RBR Multi-parameter Probe: Physical Limnology Information Sheet

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Last update: 28th July 2017 (KS); 18th June 2020 (PF); 9th December 2021 (PF);

IISD-ELA Database Fields for RBR

Location ID, Sublocation, Station ID
Date and Time (CST)
Depth (m)
Temperature* (°C)
Conductivity (µS/cm^2)
Specific Conductivity ((µS/cm^2)
Dissolved Oxygen (mg/L)
Dissolved Oxygen Saturation (%)
Chlorophyll α (µg/L using the Seapoint Fluorometer, volts using the Turner Cyclops 7)
Data Set ID = GC5

* The data are an average of 10 seconds worth of data, however, temperature profile data from the Physical Limnology section of the ELA Data retriever are instantaneous manual readings from the keypad display, so RBR temperature data won't be the same as the temperature profile data.

General

This information sheet describes the methods for operating the RBR XRX620 CTD+ multi-parameter probes (RBRs). RBRs are used to collect data on multiple physical limnological parameters including temperature, depth, dissolved oxygen, conductivity, and chlorophyll α. These instruments are used in concert with Campbell Scientific CR1000 data loggers, which provide power to the RBRs and storage for the high-resolution data collected. This instrument setup is the standard used for the collection of temperature and oxygen profile data by the HydroLim team. All active lakes (both LTER and experimental) are sampled by the HydroLim team each season.

Data are offloaded from the CR1000 loggers using LoggerNet software. Profile data are stored and processed using AQUARIUS software, before being uploaded to the IISD-ELA database.

* These probes are integrated with the RBR.

<u>Related information sheets:</u>

Lake Sampling & Field Observation Information Sheet

Background

In 2009 and 2010, two RBRs were purchased (SNs 18018 and 18033, respectively) to replace the Flett Research Mark II digital telethermometers used for lake sampling. RBR XRX620 CTD+ were chosen because they have a fast temperature sensor and can sample at a high frequency (6Hz). These multi-parameter probes can also accommodate additional sensors- the current array includes sensors for conductivity*, temperature*, depth*, dissolved oxygen, and chlorophyll α. The dissolved oxygen sensor is an Aanderaa 4330F Oxygen Optode, and the chlorophyll α sensors are either a Seapoint Chlorophyll Fluorometer or a Turner Cyclops 7 Fluorometer.

One of the goals in upgrading the sampling equipment was to collect high-resolution data on multiple lake quality parameters. For example, sensors like the Aanderaa 4330F optodes allow for more detailed oxygen profiles (i.e. each metre) compared to the previous standard of taking water samples for Winkler titration at pre-determined chemistry profile sampling depths. All sensors on the RBRs record data simultaneously, providing a detailed snapshot of lake quality at each logged interval.

Since September 2010, one RBR has been equipped with a Seapoint Chlorophyll Fluorometer. The other RBR was outfitted with a Turner Cyclops 7 Fluorometer in May of 2019. Both fluorometers were calibrated using rhodamine dye in June 2020, after sampling was completed for the month- prior to this date, neither fluorometers had been calibrated. The Seapoint Fluorometer had experienced intermittent data cable issues over the years. The data prior to July 2020 from these probes should be used with extreme caution. While the Seapoint Fluorometer produces data in µg/l, the Turner Cyclops 7 produces data in volts, which must then be converted into µg/l using an equation determined through lab analysis of water samples.

Data Collection

Instrumentation

CR1000 logger box – Campbell Scientific CR1000 data logger and power supply for all instrumentation

RBR XRX620 CTD+ - multiparameter probe with depth, temperature, and conductivity sensors built in.

Aanderaa Oxygen Optode 4330F – sensor for determination of dissolved oxygen concentration.

Seapoint Chlorophyll Fluoromoeter – sensor for determination of chlorophyll α concentration.

Turner Cyclops 7 Fluorometer – sensor for determination of chlorophyll α through voltage signal and subsequent conversion equation.

YSI probes – non-logging temperature and oxygen meters. Various models have been used over the years in place of an RBR if the RBR is out of service for any reason.

****Specification sheets for each instrument and sensor can be found at the end of this document****

Methods

RBR and CR1000

The RBR and CR1000 together allow for the collection and display of real-time data while in the field. A cable from the CR1000 to the RBR provides power to the RBR and allows for the transmission of data from the RBR to the CR1000 datalogger. The CR1000 has a keypad which allows the user to view real-time data. Reading the data in real-time (vs afterwards in the lab) is necessary for determining water sampling depths while in the field (see Lake Sampling & Field Observation Information Sheet).

At the sampling site, the RBR is first connected to the CR1000 for power up. Once the CR1000 program is initialized, the data table is configured for sampling by zeroing the RBR depth sensor (above water) as well as entering the lake #, RBR #, and optode #.

The RBR is then lowered sequentially from the surface to each desired depth. The RBR must remain at each depth until the sensors have stabilized before data are written to the CR1000.

The CR1000 has a keypad or tablet (connected via Bluetooth) which displays real-time data for the user to refer to while sampling. This information includes depth, temperature, oxygen concentration, chlorophyll (µg/L or v), as well as 'stable time'. The CR1000 is programmed to record data to the data table only once all sensors have stabilized for at least 10 seconds. When sensors have stabilized, the CR1000 records a record in the data table, triggering an audible beep, which signals the user to proceed to the next desired depth interval. The user can also look at the 'stable time' value to determine if a record has been written to the data table- if the stable time counter is over 11, a data has been recorded at the current depth.

The stable time counter will only begin counting once all sensors are stable, including depth. The program allows for a small amount of 'wiggle room' with the depth sensor, so that data can still be recorded on wavy and windy days, when the depth of the RBR may change slightly due to boat motion. If depth changes more than 0.1 m between readings over the last 8 seconds, the stable time counter will reset. While this programming ensures that the data recorded for each sensor reflects the values at one particular depth, it is important that the user is decisive in moving the RBR between depths. If the user changes depths very slowly, the RBR will assess the depth as 'stable' and will not reset the stable time counter. For data that consist of an average of readings, this could skew the recorded data away from the true value for that depth.

Once the profile is complete, the CR1000 can be turned off. The data collected are saved to the data table and can be offloaded once back in lab.

YSI Probe

If an RBR is out of service, various models of YSI dissolved oxygen meters have been used to collect temperature and oxygen data. In these cases, no conductivity or chlorophyll data are recorded, and the temperature and oxygen data are instantaneous readings recorded by hand, not logged data.

Older profiles collected with 'YSI' as the method in field notes used a YSI model 550A, which is a membrane style probe to measure oxygen. Since 2016, the YSI used in place would have been the 'Fish ProODO', and since 2019, the 'General Use ProSolo'. These two newer YSI units are optical rather than membrane-based, and are maintained by the Fish crew and HydroLim crew, respectively. In field notes, method records should indicate which specific YSI was used, however this has not always been the case. These time periods can give an idea of which YSI was used over time.

Data processing performed by the CR1000

The RBR sensors read data at 6 Hz (i.e. 6 times per second). The CR1000 is programmed to store the raw RBR data each second, as well as one data record for each depth once the sensors have stabilized. Since the Aanderaa Optode is the slowest sensor, the oxygen data is used to determine when the data is stable. The logger compares the current oxygen and depth values to the values 8 seconds previous, and if the absolute difference is less than 0.1 mg/L and 0.1 m, respectively, the data is considered 'stable'. Once 10 seconds of continuously stable data are collected the average is calculated over the 10 seconds and stored. All data is obtained on the downcast. Any data collected on the upcast is discarded during post-processing.

Specific conductivity calculation

$$\text{Specific Conductivity} = \frac{\text{Conductivity}}{1+(0.0191 * (\text{Temperature} - 25))}$$

Specific conductivity is standardized to 25°C to match the conductivity as measured by the IISD-ELA chemistry lab.

Depth measurement calculation

The RBR measures depth with a pressure sensor. Depth is calculated as follows:

$$\text{Depth (m)} = \frac{\text{measured pressure} - \text{atmospheric pressure}}{\text{water density} * 0.980665}$$

Where atmospheric pressure is entered in the settings of the RBR Ruskin software, and density of water is 1.0 for freshwater.

Since atmospheric pressure is always changing, the depth must be zeroed each time the RBR is used.

To do this, the user holds the RBR so that the pressure sensor is out of the water, and uses the keypad to 'Zero' the depth sensor and have the CR1000 logger set the atmospheric pressure equal to the current pressure reading. The logger then uses the formula above to calculate depth.

Note that because the atmospheric pressure is not set in the software preferences when the RBR logger is started each day, the depths recorded in the raw RBR logger data are incorrect. If you are using the raw 6hz data from the RBR, you must take this into account.

Dissolved oxygen saturation calculation

Percent saturation of oxygen is calculated using the following formula:

Where P is 0.95657 atm (ELA is approximately 391m above sea level, which works out to 0.95657 atm)

$$C_p = C^* \times P \left[\frac{(1-P_{wv}/P)(1-\theta P)}{(1-P_{wv})(1-\theta)} \right]$$

C_p = equilibrium oxygen concentration at nonstandard pressure, mg/L

C^* = equilibrium oxygen concentration at standard pressure of 1 atm, mg/L

P = nonstandard pressure, atm

P_{wv} = partial pressure of water vapor, atm, computed from:

$\ln P_{wv} = 11.8571 - (3840.70/T) - (216{,}961/T^2)$

T = temperature, °K

$\theta = 0.000975 - (1.426 \times 10^{-5}\, t) + (6.436 \times 10^{-8}\, t^2)$

t = temperature, °C

Dissolved oxygen equation from: http://www.waterontheweb.org/under/waterquality/oxygen.html

Results from this calculation match oxygen solubility tables such as
http://water.usgs.gov/owq/FieldManual/Chapter6/6.2.4.pdf

Reporting of data

Data collected by the RBR is an average of 10 seconds worth of readings, however, temperature profile data from the Physical Limnology section of the ELA data retriever are in fact, manual readings from the keypad display written down into the field book once the CR1000 has recorded a record (i.e. after a beep). Logged RBR temperature data is an average and so won't be exactly the same as the temperature profile data, which is an instantaneous reading

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ELA database under re-construction, this section is not totally up to date

Data can be queried from the ELA data retriever in two formats:

All of the data

or

Averages based on the data being grouped in depth bins.

The first option gives you all of the data collected when the Campbell Logger detected stable oxygen data (Averages of 10 seconds of data once the oxygen data is stable). However, sometimes if the RBR was held at the same depth for a period of time, this process could happen multiple times, giving multiple data records for the same depth. Also, even though the user tried to hold the RBR at depths either at the whole metre or quarter metre intervals, data was recorded at other depths around these depths (eg. during windy days it is difficult to hold the RBR at exactly 6.25m until it stabilized).
Since there are many depths that do not match the intended sampling depths exactly, the depth-bin field was created so that depths within 10cm of the intended depth are binned into pre-determined depth intervals. For example, a depth of 3.40m would be put in the 3.5 depth bin, 3.39 would not fall into a depth bin as it is not within 10cm of either 3.25 or 3.50m. Depths bins for less than 10 m are in 0.25m increments, and 1m increments for greater than 10 m.

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Instrument specifications

Seapoint Chlorophyll Fluorometer

The Seapoint Chlorophyll Fluorometer (Model SCF serial 3209) was purchased in September 2010 which allowed real-time *in situ* measurements to be added to the RBR dataset. The RBR is supposed run the fluorometer in auto-ranging mode which is supposed to adjust the gain depending on chlorophyll levels, however this often didn't work, and chlorophyll values reached the maximum range at about 5ug/L. When this happened it was noted in the "comments" field of the data.

Below is a description of the fluorometer from Seapoint:

"The Seapoint Chlorophyll Fluorometer (SCF) is a high-performance, low power instrument for in situ measurements of chlorophyll. Its small size, very low power consumption, high sensitivity, wide dynamic range, 6000 meter depth capability, and open or pump-through sample volume options provide the power and flexibility to measure chlorophyll in a wide variety of conditions. The SCF uses modulated blue LED lamps and a blue excitation filter to excite chlorophyll. The fluorescent light emitted by the chlorophyll passes through a red emission filter and is detected by a silicon photodiode. The low level signal is then processed using synchronous demodulation circuitry which generates an output voltage proportional to chlorophyll concentration. The SCF may be operated with or without a pump. The sensing volume may be left open to the surrounding water, or, with the use of the supplied cap, can have water pumped through it. Two control lines allow the user to set the range to one of four options. These lines may be hardwired or microprocessor controlled to provide a suitable range and resolution for a given application. The sensor is easily interfaced with data acquisition packages; a 5 ft. pigtail is supplied. Custom configurations are available."

SPECIFICATIONS

• Power Requirements:	8-20 VDC, 15mA avg., 27mA pk.		
• Output	0-5.0 VDC		
• Output Time Constant	0.1 sec.		
• Power-up Transient Period	< 1 sec.		
• Excitation Wavelength	470 nm CWL, 30 nm FWHM		
• Emission Wavelength	685 nm CWL, 30 nm FWHM		
• Sensing Volume	340 mm^3		
• Minimum Detectable Level	0.02 µg/l		
	Gain	Sensitivity, V/µg/l	Range, µg/l
Sensitivity/Range	30x	1.0	5
	10x	0.33	15
	3x	0.1	50
	1x	0.033	150
	< 0.2%/°C		
• Temperature Coefficient	6000 m (19,685 ft)		
• Depth Capability	1000 g (2.2 lbs)		
• Weight (dry)	0°C to 65°C (32°F to 149°F)		
• Operating Temperature	Rigid polyurethane		
• Material	Impulse AG-306/206 (others available on request)		
• Underwater Connector			

Turner Cyclops 7 Chlorophyll Fluorometer

OPTICAL SPECIFICATIONS

	Minimum Detection Limit	Linear Range
Chlorophyll *in vivo* Blue Excitation	0.03 µg/L	0 - 500 µg/L

FLUOROMETER PERFORMANCE

Linearity: $0.99R^2$

PHYSICAL DIMENSIONS

Length x Diameter:

5.7" x 0.9"; 14.48 x 2.23 cm (SSt or Ti)

5.7" x 1.25", 14.48 x 3.18 cm (Delrin)

Weight: 5.0 oz; 142 grams

ENVIRONMENTAL CHARACTERISTICS

Temperature Range:

Ambient: 0 to 50 deg C

Water Temp: -2 to 50 deg C

Depth Range: 600 meters

Signal Output: 0 - 5 VDC

Supply Voltage Range: 3 - 15 VDC

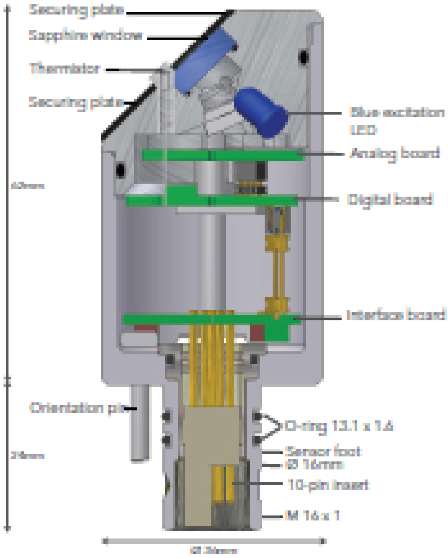
Aanderra 4330F Oxygen Optodes

Dissolved oxygen data from the optodes (Model 4330F, Serial 249 & 138) begins the same time as the RBR data. Optodes foils and calibration is checked before each field season, and foils are changed and recalibrated is necessary.

Optode data from 2011 was compared to Winkler Titration results. These samples were collected at the same depth and time. These two methods agreed much better than when data was compared in 2010 when the water samples were not necessarily taken at the exact same depth and time.

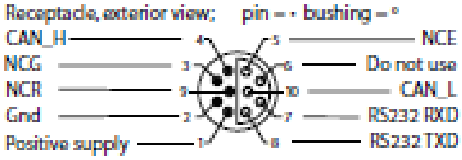
Spec sheet below:

Specifications



PIN CONFIGURATION

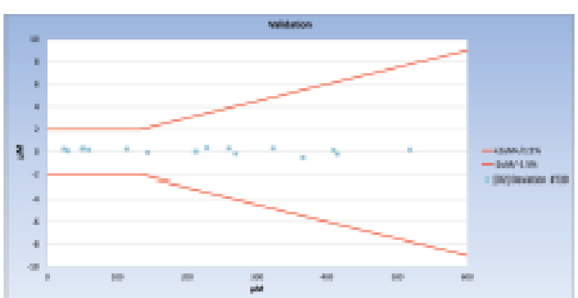
Receptacle, exterior view; pin = • bushing = °



Cable from sensor to:	Cable
PC with waterproof SP (Sealing Plug), RS-232	4865
Seaguard as sixth sensor on top-end plate	4999
Seaguard with waterproof top end plate connection	4793
SmartGuard single sensor with SP	5236
User furnished datalogger, SP to free end	4762

Sensing Foil Considerations

The standard sensing foil is protected by an optical isolation layer which makes the foil extra rugged and insensitive to direct sunlight. The fast response sensing foil is not equipped with this layer; ambient light intensity higher than 15000 lux may cause erroneous readings. To avoid potential bleaching the fast response foil should be protected from ambient light when storing the sensor. We recommend the standard foil in applications where fast response time is not needed.



Typical validation at 20 points after calibration

xylem
Let's Solve Water

Aanderaa Data Instruments AS
Sanddalsringen 5b
P.O. Box 103 Midtun
5843 Bergen, Norway

Oxygen: O_2- Concentration | Air Saturation

- Measurement Range: 0 – 1000 µM[1] | 0 - 300%
- Calibration method: 40-point automatic calibration, 20-point verification, 3 fully Winkler calibrated optodes for referencing
- Foils: Pre-burned PreSens Pst3 foils
- Calibration Range[2]: 0 – 500 µM[2] | 0 - 150%
- Resolution: < 0.1 µM | 0.05 %
- Accuracy: < 2 µM or 1.5%[3] | <1.5 %[4]
- Response Time (63%): 4330F (with fast response foil) <8 sec; 4330 (with standard foil) <25 sec
- Typical field drift: <0.5 % per year

Temperature:

- Range: -5 to +40°C (23 - 104°F)
- Resolution: 0.01°C (0.018°F)
- Accuracy: ±0.03°C (0.18°F)[5]
- Response Time (63%): <2 sec

Output format: AiCaP CANbus, RS-232

Output Parameters: O_2-Concentration in µM, air saturation in %, temperature in °C, oxygen raw data and temperature raw data

Sampling interval: 2 sec – 255 min

Supply voltage: 5 to 14Vdc

Current drain:

- Average: 0.16 +48 mA/S where S is sampling interval in seconds
- Maximum: 100 mA
- Quiescent: 0.16 mA

Operating depth: SW: 0-300m (0-984ft)
IW: 0-3000m (0-9,845ft)
DW: 0-6000m (0-19,690ft)
Hadal[6]: 0-12000m (0-39,380ft)

Elec. connection: 10-pin receptacle mating plug SP

Dimensions (WxDxH): Ø36 x 86 mm (Ø1.4"x 3.4")

Weight: 175g (6.17oz)

Materials: Epoxy coated Titanium, PA

Accessories: not included: Foil Service Kit 4733/4733O (standard)/4794 (fast)
AiCap extension cable with SP 4793
SP to Free End Cable 4762
SP to PC Cable 4865
Setup and Config Cable 3855[7]/3855A[7]

1) O_2 concentration in µM = µmol/l. To obtain mg/l, divide by 31.25
2) Other ranges available on request
3) Requires salinity compensation for salinity variations > 1mS/cm, and pressure compensation for pressure > 100meter
4) Within calibrated range 0 - 120% / 0 - 30°C
5) Within calibrated range 0 - 30°C
6) Productnumber 5420
7) Laboratory use only

Specifications subject to change without prior notice.

Misleading specifications

When Aanderaa states an absolute accuracy of e.g (±1.5% or ±2 µM) we mean the accuracy of the sensor in the field over the entire range of oxygen concentrations and temperatures, others might refer to accuracy in the laboratory just after the sensor was calibrated. When Aanderaa give response time in water others refer to response time in air which is much faster. For more information read our Best Practice document on Oxygen Optodes.

YSI ProSolo Datasheet:

ProSolo Specifications	
Dimensions	8.3 cm width x 21.6 cm length x 5.6 cm depth; 567 g (with battery)
Power	Rechargeable lithium-ion battery pack provides ~48 hours with the handheld only; Battery recharge time is ~ 9 hours with the AC power adapter; The instrument can also be powered via AC or external power through the USB port
Operating Temperature	0 to 50°C
Storage Temperature	0 to 45°C with battery installed; 0 to 60°C without battery installed
Display	Color, LCD graphic display; 3.9 cm width x 6.5 cm height
Memory	>100,000 data sets
Barometer Units: mmHg, inHg, mbar, psi, kPa, atm	Range: 375 to 825 mmHg; Accuracy: ±1.5 mmHg from 0 to 50°C; Resolution: 0.1 mmHg
Sites and Data ID	100 user-defined sites and 100 user-defined data ID tags; Site pictures can be sent to the handheld via KorDSS Software
Calibration Records	400 detailed calibration records can be stored and are available to view, download, and print (printing only available via KorDSS Software)
Languages	English, Spanish, German, French, Italian, Norwegian, Portuguese, Japanese, Chinese (Simplified & Traditional), Korean, Thai
Certifications	CEC, CE; RoHS; IP-67; WEEE; FCC; UN Part III, Section 38.3, Test methods for lithium-ion batteries (Class 9)
Warranty	3 years on handheld

ODO/T Specifications	
Size	2.46 cm diameter, cable options for 1, 4, 10, 20, 30, 50, and 100 m lengths
Dissolved Oxygen (Optical luminescence) Units: % saturation, % saturation local, mg/L, ppm	Range: 0 to 500%, 0 to 50 mg/L; Accuracy: 0 to 200%: ±1% of reading or 1% saturation, whichever is greater; 200 to 500%: ±8% of reading; 0 to 20 mg/L: ±0.1 mg/L or 1% of reading, whichever is greater; 20 to 50 mg/L: ±8% of reading; Resolution: 0.01 mg/L and 0.1%, or 0.1 mg/L and 1% (auto-adjusts based on range)
Temperature (Thermistor) Units: °C, °F, K	Range: -5 to 70°C (temperature compensation range for DO mg/L measurement: -5 to 50°C); Accuracy: ±0.2°C; Resolution: 0.1°C or 0.1°F (auto-adjusts based on range)
Warranty	2 years on cable, probe, and ODO sensor cap