



**PERFORMANCE VERIFICATION STATEMENT**  
**for the Greenspan Technology Dissolved Oxygen Sensor**  
**DO300/DO1200**

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<b>TECHNOLOGY TYPE:</b>	Galvanic cell
<b>APPLICATION:</b>	In situ measurements of dissolved oxygen
<b>PARAMETERS EVALUATED:</b>	Accuracy, precision, instrument drift, and reliability
<b>TYPE OF EVALUATIONS:</b>	Laboratory and Field Performance Verification at seven ACT Partner sites
<b>DATE OF EVALUATION:</b>	Testing conducted from May through September 2004

**NOTICE:**

ACT verifications are based on an evaluation of technology performance under specific, agreed-upon protocols, criteria, and quality assurance procedures. ACT and its Partner Institutions do not certify that a technology will always operate as verified and make no expressed or implied guarantee as to the performance of the technology or that a technology will always, or under circumstances other than those used in testing, operate at the levels verified. ACT does not seek to determine regulatory compliance; does not rank technologies nor compare their performance; does not label or list technologies as acceptable or unacceptable; and does not seek to determine “best available technology” in any form. The end user is solely responsible for complying with any and all applicable federal, state, and local requirements.

This document has been peer reviewed by ACT Partner Institutions and a technology-specific advisory committee and was recommended for public release. Mention of trade names or commercial products does not constitute endorsement or recommendation by ACT for use.

Questions and comments should be directed to: Dr. Mario Tamburri  
Alliance for Coastal Technologies  
Chesapeake Biological Laboratory  
PO Box 38 / One Williams Street  
Solomons, Maryland 20688, USA  
Email: [tamburri@cbl.umces.edu](mailto:tamburri@cbl.umces.edu)

## **BACKGROUND:**

Instrument performance verification is necessary so that effective existing technologies can be recognized and so that promising new technologies can become available to support coastal science, resource management, and ocean observing systems. To this end, the NOAA-funded Alliance for Coastal Technologies (ACT) serves as an unbiased, third party testbed for evaluating coastal sensors and sensor platforms for use in coastal environments. ACT also serves as a comprehensive data and information clearinghouse on coastal technologies and a forum for capacity building through workshops on specific technology topics (for more information visit [www.act-us.info](http://www.act-us.info)).

This document summarizes the procedures used and results of an ACT Evaluation to verify manufacturer claims regarding the performance of the Greenspan Dissolved Oxygen Sensor. Detailed protocols, including QA/QC methods, are described in the *Protocols for the ACT Verification of In Situ Dissolved Oxygen Sensors* (ACT TV04-01), which can be downloaded from the ACT website ([www.act-us.info/tech\\_evaluations.php](http://www.act-us.info/tech_evaluations.php)). Appendix 1. is an interpretation of the Performance Verification results from the manufacturer's point of view.

## **TECHNOLOGY TYPE:**

Galvanic sensors produce a millivolt output proportional to the oxygen present in the medium in which it is placed. The galvanic probe principle was introduced by Macreth in 1964. Unlike the Clark Cell, a galvanic probe does not need an external power supply to provide polarization. This is achieved by using two dissimilar metals. In the presence of an electrolyte, there is an electromotive voltage produced between the two metals. At approximately 800 mV, this is large enough potential to reduce the oxygen at the cathode. If lead and gold or lead and silver is used, the differential voltage is approximately 800 mV. Hence, a galvanic probe is essentially a self-polarizing amperometric cell, which means these sensors do not require a warm up period prior to collection a DO reading.

The following is a description of the Greenspan DO sensor based on information provided by the vendor and was not verified in this test. The Greenspan DO sensor is a two-part instrument. The first is the Galvanic DO cell and the second part is the patented Diffusion Rod. The rod is covered with a membrane that allows the transfer of oxygen into the rod. The oxygen then travels through the rod to a sensing cell positioned inside in the sensor body. This design removes the need for stirring, which means Greenspan DO sensors can be used in applications with low flow rates. The Dissolved Oxygen Sensor model DO300 tested in this evaluation is a complete, self-contained dissolved oxygen measurement and data-logging unit. The DO300 is a RS232 output sensor, which can measure dissolved oxygen as ppm or % saturation. Membrane housing can also be supplied as full copper for installations where high biofouling growth concerns exist.

The manufacturer's published performance specifications for the Greenspan DO sensors include: Range 0-20 ppm or 0-200% saturated, Accuracy +/- 2 % saturation (over range 0 – 50°C) or 0.3 ppm (over range of 5 – 35°C), and Response Time of 40 minutes to 90% of reading for a 10 ppm step change. More information can be found at [www.greenspan.com.au](http://www.greenspan.com.au).

## **APPLICATION - OBJECTIVES AND FOCUS OF PERFORMANCE VERIFICATION:**

The basic application and parameters evaluated were determined by surveying users of in situ DO sensors. The majority of survey respondents indicated that they typically deploy instruments on remote platforms in estuarine and near shore environments, and in relatively shallow water (< 10 meters depth). Therefore, this performance verification was focused on these applications. Accuracy, precision, instrument drift/calibration life, reliability, and operating life were found to be the most important parameters guiding instrument selection decisions. Protocols were therefore developed, with the aid of manufacturers, to evaluate these specific parameters excluding operating life, which is beyond the scope of this program.

#### **PARAMETERS EVALUATED:**

Definitions below were agreed upon with the manufacturer as part of the verification protocols.

**Accuracy** – Accuracy is the absolute value of a mean measured value minus the mean true value. Accuracy was determined in the laboratory at a fixed oxygen concentrations by the difference of the mean values from the instrument (I; n=3) from the mean of values determined by Winkler titration (W; n=3) on water samples in proximity to the sensor (accuracy =  $\Sigma W/n - \Sigma I/n$ ). Accuracy was determined on 36 different combinations of salinity, temperature and DO.

**Precision** – Precision is a measure of the repeatability of a measurement Instrument precision was determined by calculating the coefficient of variation (STD/Mean x 100) of 30 replicate DO measurements at a fixed dissolved oxygen concentration in the laboratory. Thus both accuracy and precision were determined in the laboratory only.

**Instrument Drift** – Instrument drift is a measure of the error through a month long deployment in the laboratory or the field. The error is the difference between a single instrument measurement and a single Winkler at a single point in time (I-W) is presented as plots of DO values over time. There was one laboratory drift study and seven field studies, representing the seven partner institution sites.

**Reliability** – Reliability is the ability to maintain integrity of the instrument and data collections over time. Reliability was determined in the laboratory and field by comparing percent of data recovered versus percent of data expected. Comments on the physical condition of the instruments (e.g., physical damage, flooding, corrosion, battery failure, etc.) were also recorded.

#### **TYPE OF EVALUATIONS - SUMMARY OF VERIFICATION PROTOCOLS:**

In conference with the participating instrument manufacturers it was determined that the verification protocols would have the following elements A) Winklers chemical titration for dissolved oxygen would serve as the reference standard for evaluating performance characteristics, B) performance would be evaluated across a range of water types in controlled laboratory conditions, C) long term, unattended performance would be evaluated across a range of environmental conditions, and D) performance of the DO sensor in the context of the vendors data acquisition package would be evaluated for instruments with and without manufacturer-designed biofouling prevention solutions.

Winkler titration methods used were based on WOCE protocols; although DO was quantified in mg/L not mol O<sub>2</sub>/kg. Water samples collected adjacent to the sensors were analyzed and compared to values collected and reported by test instruments. All laboratory tests were conducted at the NOAA Great Lake Environmental Research Laboratory (in conjunction with the ACT Partner, Cooperative Institute for Limnology & Ecosystems Research) in specially designed water baths that allow the control of temperature, salinity and DO level (by bubbling different oxygen and nitrogen gas mixtures). Field tests were conducted by all seven ACT Partner Institutes at a fixed depth of 1 m from secure deployment sites representing a range of environmental conditions (see Table 2), representative of the range of coastal environments in North America. Field sites included the Chesapeake Biological Laboratory (Solomons, Maryland), French Landing Dam (Belleville Lake, Michigan, CILER/University of Michigan), Darling Marine Center (Walpole, Maine, GoMOOS/University of Maine), Moss Landing Harbor (Moss Landing, California, MLML), western shore of Skidaway Island (Skidaway, Georgia, SkIO), Kaneohe Bay Barrier Reef (Kaneohe Bay, Hawaii, University of Hawaii), and Bayboro Harbor (Tampa Bay, Florida, University of South Florida).

Instruments tested, both in the laboratory and in the field, were incorporated in a stand-alone package, which included data logging and independent power provided by the manufacturer. It is important to note that the data presented here was not corrected for the salinity at which readings were taken. A total of eight sensors were evaluated, four with the manufacturer's biofouling prevention system and four without. Greenspan provides copper sensor frames and covers to prevent or reduce biofouling. Two individual sensors (one with a biofouling prevention and one without) were randomly selected for the initial laboratory exercise. One pair of instruments each was then sent out to four of the ACT Partner Institution test sites for four-week field deployments. All instruments were reconditioned and recalibrated by the manufacturer prior to the second set of deployments at the remaining ACT Partner test sites.

Prior to deployment, instruments were calibrated at the field sites (according to manufactures specified calibration protocols) and programmed to record dissolved oxygen data every 15 minutes. Instruments were placed in a water bath and allowed to record three data points with three corresponding Winkler titration values as a baseline reference before placement in the field. This same baseline reference procedure was repeated immediately after the instruments were recovered following the four-week deployment.

Water samples for Winkler titrations were collected (at the same depth and as close as possible to the sensor heads) at least twice a day, Mondays through Fridays during the four-week field test at the time instruments were programmed to sample. In conjunction with each water sample collection, site-specific conditions were also noted (e.g., date, time, barometric pressure, weather conditions, natural or anthropogenic disturbances, and tidal state).

**Quality Assurance/Quality Control** – This performance verification was implemented according to the test/QA plans and technical documents prepared during planning of the verification test. Prescribed procedures and a sequence for the work were defined during the planning stages, and work performed followed those procedures and sequence. Technical procedures included methods to assure proper handling and care of test instruments, samples, and data. Performance evaluation, technical system, and data quality audits were performed by QA personnel independent of direct responsibility for the verification test. All implementation activities were documented and are traceable to the test/QA plan and to test personnel.

The following is a short summary of QA findings and complete reports are available upon request. The main component to the QA plan included technical systems audits (TSA), conducted by ACT Quality Assurance Specialists at four of the ACT Partner test sites selected at random (Moss Landing Harbor, MLML; Darling Marine Center, GoMOOS; Solomons MD, CBL; Bayboro Harbor, USF). These audits were designed to ensure that the verification test was performed in accordance with the test protocols and the ACT *Quality Assurance Guidelines*. (e.g., reviews of sample collection, analysis and other test procedures to those specified in the test protocols, and data acquisition and handling). During the verification tests, only two deviations from the test protocols were necessary. One involved re-securing test instruments to the field deployment frame and the second involved a set of corrupted samples due to bubbles forming on the tops of the BOD bottles during transport back to the laboratory. Appropriate corrective action was taken (including discarding compromised samples and collecting new ones) and the deviations had no impact on the results of the test.

Finally, in addition to uniform training prior to the tests and employing the identical method for sampling, Winkler titrations, data recording, etc., each site also conducted a Winkler titration precision evaluation of its particular personnel, reagents, and equipment. The precision as a percentage (expressed as coefficient of variation  $STD/Mean \times 100$ ) of each ACT Partner Institution for the Winkler titration analysis (using air saturated bathwater varying in salinity and temperature) is shown below in Table 1.

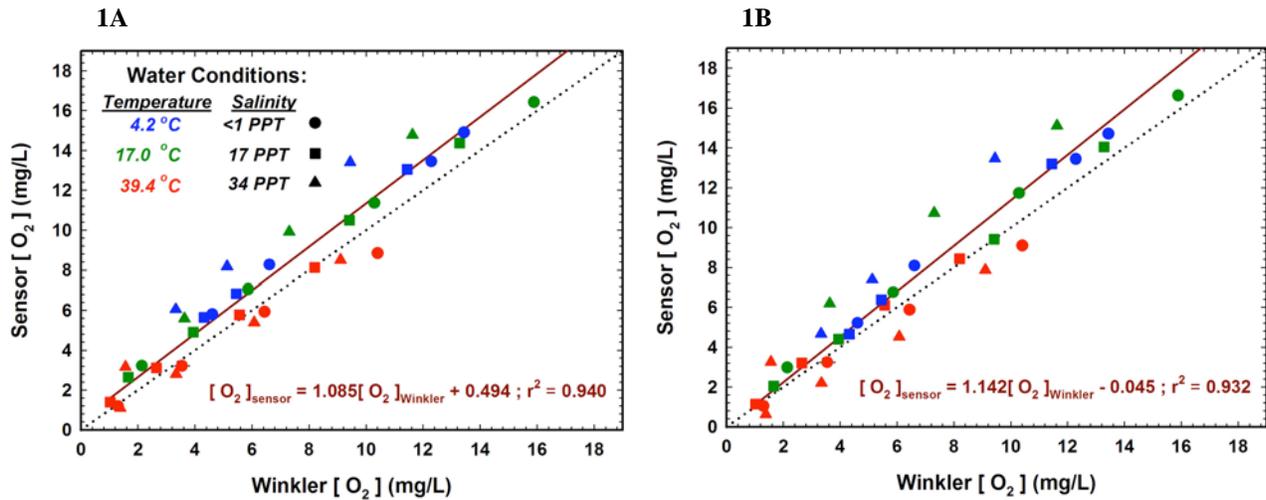
<b>ACT Partner Institution</b>	<b>Precision</b>
Chesapeake Biological Laboratory	0.21 %
CILER/University of Michigan	0.22 %
GoMOOS/University of Maine	0.11 %
Moss Landing Marine Laboratories	0.20 %
Skidaway Institute of Oceanography	0.40 %
University of Hawaii	0.08 %
University of South Florida	0.29 %

**SUMMARY OF VERIFICATION RESULTS, LABORATORY TESTS:** *(data has not been salinity corrected)*

**Laboratory Accuracy** – Table 2 below presents the mean, standard deviation (STD), and accuracy (Accur) of three replicate DO values in mg/L recorded by two test instruments (one with and one without the Clean Sweep biofouling prevention system, BPS) and the corresponding mean and standard deviation of DO (mg/L) generated by Winkler titrations of three replicate water samples. Instruments were programmed to record DO values every 2 minutes and the mean and STD were calculated from three consecutive values as the reference water samples were collected. The replicate instrument readings and samples were taken under 36 distinct water conditions that varied in temperature, salinity, and DO. The greater absolute accuracy value the less accurate the measurement.

Temp (°C)	Sal (ppt)	Winkler DO		Greenspan DO w/out BPS			Greenspan DO with BPS		
		Mean	STD	Mean	STD	Accur	Mean	STD	Accur
17.0	0.0	15.89	0.02	16.42	0.00	0.53	16.63	0.08	0.74
17.0	0.0	10.30	0.03	11.36	0.02	1.06	11.73	0.02	1.43
17.0	0.0	5.86	0.04	7.04	0.02	1.18	6.75	0.01	0.88
17.0	0.0	2.14	0.04	3.22	0.01	1.08	2.98	0.03	0.84
17.0	16.8	1.66	0.00	2.65	0.01	0.99	2.04	0.00	0.38
17.0	16.8	3.94	0.01	4.90	0.01	0.96	4.40	0.02	0.46
17.0	16.9	9.42	0.04	10.50	0.01	1.08	9.42	0.04	0.00
17.0	16.9	13.28	0.06	14.38	0.03	1.10	14.05	0.07	0.77
17.0	34.0	11.62	0.06	14.79	0.03	3.16	15.12	0.01	3.49
17.0	34.0	7.30	0.02	9.91	0.01	2.61	10.73	0.06	3.42
17.0	34.0	3.63	0.03	5.59	0.01	1.95	6.19	0.05	2.56
17.0	34.0	1.56	0.01	3.16	0.02	1.60	3.26	0.05	1.70
39.4	0.3	10.41	0.05	8.83	0.01	- 1.57	9.09	0.01	- 1.31
39.4	0.3	6.44	0.04	5.92	0.03	- 0.52	5.87	0.00	- 0.57
39.4	0.3	3.55	0.28	3.21	0.00	- 0.34	3.24	0.03	- 0.31
39.4	0.3	1.31	0.01	1.19	0.00	- 0.12	1.03	0.02	- 0.27
39.4	17.0	1.38	0.04	1.09	0.01	- 0.29	0.63	0.01	- 0.75
39.4	17.0	3.34	0.04	2.80	0.01	- 0.54	2.19	0.01	- 1.15
39.4	17.0	6.08	0.05	5.39	0.02	- 0.68	4.52	0.02	- 1.56
39.4	17.0	9.10	0.04	8.51	0.01	- 0.59	7.87	0.05	- 1.23
39.4	33.9	8.20	0.02	8.12	0.02	- 0.08	8.43	0.01	0.23
39.4	33.9	5.56	0.09	5.77	0.01	0.21	6.09	0.03	0.53
39.4	33.8	2.65	0.10	3.12	0.01	0.47	3.21	0.03	0.56
39.4	33.9	1.03	0.03	1.39	0.01	0.37	1.15	0.01	0.12
4.2	0.3	13.44	0.09	14.90	0.06	1.46	14.71	0.05	1.28
4.2	0.3	12.29	0.05	13.45	0.00	1.16	13.44	0.01	1.15
4.2	0.3	6.62	0.04	8.26	0.02	1.65	8.09	0.04	1.48
4.2	0.3	4.61	0.01	5.80	0.00	1.19	5.22	0.01	0.61
4.2	16.9	4.32	0.01	5.65	0.01	1.33	4.65	0.04	0.33
4.2	16.9	5.45	0.04	6.83	0.00	1.38	6.37	0.01	0.93
4.2	16.9	11.44	0.06	13.04	0.01	1.60	13.20	0.02	1.76
4.2	16.9	17.50	0.17	19.82	0.04	2.33	20.56	0.06	3.07
4.2	34.1	16.03	0.05	20.13	0.01	4.10	21.48	0.00	5.45
4.2	34.1	9.44	0.05	13.41	0.05	3.97	13.47	0.04	4.03
4.2	34.1	5.13	0.10	8.18	0.03	3.05	7.39	0.03	2.26
4.2	34.1	3.33	0.02	6.05	0.03	2.72	4.67	0.02	1.34

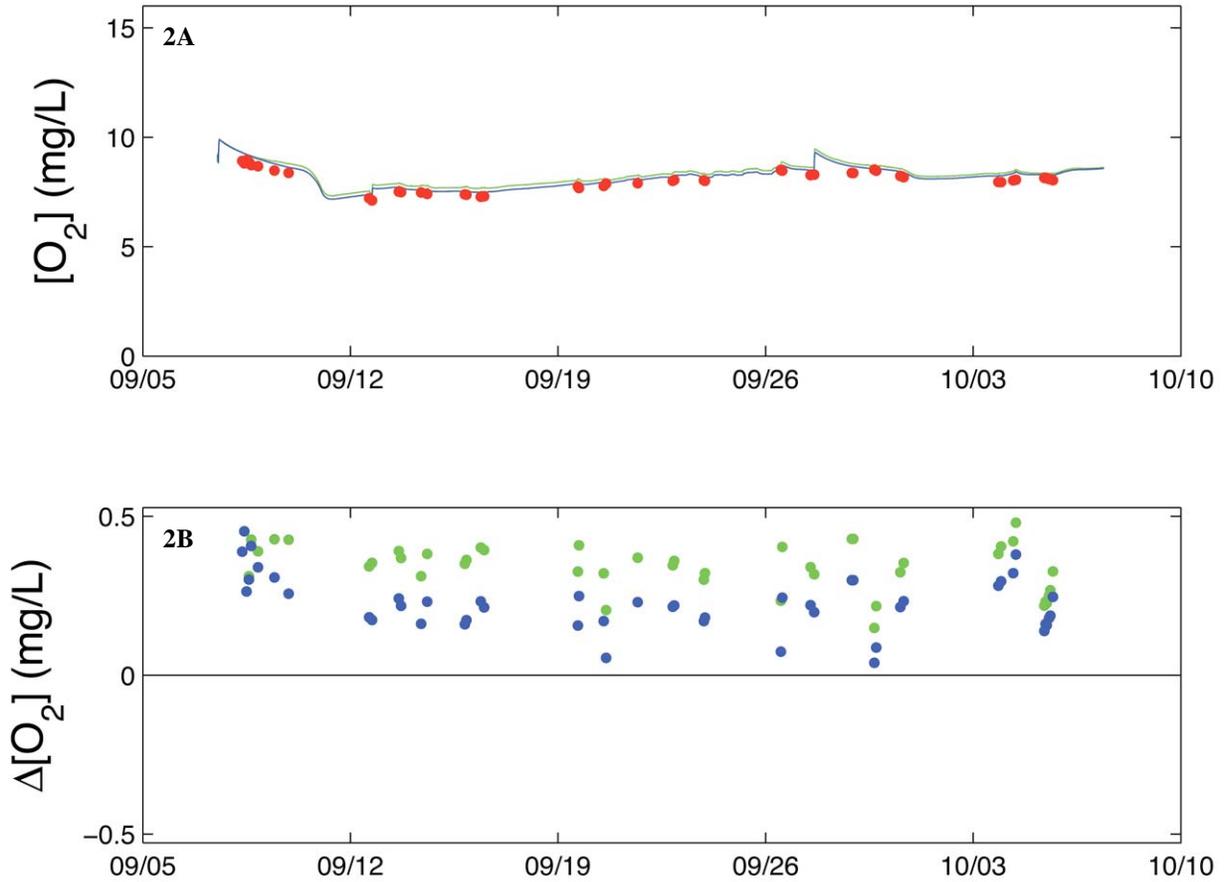
Figures 1A (without Biofouling Prevention System, BPS) and 1B (with BPS) below are plots of the mean of three replicate DO values recorded by the test instrument versus the corresponding mean DO generated by Winkler titrations of three replicate water samples (complete data including standard deviations are presented in Table 2). The dotted line represents a 1:1 relationship.



**Laboratory Precision** – The precision test was conducted in a well-mixed freshwater bath (0.0 ppt) held at 17.2 °C that was continuously aerated (i.e., air saturated). The mean, standard deviation (STD), and coefficient of variance (% CV = STD/Mean x 100) for DO values (mg/L) generated from 30 replicate Winkler titrations of water samples collected from the bath and 30 replicate instrument values taken simultaneously, are listed below in Table 3.

Winkler DO			Greenspan DO - w/out BPS			Greenspan DO - with BPS		
Mean	STD	CV	Mean	STD	CV	Mean	STD	CV
8.97	0.02	0.22 %	9.74	0.02	0.15 %	9.75	0.02	0.18 %

**Laboratory Instrument Drift** – Figure 2A displays the DO values (mg/L) collected by an instrument without the biofouling system (green line) and a second instrument with the biofouling prevention system (blue line) through time with the corresponding Winkler titration DO (red circles,  $n = 3$ , standard deviation are smaller than the thickness of the symbols used in graphs). Figure 2B displays the drift (Instrument value – Winkler mean) of DO (mg/L) recorded by an instrument without the biofouling prevention system (green circles) and with the biofouling prevention system (blue circles).



Sensor without the biofouling prevention system after four-week laboratory deployment.



Sensor with the biofouling prevention system after four-week laboratory deployment.

**Laboratory Reliability** – The Greenspan DO sensors were programmed to collect and record DO values every 15 minutes during the four-week laboratory, freshwater bath deployment. All expected data points were successfully downloaded from both instruments and are plotted above. There were no obvious instrument malfunctions.

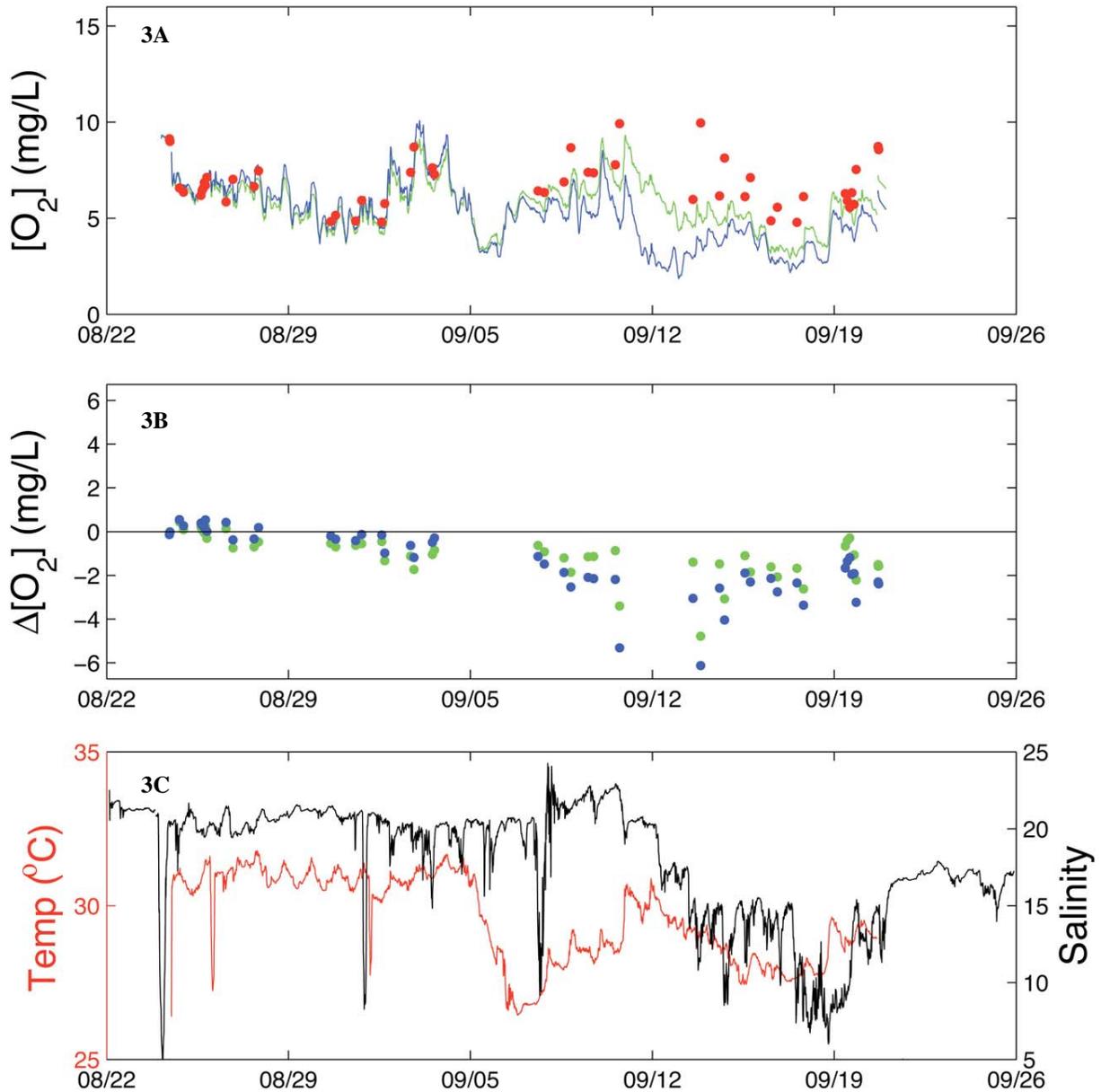
**SUMMARY OF VERIFICATION RESULTS, FIELD TESTS:** *(data has not been salinity corrected)*

Table 2. lists the basic test site descriptions and field conditions during testing.

<b>ACT Partner Test Site</b>	<b>Basic Characterization</b>	<b>Range in Water Temperature (°C)</b>	<b>Range in Salinity (ppt)</b>
Bayboro Harbor, FL	An estuary in the southwestern region of Tampa Bay	26.4 – 31.8	4.4 – 24.2
Belleville Lake, MI	A freshwater impoundment on the Huron River	22.5 – 27.1	0.0 – 0.1
Kaneohe Bay Reef, HI	A high energy barrier coral barrier reef	25.1 – 28.7	34.4 – 34.9
Moss Landing, CA	An estuarine tributary of the Salinas River in Monterey Bay	14.0 – 17.3	30.9 – 33.5
Skidaway Island, GA	A subtropical estuary on the Skidaway River on the western shore of Skidaway Island	23.8 – 29.8	18.4 – 30.9
Solomons, MD	An estuary at the mouth of the Patuxent River in the Chesapeake Bay	24.3 – 28.1	9.8 – 12.0
Walpole, ME	A tide dominated embayment/ Damariscotta River estuary	13.1 – 18.7	29.6 – 31.2

**Field Instrument Drift** – Figures 3A, 4A, 5A, 6A, 7A, 8A, and 9A on the following pages display the DO values (mg/L) collected by an instrument without the biofouling prevention system (green line) and a second instrument with the biofouling prevention system (blue line) through time (month/day on x axis) with the corresponding Winkler titration DO mean (red circles, n = 3, standard deviation is plotted although values are smaller than symbols used in graphs) taken periodically during the four-week field deployments. Figure 3B, 4B, 5B, 6B, 7B, 8B, and 9B display the drift (Instrument value – Winkler mean) of DO (mg/L) recorded by an instrument without (green circles) and with the biofouling prevention system (blue circles). Figure 3C, 4C, 5C, 6C, 7C, 8C, and 9C shows the corresponding temperature and salinity at field site during deployments.

Figures 3A and 3B. Instrument drift at Bayboro Harbor, FL, 3C (USF).

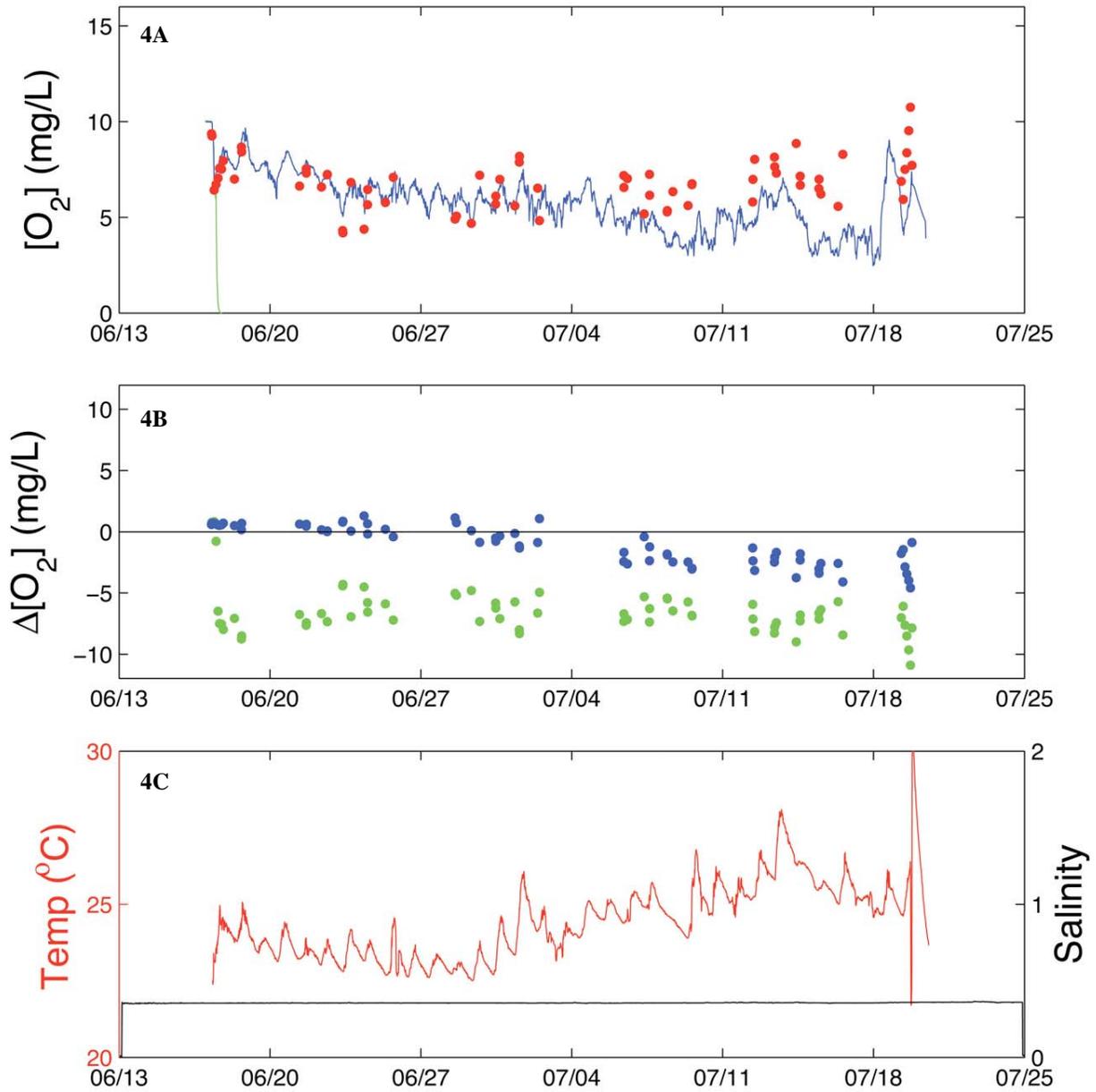


Sensor without the biofouling prevention system after four-week field deployment.



Sensor with the biofouling prevention system after four-week field deployment.

Figures 4A and 4B. Instrument drift at Belleville Lake, MI, 4C (CILER/University of Michigan).

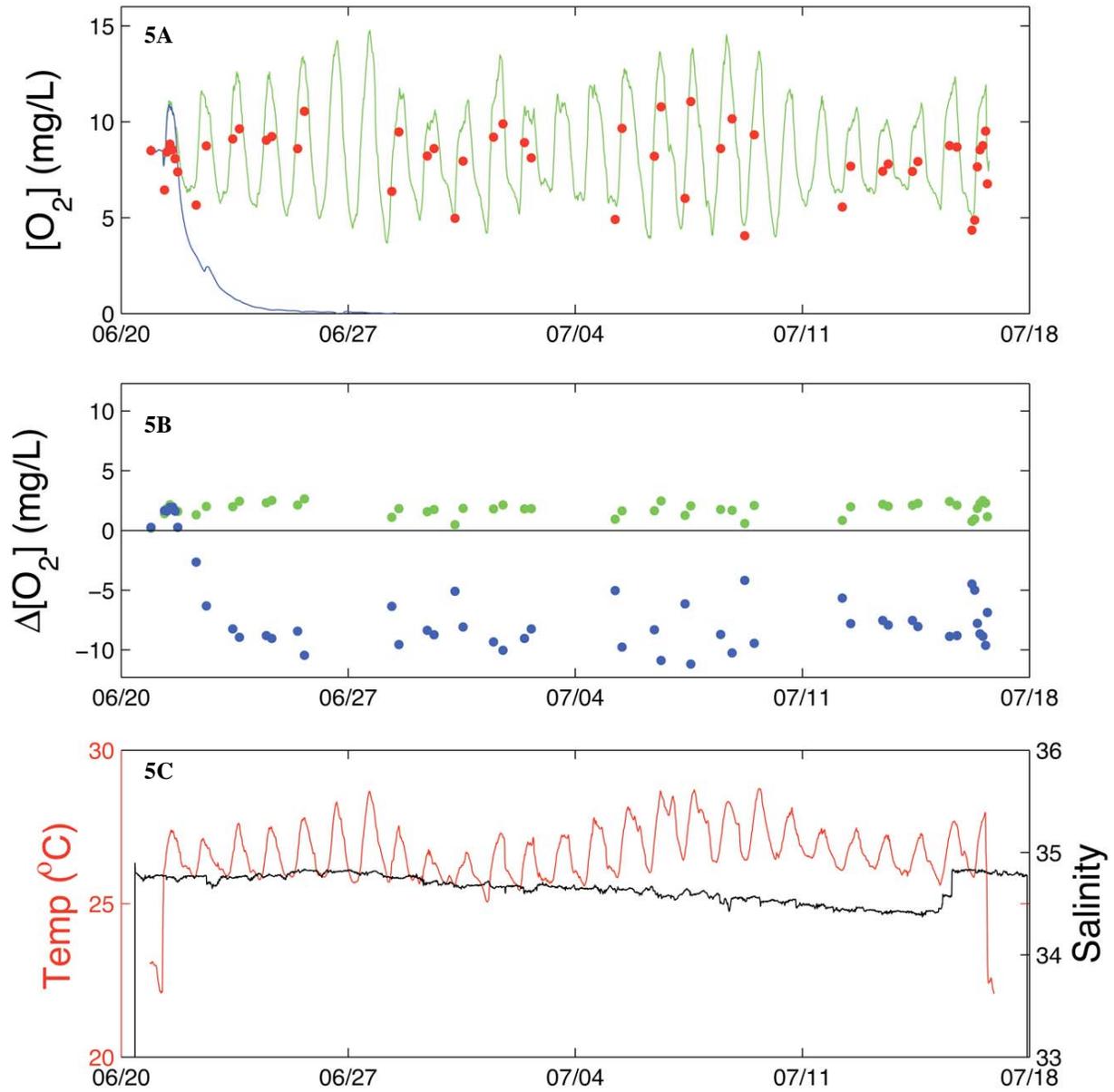


Sensor without the biofouling prevention system after four-week field deployment.



Sensor with the biofouling prevention system after four-week field deployment.

Figures 5A and 5B. Instrument drift at Kaneohe Bay Reef, HI, 5C (University of Hawaii).

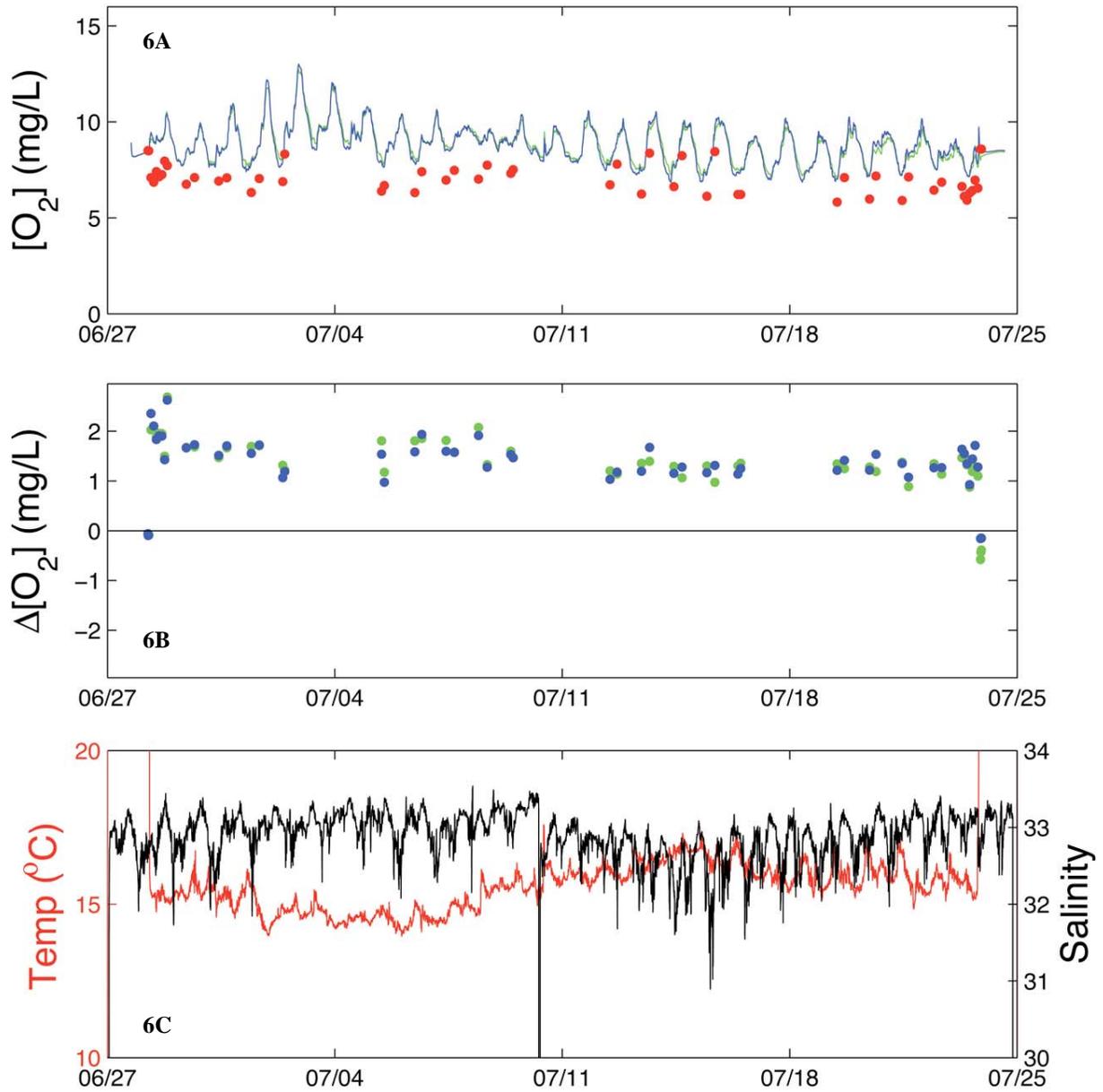


Sensor without the biofouling prevention system after four-week field deployment.



Sensor with the biofouling prevention system after four-week field deployment.

Figures 6A and 6B. Instrument drift at Moss Landing, CA, 6C (MLML).

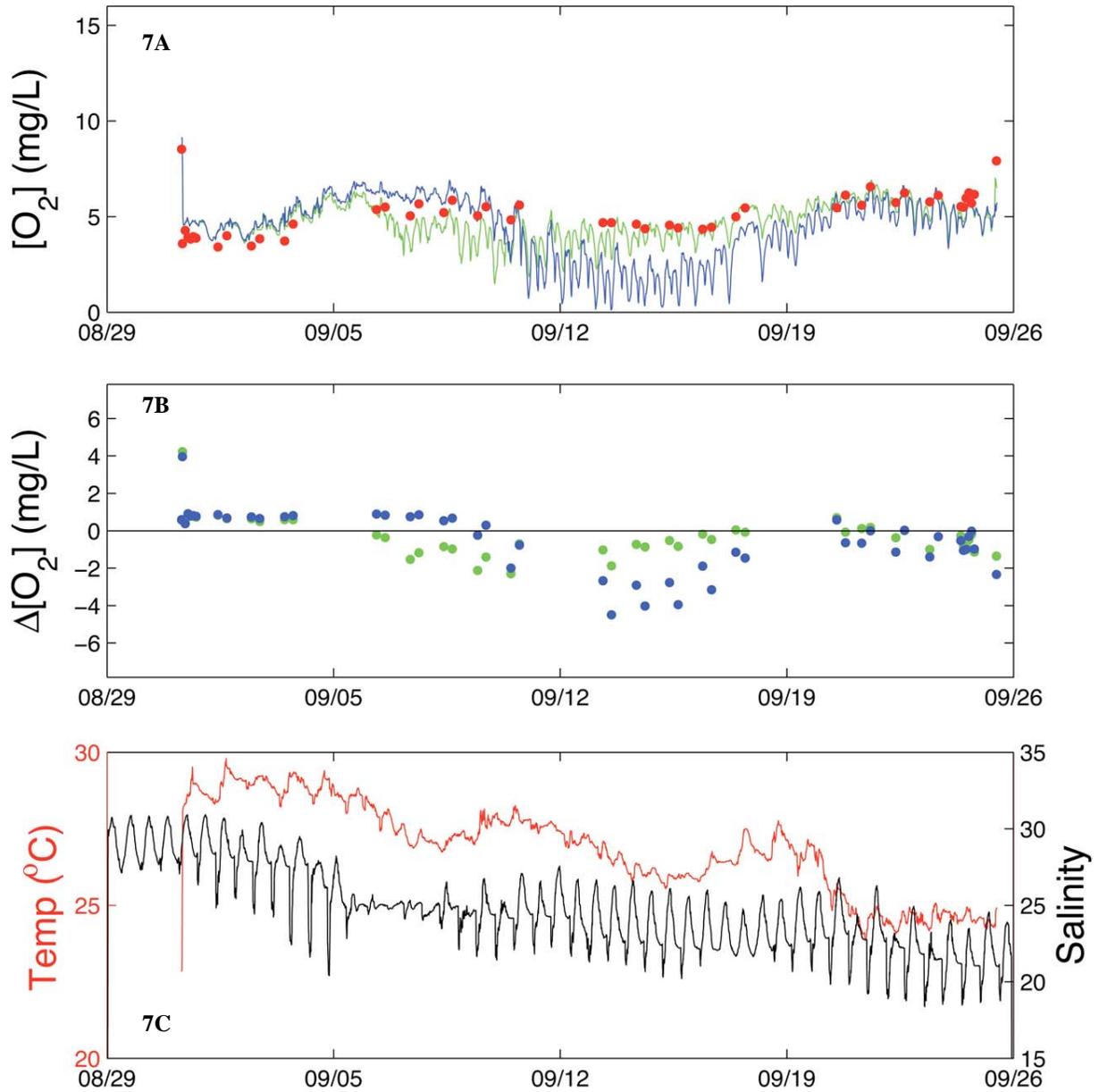


Sensor without the biofouling prevention system after four-week field deployment.



Sensor with the biofouling prevention system after four-week field deployment.

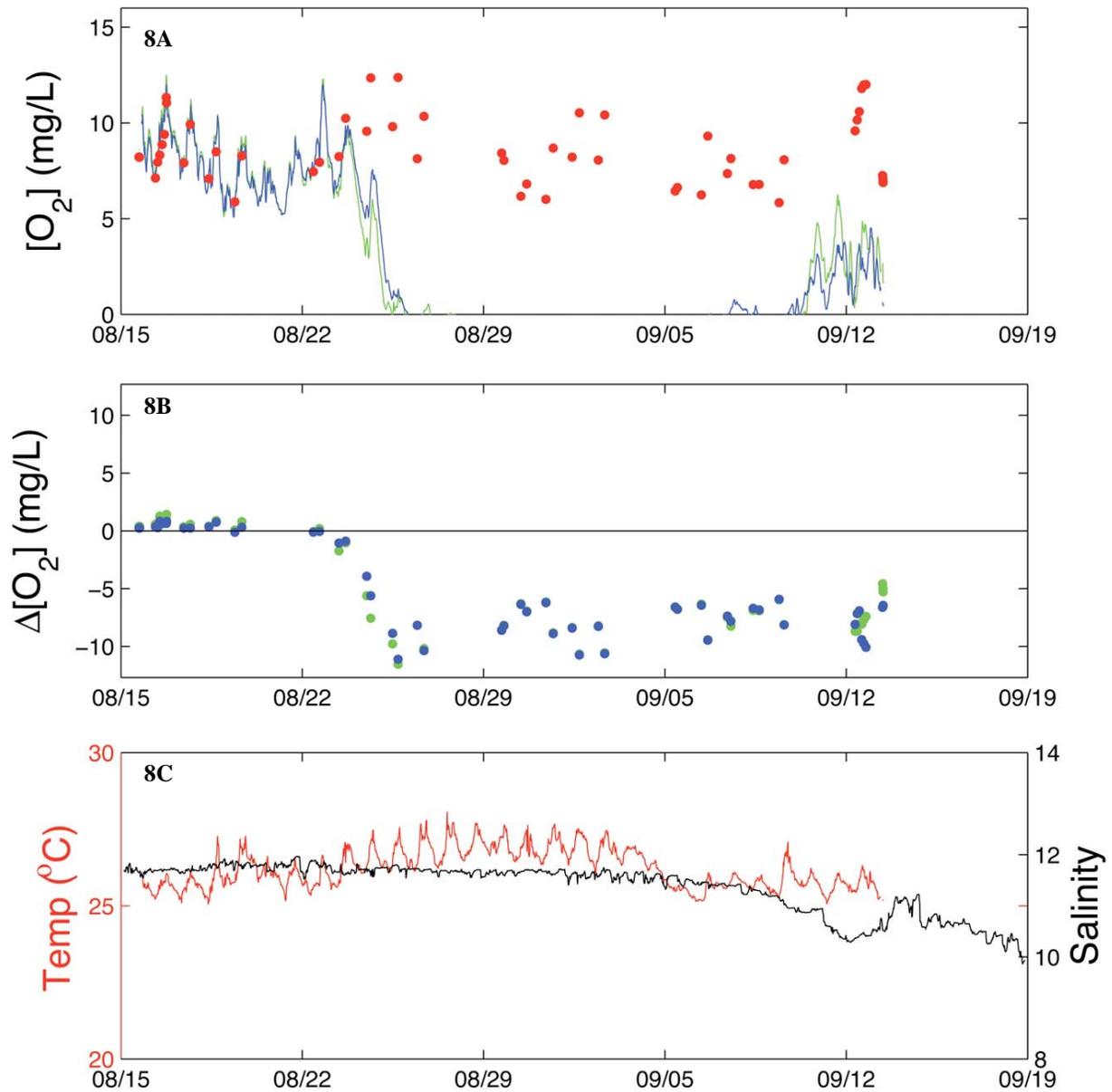
Figures 7A and 7B. Instrument drift at Skidaway Island, GA, 7C (SkIO).



Sensor without the biofouling prevention system (on bottom) and sensor with the biofouling prevention system (on top) after the four-week field deployment,



Figures 8A and 8B. Instrument drift at Solomons, MD, 8C (CBL).

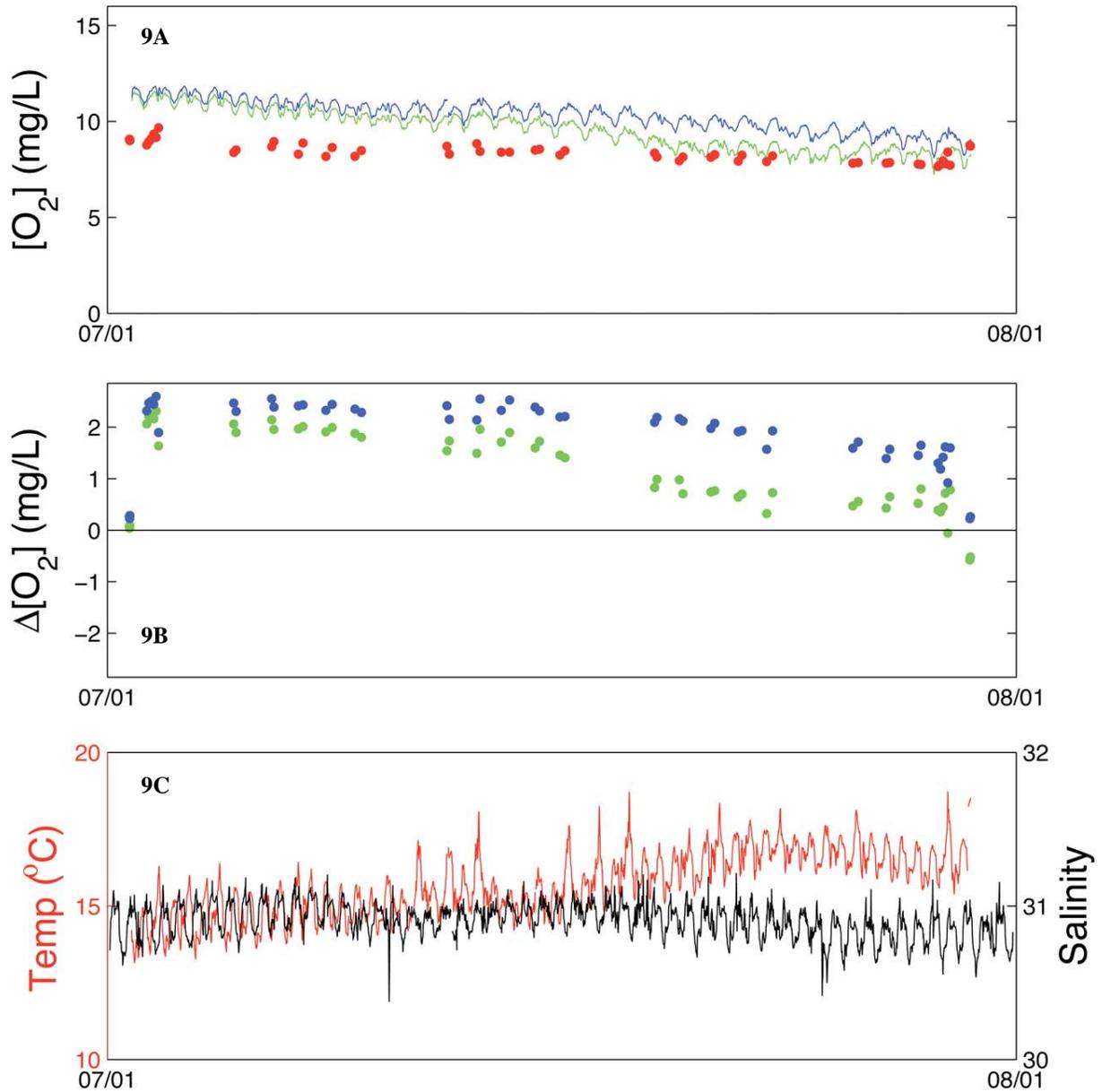


Sensor without the biofouling prevention system after four-week field deployment.



Sensor with the biofouling prevention system after four-week field deployment.

Figures 9A and 9B. Instrument drift at Walpole, ME, 9C (GoMOOS/University of Maine).



Sensor without the biofouling prevention system after four-week field deployment.



Sensor with the biofouling prevention system after four-week field deployment.

Table 3. lists the mean instrument drift in measured DO values (mg/L) from Winkler means per week of field deployment. The smaller the absolute number, the less drift.

ACT Partner Test Site	Greenspan DO - w/out BPS				Greenspan DO - with BPS			
	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4
Bayboro Harbor, FL	- 0.14	- 0.96	- 1.74	- 1.53	0.10	- 0.53	- 2.79	- 2.34
Belleville Lake, MI	0.50	0.09	- 1.20	- 2.38	- 5.26	- 5.95	- 6.70	- 6.97
Kaneohe Bay Reef, HI	1.88	1.61	1.60	1.84	- 3.58	- 8.29	- 8.39	- 7.57
Moss Landing, CA	1.46	1.65	1.24	0.95	1.45	1.54	1.24	1.10
Skidaway Island, GA	0.77	- 1.40	- 0.30	- 0.50	0.96	- 0.71	- 2.14	- 0.75
Solomons, MD	0.65	- 6.96	- 8.01	- 7.74	0.36	- 6.26	- 8.06	- 7.69
Walpole, ME	1.69	1.73	0.92	0.49	2.02	2.35	2.09	1.49

**Field Reliability** – The Greenspan sensors were programmed to collect and record DO values every 15 minutes during the four-week field deployments at each of the ACT test sites. As shown in the plots above, 2 individual instruments (one in Michigan and one in Hawaii) did not collect any reliable field data. This appears to be a result of instrument flooding and malfunction.



**Greenspan Comments on ACT Verification Statement**

**November 18, 2004**

Our reading of the data in the report is that given the sensors were deployed in high salinity conditions, they recorded reading high due to absence of salinity correction. Fouling also had an effect on the readings over time.

The units are a membrane type sensor and as such measure the partial pressure of oxygen. Assuming the system is in equilibrium and ignoring changes in atmospheric pressure this can be reported as % Saturation. Greenspan DO300 sensors that output results in ppm make no correction for salinity in the conversion of % Sat to ppm. To correct for salinity results must be post processed.

Below is an example of correcting the last four readings of the lab results on page 5 of the report. For full details on these formulas and complete steps on compensations, see *Standard Methods for Evaluation of Water and Wastewater*.

Convert salinity to chlorinity (From standard methods)

$$\text{chl}(\text{sal}) := \frac{\text{sal}}{1.80655}$$

Correct for salinity by multiplying the output of the sensor by the ratio of the solubility of oxygen in water with the actual salinity, to the solubility of oxygen in water with salinity 0.

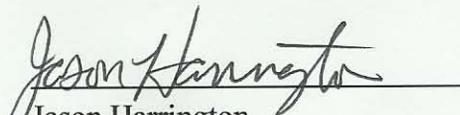
$$\text{greenCors1}_i := \frac{\text{stdmDoSolChl}\{\text{temp}_i + 273.15, \text{chl}\{\text{salinity}_i\}\}}{\text{stdmDoSolChl}\{\text{temp}_i + 273.15, 0\}} \cdot \text{greens1}_i$$

$$\text{greenCors2}_i := \frac{\text{stdmDoSolChl}\{\text{temp}_i + 273.15, \text{chl}\{\text{salinity}_i\}\}}{\text{stdmDoSolChl}\{\text{temp}_i + 273.15, 0\}} \cdot \text{greens2}_i$$

Looking at the last four data sets of the lab results on page 5 the corrected values for the Greenspan Sensors would be as follows:

Temp	Salinity	Winkler	Greenspan w/o BPS <b>Green 1 Corrected</b>	Greenspan w/BPS <b>Green 2 Corrected</b>
4.2	34.1	16.03	<b>16.00</b>	<b>17.07</b>
4.2	34.1	9.44	<b>10.66</b>	<b>10.70</b>
4.2	34.1	5.13	<b>6.50</b>	<b>5.87</b>
4.2	34.1	3.33	<b>4.81</b>	<b>3.71</b>

Every monitoring event is site specific and requires a scheduled maintenance based in part on fouling. In addition to salinity, the sensors are effected by fouling and response time, which made the sensors drift low to a greater or lesser degree throughout the life of the test. We confirm that two sensors had damage to the diffusion rods that caused zero readings. This damage is not likely to have been caused by anyone administering the test.

  
Jason Harrington  
Greenspan Analytical