater buffer. A known volume (~25 ml) of sample is measured in a calibrated, thermostated pipette and dispensed in to an open cup. The alkalinity of the sample is estimated from its salinity and acid equivalent to 0.7 of this amount is added and the pH measured. A further three aliquots of acids are added to bring the titration to 90% completion. The Gran Function F3 (Stumm and Morgan, 1970) is then applied to these points to obtain a more refined estimate of the alkalinity. Five additional aliquots are then added to complete the titration.

b. Sampling Procedure and Data Processing Technique

Samples were collected using the same procedure as for Dissolved Inorganic Carbon (see Section 5b).

The pH values for the last five points of the titration were used to evaluate the Gran Function F1 from which the final estimate of the equivalence point was obtained. Values are reported in units of $\mu\text{mol/kg}$. The overall precision of the analysis is $1.5 \mu\text{mol/kg}$ for samples with concentrations in the range of 1900-2400 $\mu\text{mol/kg}$.

c. Replicate Analysis

The precision of the alkalinity data was $9.5 \mu\text{mol/kg}$. The alkalinity replicates consisted of 22 duplicate measurements. But eight of these sample id numbers had questionable or bad data. A statistical summary of the absolute value of the replicate differences is below. Only acceptable sample values were used when calculating replicate differences. All replicates and their quality flags are given in Table C.6.

Statistic	Value
Number of Replicate Differences	14
Minimum ($\mu\text{moles/kg}$)	0.0
Maximum ($\mu\text{moles/kg}$)	19.6
Mean ($\mu\text{moles/kg}$)	3.5
Median ($\mu\text{moles/kg}$)	2.2
Standard Deviation ($\mu\text{moles/kg}$)	5.0

Table C.6 Replicate water sample total alkalinity values in $\mu\text{moles/kg}$.

Sample ID Number	Total Alkalinity	WOCE QF	Sample ID Number	Total Alkalinity	WOCE QF
158188	2164.6	2	158294	2336.3	4
158188	2161.4	2	158294	2272.1	4
158191	2207.2	2	158314	2290.1	2
158191	2212.7	2	158314	2292.9	2
158195	2178.2	2	158339	2283.1	2
158195	2197.8	2	158339	2284.8	2
158199	2202.3	2	158367	2301.0	2
158199	2203.2	2	158367	2301.7	2
158210	2205.7	2	158368	2299.9	3
158210	2210.6	2	158368	2316.1	3
158215	2252.8	2	158412	2312.8	3
158215	2252.8	2	158412	2322.7	3
158216	2252.2	2	158435	2360.1	4
158216	2249.6	2	158435	2301.2	3
158226	2275.5	3	158459	2261.0	4
158226	2290.7	2	158459	2308.9	3
158236	2280.1	2	158511	2287.7	2
158236	2285.5	2	158511	2287.9	2
158253	2281.7	3	158551	2287.3	3
158253	2293.4	3	158551	2295.6	3
158273	2283.6	2	158613	2297.4	2
158273	2284.5	2	158613	2297.3	2

7. CFCs

Mike Hingston

a. Description of Equipment and Technique

The analyses were carried out on two Purge and Trap systems developed at the Bedford Institute of Oceanography. The water samples were injected into the systems directly from the syringes. To ensure proper rinsing, at least two volumes of water were passed through the sample pipette before the actual sample volume. The samples were purged for 4 minutes with ultra high purity nitrogen at a flow rate of 80 ml/min. The components were trapped in Porapak-N trap which were then cooled to a temperature of less than 10°C. The trap was heated up to at least 170°C causing the components to be desorbed. The contents of the trap were then passed through a 75 m DB-624 megabore column.

b. Sampling Procedure and Data Processing Technique

All samples were collected directly from the Niskin bottles using 100 ml syringes. The syringes were rinsed three times before they were filled. To prevent contamination, the CFC samples were the first samples collected from the Niskin bottles. The samples were stored in a water bath of surface seawater that flowed continuously until analysis. Air samples were taken in the winch room at the start of the cruise to ensure that it was not contaminated. The analyses of the samples were always completed within 24 hours after they had been drawn.

c. Replicate analysis

A total of 22 unique sample id numbers had triplicate CFC water samples drawn. Replicates were taken at most stations, with some of these being run on each system to ensure that the results were comparable. A statistical summary of the absolute value of the replicate differences is below. Only acceptable sample values were used when calculating replicate differences. All replicates and their quality flags are given in Table C.7.

Statistic	CFC11	CFC12	CFC113	Carbon Tet.	Methyl Chl.
Number of Replicate Differences	66	62	49	59	37
Minimum (pmoles/kg)	0.009	0.001	0.000	0.007	0.015
Maximum (pmoles/kg)	0.338	0.520	0.222	0.655	1.861
Mean (pmoles/kg)	0.125	0.087	0.060	0.185	0.633
Median (pmoles/kg)	0.109	0.064	0.039	0.131	0.589
Standard Deviation (pmoles/kg)	0.086hu	0.091	0.060	0.164	0.425
Detection Limits (pmoles/kg)	0.14	0.10	0.13	0.29	0.63

Table C.7 Replicate water sample CFC values in pmoles/kg.

Sample ID Number	Freon 11	Freon 12	Freon 113	Carbon Tet.	Methyl Chl.	WOCE QF
158187	5.824	2.999	0.347	9.712	12.348	2 2 2 2 4
158187	6.120	2.905	0.442	9.466	15.579	2 2 2 2 4
158187	6.064	3.037	0.000	9.095	14.801	2 2 4 2 2
158193	6.192	3.067	0.000	9.708	14.949	2 2 4 4 2
158193	6.290	3.172	0.364	10.828	13.088	2 2 2 3 2
158193	6.222	3.173	0.370	11.571	14.207	2 2 2 3 2
158207	6.126	3.119	0.443	9.541	14.999	2 2 2 2 2
158207	6.068	3.039	0.512	9.256	14.456	2 2 2 2 2
158207	5.788	0.000	0.000	8.911	10.566	2 4 4 2 4
158208	4.964	2.434	0.376	7.231	11.513	2 2 2 2 4
158208	5.049	2.391	0.427	7.159	13.610	2 2 2 2 2
158208	4.948	2.402	0.349	7.460	13.357	2 2 2 2 2
158216	4.123	2.161	0.296	5.632	8.661	2 2 2 2 4
158216	4.089	2.184	0.335	5.693	7.973	2 2 2 2 4
158216	4.162	2.152	0.499	5.562	10.047	2 2 2 2 2
158228	4.058	1.973	0.182	5.899	11.194	2 2 2 2 4
158228	3.933	1.922	0.265	5.832	9.630	2 2 2 2 2
158228	4.020	1.906	0.382	6.487	9.327	2 2 2 2 2
158242	3.445	1.604	0.000	5.486	9.079	2 2 4 2 4
158242	3.646	1.693	0.000	5.283	10.355	2 2 4 2 2
158242	3.628	1.706	0.000	5.353	10.670	2 2 4 2 2
158260	3.415	1.994	0.222	6.421	8.769	2 2 2 4 2
158260	3.594	1.849	0.000	5.252	10.851	2 2 2 2 4
158260	3.393	2.003	0.199	5.285	7.856	2 2 2 2 2
158286	3.938	2.033	0.305	5.809	8.107	2 2 2 2 4
158286	4.096	2.083	0.000	5.854	10.676	2 2 4 2 2
158286	4.051	2.020	0.293	5.775	10.346	2 2 2 2 2
158299	2.023	0.963	0.205	3.333	3.811	2 2 2 2 4
158299	2.211	1.063	0.261	3.645	6.822	2 2 2 2 2
158299	2.136	1.061	0.277	3.415	4.119	2 2 2 2 4
158329	3.662	1.704	0.242	5.255	10.511	2 2 2 2 2
158329	3.469	1.604	0.208	5.142	8.806	2 2 2 2 4
158329	3.650	1.697	0.247	5.083	10.222	2 2 2 2 2
158354	3.905	2.109	0.320	6.227	9.207	2 2 2 2 2
158354	3.973	2.099	0.381	5.846	9.169	2 2 2 2 2
158354	4.169	2.038	0.299	5.936	11.491	2 2 2 2 4
158374	3.297	1.556	0.210	4.943	9.737	2 2 2 2 2
158374	3.078	1.512	0.224	4.748	9.563	2 2 2 2 2
158374	3.316	1.537	0.243	4.854	9.548	2 2 2 2 2
158404	3.429	1.731	0.255	5.240	10.053	2 2 2 2 2
158404	3.460	1.915	0.328	5.791	9.355	2 2 2 2 2
158404	3.699	1.787	0.000	5.562	10.641	2 2 4 2 2
158421	3.326	1.749	0.275	5.080	10.292	2 2 2 2 2
158421	3.553	1.724	0.326	5.111	10.509	2 2 2 2 2
158421	3.516	1.759	0.258	5.250	11.289	2 2 2 2 2
158450	3.551	1.805	0.238	5.205	10.819	2 2 2 2 4
158450	3.393	1.835	0.352	5.364	8.503	2 2 2 2 2
158450	3.342	1.844	0.353	5.082	9.514	2 2 2 2 2

Table C.7 Replicate water sample CFC values in pmoles/kg.

Sample ID Number	Freon 11	Freon 12	Freon 113	Carbon Tet.	Methyl Chl.	WOCE QF
158460	2.069	1.177	0.000	3.472	5.132	2 2 2 2 4
158460	2.222	1.011	0.132	3.464	7.162	2 2 2 2 2
158460	2.234	0.978	0.138	3.457	6.950	2 2 2 2 2
158485	1.704	0.781	0.000	2.875	5.323	2 2 2 2 2
158485	1.822	0.717	0.000	3.055	5.710	2 2 2 2 2
158485	1.732	1.020	0.000	2.791	4.504	2 2 2 2 2
158516	3.598	1.585	0.249	5.186	10.557	2 2 2 2 2
158516	3.635	1.738	0.000	5.240	11.072	2 2 4 2 2
158516	3.499	1.667	0.248	5.096	9.897	2 2 2 2 2
158544	3.913	2.136	0.307	6.074	8.819	2 2 2 2 2
158544	3.879	2.033	0.278	5.948	9.437	2 2 2 2 2
158544	4.100	2.052	0.283	5.974	10.206	2 2 2 2 2
158601	3.071	1.395	0.000	4.542	9.382	2 2 4 2 2
158601	3.167	1.589	0.166	4.821	9.276	2 2 2 2 2
158601	3.062	2.056	0.185	6.171	8.793	2 4 2 4 2
158620	3.989	1.810	0.338	5.785	9.038	2 2 2 2 2
158620	4.202	2.110	0.286	5.859	9.948	2 2 2 2 2
158620	4.185	2.330	0.289	5.844	9.735	2 2 2 2 2

d. Standards Used

Standardization was carried out using gas standards made up at Brookhaven National Laboratories. Standard volumes were corrected for lab temperature and pressure. Results were reported in units of pmol/kg of seawater. Clean air samples were also analyzed with each station, as a check on the standardization.

8. Reversing Thermometers

Anthony W. Isenor

a. Description of Equipment and Technique

Sensoren-Instrumente-Systeme digital reversing thermometers model RTM 4002 were used to verify CTD thermistor readings on some stations. These thermometers have a depth range of up to 10000 m. The pressure housing is made of a glass tube closed at the ends by metal stoppers. One end contains the platinum sensor and the other end is the battery compartment. The thermometers were placed on bottles 2 and 4 on the rosette, thus sampling temperature at the second and fourth deepest bottle trips.

The thermometers were placed in standard reversing thermometer racks on the Niskin bottles. Before deployment, a magnet was passed over the thermometers to clear the display and place the thermometer in sample mode. A new temperature was then recorded upon reversal of the thermometer.

b. Sampling Procedure and Data Processing Technique

The digital thermometers indicated the temperature reading via a digital display. The temperature was read and noted on log sheets. The readings were later digitized and corrections applied using the water sample database system.

The following table lists the number of readings from each thermometer.

Thermometer Serial Number	Number of Readings
000T347	12
000T352	12
000T878	11
000T881	10

In total, 59 readings were obtained. Of these, 14 had problems with either tripping or soaking time. Thus, 45 valid comparisons with the CTD thermistor can be made.

c. Calibration Data

The digital reversing thermometers were calibrated at BIO in February 1996.

d. Replicate Analysis

Typically, a rack containing two thermometers would be tripped when the second and fourth Niskin bottles were fired. Thus, we would obtain two independent temperature readings.

However, due to the removal of the thermometers during rough weather, many stations near the end of the cruise did not have thermometer readings.

Statistics calculated using the differences of all duplicate temperatures from the digital reversing thermometers are as follows:

Statistic	Value
Number of Points	29
Median	0.002 °C
Mean	0.043 °C
Minimum	0.000 °C
Maximum	0.723 °C
Standard Deviation	0.153 °C

All of the replicate reversing thermometer temperature values, along with the reversing thermometer pressure values are given in Table C.8.

Using the median difference as a measure of the inter-thermometer comparison (the mean is influenced equally by all points, including outliers), we noted that the estimated thermometer difference is 0.002 °C. Thus, the difference between thermometers was the same as the difference between thermometers and the CTD. Therefore, we could not distinguish the difference between the thermometers and the CTD. Consequently, we did not apply any temperature calibration to the CTD based on the thermometer data.

Table C.8 Replicate Reversing Thermometer samples. Temperature is in °C and ITS-90 scale.

Sample ID Number	Thermometer Serial Number	Main Corrected	WOCE QF
158002	T347	2.022	2
158002	T352	2.025	2
158004	T878	1.801	2
158004	T881	1.805	2
158011	T347	6.874	2
158011	T352	6.876	2
158013	T878	2.784	2
158013	T881	2.794	2
158027	T347	10.047	2
158027	T352	10.045	2
158029	T878	10.304	2
158029	T881	10.302	2
158048	T347	6.386	2
158048	T352	6.437	2
158050	T878	4.630	2
158050	T881	4.683	2
158056	T347	7.339	2
158056	T352	7.340	2
158058	T878	4.686	2
158058	T881	4.683	2
158066	T347	7.644	2
158066	T352	7.642	2
158068	T878	7.559	2
158068	T881	7.602	2
158084	T347	8.116	2
158084	T352	8.839	2
158086	T878		9
158086	T881		9
158186	T347	-1.697	2
158186	T352	-1.698	2
158188	T878	-0.718	2
158188	T881	-0.730	2
158209	T347	-0.668	2
158209	T352	-0.669	2
158211	T878	-1.461	2
158211	T881	-1.465	2
158235	T347		9
158235	T352		9
158237	T878		9
158237	T881		9
158252	T347	2.241	2
158252	T352	2.241	2
158254	T878	2.380	2
158254	T881	2.378	2
158272	T347		9
158272	T352		9
158274	T878		9
158274	T881		9
158292	T347		9
158292	T352		9
158294	T878		9
158294	T881		9
158315	T347	1.641	2
158315	T352	1.661	2
158338	T347	1.690	2
158338	T352	1.693	2
158340	T878	2.192	2
158340	T881	2.189	2

9. Helium/Tritium

Samar Khatiwala

Samar Khatiwala collected a total of 246 He and 252 Tr samples for Peter Schlosser of Lamont-Doherty Earth Observatory, Columbia University.

a. Description of Equipment and Technique

He samples were collected through tygon tubing into copper tubes (40 g capacity) bolted into aluminum channels for support and protection. Tr samples were collected into one-litre Argon filled brown glass bottles, directly from the Niskin spigot.

b. Sampling Procedure and Data Processing Technique

He samples were drawn after CFCs and occasionally after DOC (WOCE parameter 43). Delivery was through tygon tubing, cured in seawater to reduce bubbles, which was monitored for air bubbles. All detected bubbles were worked out of the line. After which the metal channel holding the copper sample tube was struck several times on one side with a ratchet in a pattern from the intake end towards the outflow end of the copper tube in order to pass any air bubbles out of the sample tube. Flushing of the copper tube took place during both parts of the bubble-removing procedure. When air removal and flushing were complete, both ends of the copper tube were sealed by tightening the two bolts at each end with a ratchet wrench, starting with the outflow end. GMT time of sampling was routinely noted for each sample. These samples were shipped to Lamont for analysis.

Tritium samples were collected into argon-filled bottles without rinsing or flushing, after all other samples were collected from the rosette. The bottle caps were secured with electrical tape at the completion of each station. These samples were shipped to Lamont for analysis. Occasionally, the Niskins were drained before the tritium was collected. Careful rinsing of all samples helped alleviate this problem.

Replacement watches were handed out to all persons in the scientific party and the winch drivers who normally wore luminous-dial watches, and a sign was posted at each rosette room door to avoid wearing luminous-dial watches inside the room.

10. Oxygen Isotopes

Anthony W. Isenor

a. Sampling Procedure

Water samples were initially collected using a 10 litre rosette bottle. Samples for salinity isotope analysis were collected last in the sampling. A total of about 550 isotope samples were drawn. Duplicates were drawn on some stations. Samples were collected in 15 ml sample bottles. Samples were sent to Bob Houghton at Lamont Geological Earth Observatory, Columbia University, Palisades, NY.

D. MOORED MEASUREMENTS - DESCRIPTIONS, TECHNIQUES AND CALIBRATIONS

1. Current Meter Moorings

John R. N. Lazier

a. Description of the Equipment and Technique

There was one partial recovery (M1194), one full recovery (M1200) and three deployments (M1227, M1229 & M1230) of BIO deep-sea moorings on cruise 96006.

Mooring 1194 consisted of 6 Seacat temperature / conductivity recorders, 6 Aanderaa current meters, 1 acoustic doppler current profiler, 1 WOTAN (weather observations through ambient noise) and 1 CTD with a device for measuring the partial pressure of dissolved gas in water. It was intended to recover this mooring and deploy a duplicate mooring in the same location. However, during the recovery process the weather deteriorated causing delays in grappling the upper float and excessive working of the buoyancy packages in the mounting seas. This in turn caused some seizing wire on the shackles to break, the shackle pins worked loose, and the mooring separated into two pieces. Recovery then proceeded from the bottom end of the mooring, but high winds pushed the ship breaking the mooring wire and the remainder of the mooring sank. The recovered components consisted of 2 current meters, 1 release, the WOTAN and CTD with dissolved gas instrumentation.

The recovered mooring (M1200) and its replacement (M1227) had the same configuration (see figure 5 below) of one main float called a Hibernia Package, one Aanderaa Current Meter, two backup buoyancy packages and one acoustic release.

Both of the other two deployed moorings (M1229 and M1230) had the same configuration (see figures 6 and 7 below) of one main float called a Hibernia Package, one Benthos acoustic release, two backup buoyancy packages and one acoustic release.

All three deployed moorings were constructed using 3/16" jacketed wire. Stainless steel shackles and swivels were used to connect the instruments and backup buoyancy packages. All shackles were secured with a short piece of wire. The acoustic releases were 723A EG&G DACs. The moorings were designed for a 12-month deployment.

The back-up buoyancy packages consisted of two 17" glass balls contained in plastic hard hats and fastened to a stainless steel tension bar one meter in length. These backup buoyancy packages were shackled together to form doubles and triples before they are shackled into the mooring line.

b. Sampling Procedure and Data Processing Techniques

The recovered Aanderaa current meters recorded at a sampling interval of three hours. The data was processed using standard software packages within the BIO Oceans suite of programs. This processing consisted of the following steps:

- sensor calibrations were applied to compute engineering units from instrument encoder numbers. This applied to all parameters.
- compass direction was converted to degrees True
- initial and end records during the deployment and recovery period were removed from the dataset. Data points out of range were also removed.

c. Calibration Data

The temperature, pressure and direction sensors of the Aanderaa current meters were calibrated in the laboratory prior to deployment. These calibrations were not included in this cruise report.

Recovery Log

Mooring No. **1194**
 Ship: Hudson
 Cruise No: 96006
 Date: 21/05/1996
 Mooring Technician: Scotney/Hartling/Boyce
 Sea State: 03-Apr
 Weather Conditions: 25kt wind, cloudy, cool

Time (Z)	Instrument	Remarks
May 21, 1996 0921	Release	Release command accepted – Release 504801
		Heavy weather – difficulty getting close and grappled
1203		Mooring hooked and float lifted on board
1205		Main float and CTD/GTD (IOS) on board
1207	CM4355	on board
1212	WOTAN	on board
1215	1	Hard hat package on board - broken from remainder
1222		Yellow balls sighted - 3 groups
1330		Package caught on 3 rd attempt – Bottom group
1335		Release 504801 and bottom package on board
1340	CM4195	on board
		Pulling in line with yellow balls - “Line Parted” Position is 56° 44.300 N, 52° 27.550 W

Recovery Log

Mooring No. **1200**
 Ship: Hudson
 Cruise No: 96006
 Date: 19/05/1996
 Mooring Technician: Scotney/Hartling
 Sea State: 2-3
 Weather Conditions: Cloudy / cool

Time (Z)	Instrument	Remarks
1335	Release	Release contacted - transponder working
		Using Benthos gear to find range = 1370 m (slant range)
1337	Release	Release command accepted
1403	Floats	On the surface
		Light flashing
1430	CM 5577	Out of the water - on deck - rotor spinning
1438		Release and lower floats on board

Deployment Log

Mooring No: **1227** Geographic Area: Labrador Slope
 Intended Duration: 1 year Ship: CSS Hudson
 Cruise Number: Date: May 19/96
 Sea State: Weather Conditions: cloudy and cool
 Mooring Tech.: Scotney/Hartling Navigation Inst.: GPS
 Latitude: 55 07.209 N Longitude: 54 05.103 W
 Time of Fix: 1739Z
 Depth Raw: Depth Corrected:
 Main Float Type: 4 Yellow Balls Main Float Markings: nil
 Radio Beacon Type: No Beacon Radio Beacon Freq.:
 Light Type: OAR Light Colour and Rate: White
 Mooring Line Type: Yellow Jacketed wire Mooring Line Colour: Yellow
 Release Type: EG&G S/N:
 Release Code:

Time (Z)	Instrument	Remarks
		Release Test OK
1637		Mooring assembly on foredeck
		Light working
		Wait while oil spill on port side attended to
1737	RCM 6404	Over the side - in water
1740		Anchor released
1755		Release disabled

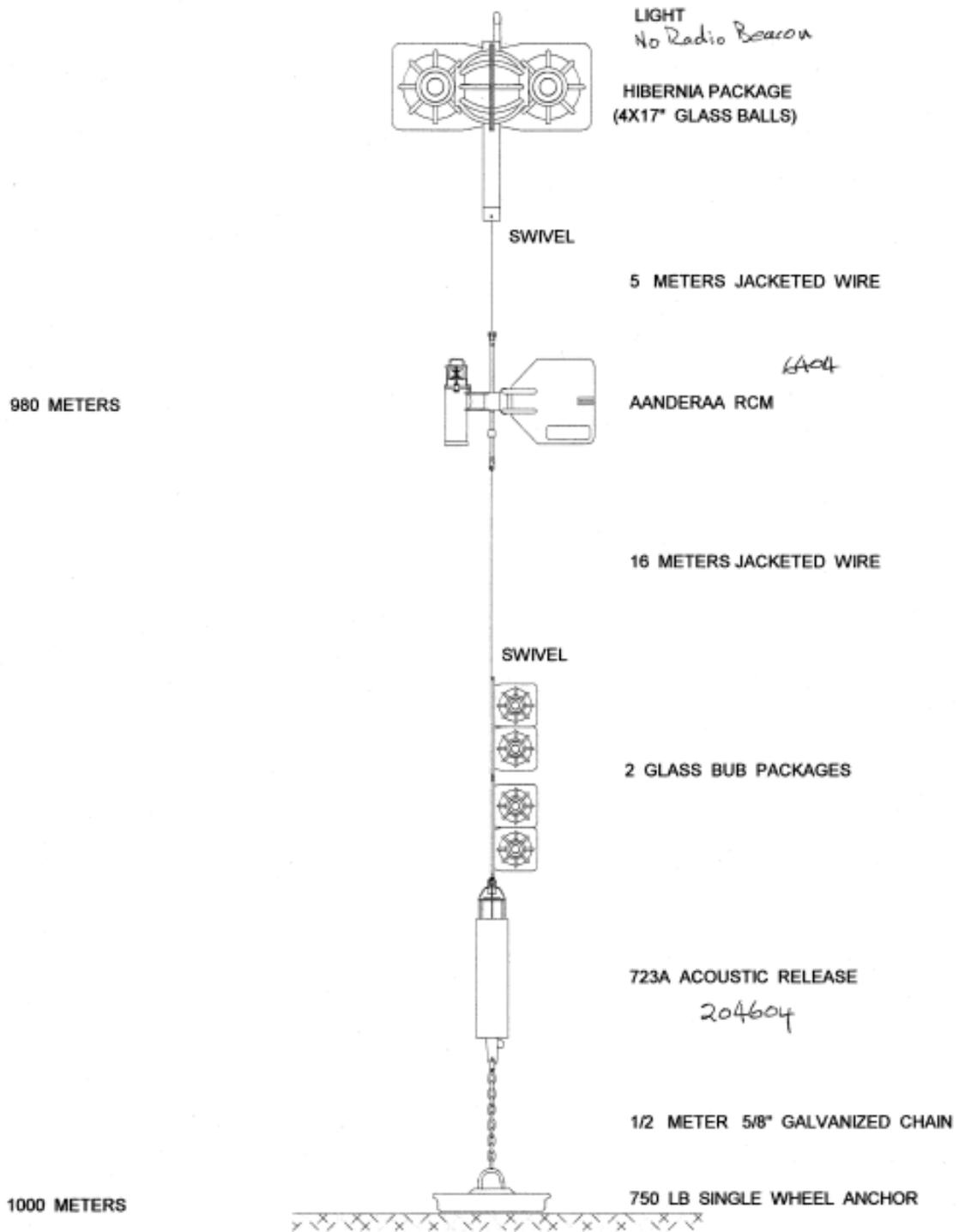


Figure 5. Mooring No. 1227

Deployment Log

Mooring No:		Geographic Area:	Emerald Basin
Intended Duration:	1 year	Ship:	Hudson
Cruise no.:		Date:	May 13/96
Sea State:		Weather Conditions:	clear and windy
Mooring Tech.:	Scotney/Hartling	Navigation Inst.:	DGPS
Latitude:	43 53.17 N	Longitude:	62 51.89 W
Time of Fix::	1206Z		
Raw Depth:	256 m	Corrected Depth:	261 m
Main Float Type:	Hibernia	Main Float Markings:	
Radio Beacon Type:		Radio Beacon Freq.:	
Light Type:		Light Colour and Rate:	
Mooring Line Type:	Jacketed wire	Mooring Line Colour:	Yellow
Release Type:	EG&G	Release S/N:	
Release Code:			
Release Type:	Benthos	Release S/N:	
Release Code:	C		

Time (Z)	Instrument	Remarks
1206		Anchor away

SUBSURFACE LIGHT

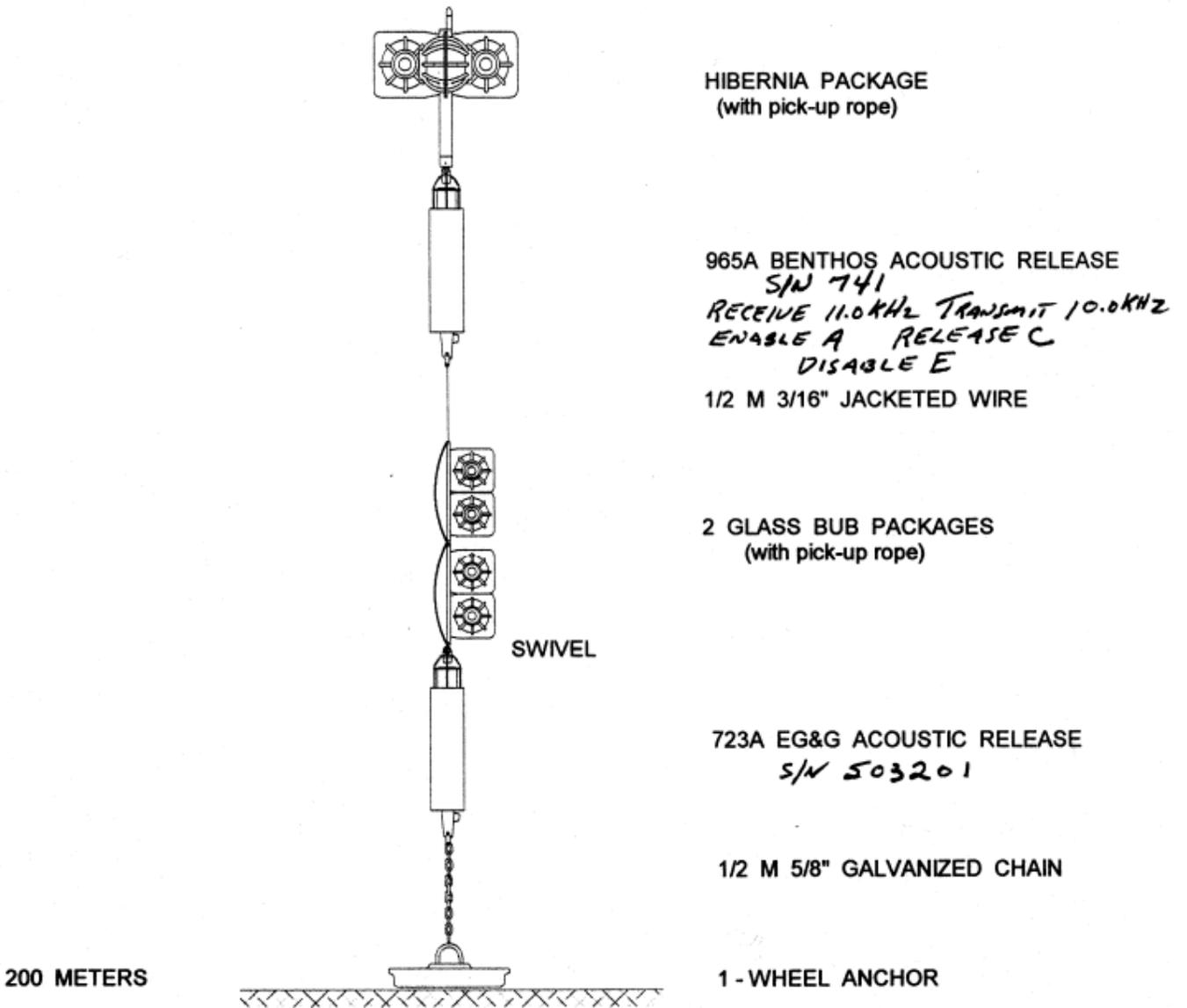


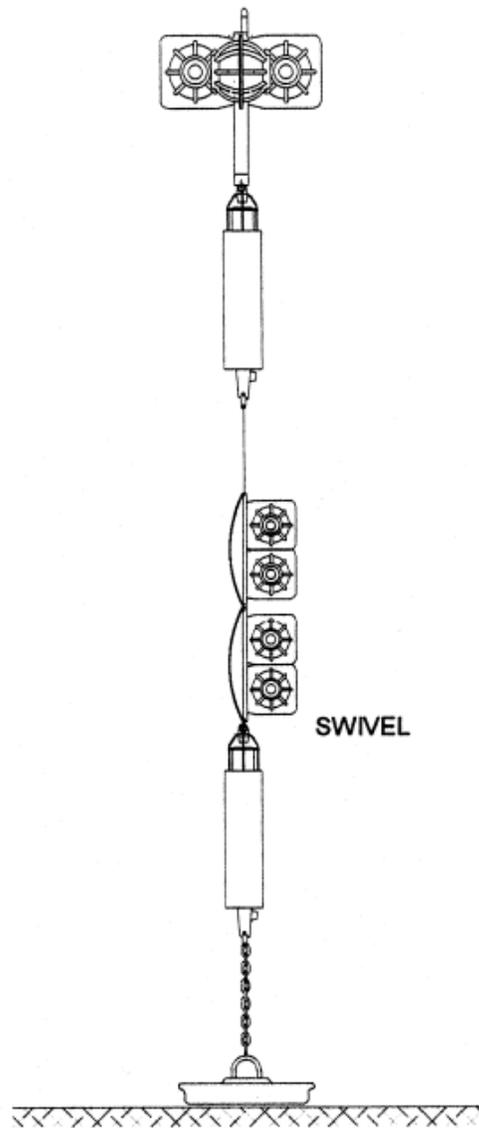
Figure 6. Mooring No. 1229

Deployment Log

Mooring No:	1230	Geographic Area:	Hamilton Bank
Intended Duration:	1 year	Ship:	Hudson
Cruise no.:		Date:	May 25/96
Sea State:		Weather Conditions:	sunny and clear
Mooring Tech.:	Scotney/Hartling/Boyce	Navigation Inst.:	GPS
Latitude:	58 37.86 N	Longitude:	50 24.64 W
Time of Fix::	1657Z		
Raw Depth:	3450 m	Corrected Depth:	3456 m
Main Float Type:	Hibernia	Main Float Pack Markings:	
Radio Beacon Type:		Radio Beacon Freq.:	
Light Type:	Novatech	Light Colour and Rate:	white
Mooring Line Type:	Jacketed wire	Mooring Line Colour:	Yellow
Release Type:	EG&G	Release S/N:	
Release Code:			
Release Type:	Benthos	Release S/N:	
Release Code:	D		

Time (Z)	Instrument	Remarks
1657		Mooring away
1746		Mooring on bottom
1750		Releases disabled

SUBSURFACE LIGHT



HIBERNIA PACKAGE
(with pick-up rope)

965A BENTHOS ACOUSTIC RELEASE
S/N 742
RECEIVE 11.0KHz TRANSMIT 10.0KHz
ENABLE B RELEASE D
DISABLE F

1/2 M 3/16" JACKETED WIRE

2 GLASS BUB PACKAGES
(with pick-up rope)

SWIVEL

723A EG&G ACOUSTIC RELEASE
S/N 107402
Release Code 0145

1/2 M 5/8" GALVANIZED CHAIN

1 - WHEEL ANCHOR

200 METERS

Figure 7. Mooring No. 1230

E. REFERENCES

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