ORCAWALE 2008 McArthur II CTD PROCESSING

ORCAWALE 2008 CTD data files were collected using a Sea-Bird 911*plus* profiling instrument aboard the NOAA Ship McArthur II (MACII). The 911*plus* consists of the 9*plus* underwater CTD and 11*plus* V2 Deck Unit, which has high resolution sampling (24Hz) and pump-controlled conductivity and temperature flow-through sensors. Data were collected using Sea-Bird's SeaSave Win32 Version 7.14c and have been processed using Sea-Bird's SBE Data Processing v. 7.26.7. More information regarding the SBE software and recommended data processing procedures can be found online at www.seabird.com.

Each CTD directory on the data server contains two folders named Raw and Data. CTD set-up information, pressure test results, and data collected at sea are stored in the Raw folder. All information and files used in processing are saved in the Data folder, including documentation, configuration files, calibration sheets, intermediate processing steps and final data.

Sensor use on the MACII CTD during the ORCAWALE 2008 cruise went through several changes at the beginning of Leg 5 when spiking was noted in the dissolved oxygen (DO) data. The table below describes the period for which each sensor was used. Voltage sensors, such as dissolved oxygen, can be assigned to one of eight analog/digital channels; if problems with the sensor are observed, the sensor may be assigned to a new channel. Consequently, the channel for the oxygen sensor is included in the table below. The temperature and conductivity sensors, both primary and secondary, did not change during the cruise. The owners of the sensors were responsible for their maintenance.

	Casts	Temp 1, 2	Cond 1, 2	DO, channel	Pressure
Leg 1	001-021	*T4667*, T4803	*C3201*, C3353	O1294, 0	*P0405*
Leg 2	022-034	*T4667*, T4803	*C3201*, C3353	O1294, 0	*P0405*
Leg 3	035-054	*T4667*, T4803	*C3201*, C3353	O1294, 0	*P0405*
Leg 4	055-069	*T4667*, T4803	*C3201*, C3353	O1294, 0	*P0405*
Leg 5	070-071	*T4667*, T4803	*C3201*, C3353	O1294, 0	*P0405*
Leg 5	072	*T4667*, T4803	*C3201*, C3353	O1295, 2	*P0405*
Leg 5	073	*T4667*, T4803	*C3201*, C3353	O1294, 0	*P0405*
Leg 5	074	*T4677*, T4803	*C3201*, C3353	O1294, 2	*P0405*
Leg 5	075	*T4667*, T4803	*C3201*, C3353	O1295, 2	*P0405*
Leg 5	076-086	*T4667*, T4803	*C3201*, C3353	O1295, 2	*P3001*

PMC-owned, MMTD-owned

ORCAWALE 2008 MACII CTD SENSOR CALIBRATION

SWFSC MMTD uses Sea-Bird Electronics conductivity, temperature, oxygen, and pressure sensors. Sea-Bird Electronics conductivity sensors drift with usage and time, while temperature and pressure sensors drift primarily over time. Annual calibrations of the conductivity and temperature sensors are necessary to estimate and correct for this drift during data processing.

Pre and post-cruise calibration certificates for the sensors used during ORCAWALE 2008 are in the \CON_Files\Calibrations folder.

Conductivity, temperature, and pressure are computed as polynomial functions of the sensor frequencies stored in the raw data file. We follow Sea-Bird recommended procedures for adjusting calibration coefficients for drift between calibrations (Sea-Bird App. Note # 31). Details can be found in the internal document "CTD Calibration Adjustments MMTD.pdf".

The Excel spreadsheet, CTDcalibrations ORCAWALE 2008 MACII.xls, in the \Documentation folder, contains the pre- and post-cruise calibration information for the conductivity, temperature, pressure, and dissolved oxygen sensors. It then derives slope or offset values used to correct the calibration coefficients used in the Data Conversion and Derive modules of Sea-Bird's SBE Data Processing software. The adjusted configuration files used to process the ORCAWALE 2008 MACII data (Appendix 1) are in the \CON_Files folder.

Conductivity Sensor Correction:

The SBE 4C series conductivity sensor has a measurement range of 0.0 to 7.0 Siemens/meter (S/m), which spans the conductivity range of SWFSC MMTD's study areas. The SBE 4C sensor is rated to have an initial accuracy of 0.0003 S/m; with a resolution (at 24Hz) of 0.00004 S/m.

The primary conductivity sensor, C3201, was calibrated on 8 January 2008 and 23 December 2008. The iSlope values at the end of the cruise was greater than 0.00015 less than 1; consequently, the average iSlope value was used for correction. Pre-cruise calibration coefficients were used to process the data with a slope adjustment of 0.99970.

The secondary conductivity sensor, C3353, was calibrated on 22 February 2008 and 8 January 2009. The iSlope values at the end of the cruise was greater than 0.00015 less than 1; consequently, the average iSlope value was used for correction. Pre-cruise calibration coefficients were used to process the data with a slope adjustment of 1.00035.

Temperature Sensor Correction:

The SBE 3*plus* series temperature sensor has a measurement range of -5.0 to 35 °C, which spans the range of temperatures in SWFSC MMTD's study areas. The SBE 3*plus* sensor is rated to have an initial accuracy of ± 0.001 °C and a resolution (at 24 samples per second) of 0.0003 °C.

The primary temperature sensor, T4667, was calibrated on 8 January 2008 and 20 December 2008. The iOffset at the end of the cruise was greater than 2mdeg C; consequently, the average of the iOffsets for the start and end of the cruise, +0.0019 °C, was used in processing.

The secondary temperature sensor, T4803, was calibrated on 12 February 2008 and 8 January 2009. The iOffset at the end of the cruise was greater than 2mdeg C; consequently, the average of the iOffsets from the start and end of the cruise, -0.0016°C, was used in processing.

Pressure Sensor Correction:

The SBE Paroscientific Digiquartz pressure sensor is rated to have an initial accuracy of 1.02m (i.e., 0.015% of the full scale range, which is 0 – 6800m). We do not exceed a maximum vertical depth of 1100m. Initial resolution (at 24Hz) is 0.068m (i.e., 0.001% of the full scale range).

Six deck tests were conducted on the CTD pressure sensor P0405, which was used during Legs 1-4 and at the start of leg 5, resulting in offsets of -0.7241, -0.6124, -0.6149, -0.5387, -0.5422 and -0.6526 db; these results were consistent with Sea-Bird calibrations from 29 January 2008 and 8 January 2009 (average iOffset=-0.831). Therefore, the average deck test offset of -0.614 was used in the *.con file.

Only one deck test was conducted on the CTD pressure sensor P3001, which was used during Leg 5, resulting in an offset of +10.9676; this result was consistent with Sea-Bird calibrations from 11 February 2008 and 7 January 2009 (average iOffset=10.626). Therefore, the average of the iOffset and the offset obtained from the single deck test, +10.797, was used in the *.con file.

Oxygen Sensor Correction:

The SBE 43 oxygen sensor has a measurement range of 0 to 120% of surface saturation (approximately 200 µmol/Kg). The SBE 43 sensor is rated to have an initial accuracy of 2% of surface saturation (approximately 4 µmol/Kg).

The sensor outputs a voltage that is linearly related to dissolved oxygen concentration by a slope (Soc) and offset (Voffset). The sensor is expected to drift over time due to a decrease in sensitivity. Drift is expected to occur only at sea because the sensor membrane is sealed against exposure to air between cruises. Sea-Bird recommends a simple interpolation based on usage time between the pre- and post-cruise calibration values of Soc. On the advice of Dave Griffiths (SWFSC Fisheries Resources Division), both Soc and Voffset are normally interpolated.

The dissolved oxygen sensor O1294, was calibrated on 21 March 2008 and 5 January 2009. The iSoc values changed by more than 4% between the start and end of the cruise, therefore separate iSoc and iVoffset values were used for each leg in the *.con file.

The dissolved oxygen sensor used at the end of Leg 5, O1295, was calibrated on 22 February 2008 and 5 January 2009. Sea-Bird recommends a simple interpolation based on usage time between the pre- and post-cruise calibration values of Soc. The iSoc values changed by less than 4% but more than 2% between the start and end of the cruise, therefore the average iSoc and iVoffset values were used in the *.con file.

Comparison of the Primary and Secondary Sensors

Differences between primary and secondary sensors by cast are summarized in Figure 1. Fortran program COMPSENS.EXE (programmer: Paul Fiedler) calculates the mean difference between the primary and secondary sensors for each profile. The output file, compsens08m.dat, is in the \Documentation folder. Figure 1 shows that the temperature and conductivity values measured by and salinity values derived from the primary and secondary sensors did not differ by more than the desired accuracy of the sensors, except for conductivity and salinity during Leg 1. Bottle salinity analyses (Appendix 2) indicate that the primary sensors were more accurate than the secondary sensors and should be used in the final CTD data file.

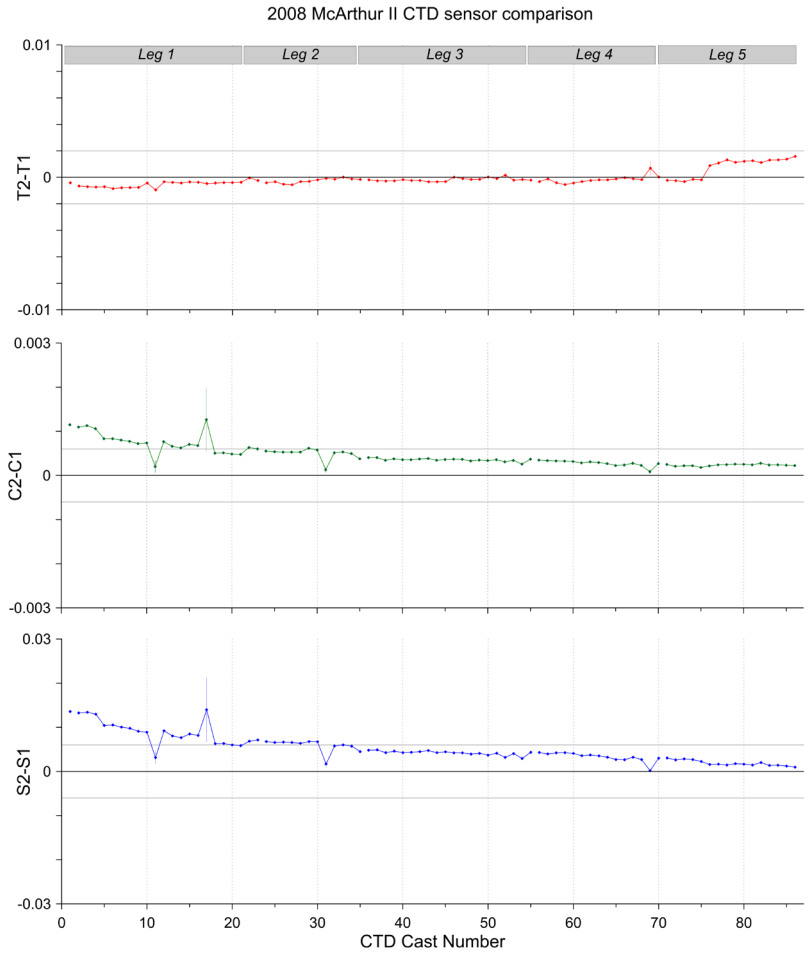


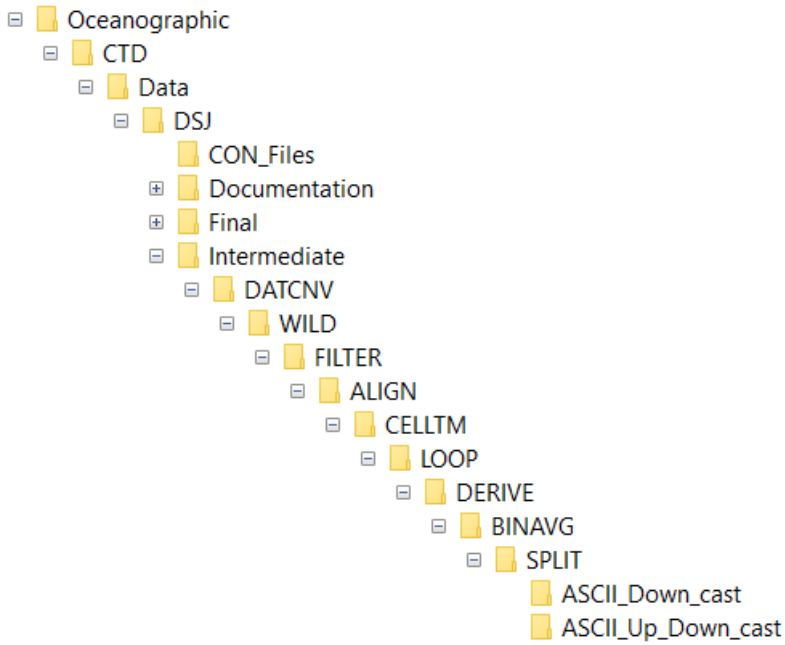
Figure 1. Time series of differences between primary and secondary temperature and conductivity sensors for ORCAWALE 2008 McArthur II CTD casts. Each temperature (T2-T1), conductivity (C2-C1), and salinity (S2-S1) difference is a mean of 1m bin-averaged downcast values (excluding the upper 10m and bins with density changes >0.003 σ_t). Gray lines represent desired accuracy (±0.002 ºC and ±0.0006 S/m, equivalent to ±0.006 psu, which are 2x the specified initial accuracies of the Sea-Bird temperature and conductivity sensors, per SIO/ODF recommendations).

We use pre-cruise calibration coefficients for each sensor when available. Before running the processing modules, it is essential to ensure that the correct sensor configuration coefficients and corrections are loaded into the *.con files used by the SBE Data Processing program. Offset and slope adjustments are obtained from CTDcalibrations ORCAWALE 2008 MACII.xlsx in the \Documentation folder. Configuration files for the sensors used on the McArthur II during ORCAWALE 2008 are listed in Appendix 1.

ORCAWALE 2008 CTD SBE MODULE PROCESSING

The SBE Data processing modules that were applied to the raw data are listed below. Each SBE module creates a program setup file, named *.psa. The *.psa files are located in the folder preceding their output, i.e. the 'Derive.psa' file is found in the 'LOOP' folder. Output .cnv files are kept in binary format to speed processing and reduce file sizes. The final module – ASCII Out – converts the binary data to ASCII format; if examination of the data is needed during earlier processing steps, the Translate module can be used to convert to the binary data to ASCII.

Modules are run in the following order: Data Conversion, Wild Edit, Filter, Align CTD (as needed), Cell Thermal Mass, Loop Edit, Derive, Bin Average, Split, ASCII Out. The processed data in various stages are in the \Intermediate folder:



1. **Data Conversion Module:**

Data Conversion converts raw SBE 911plus data, which are typically stored as frequencies and voltages in the *.dat file, to engineering units and stores the converted data in a *.cnv file.

The options selected for processing in Data Conversion were as follows:

name 0 = prDM: Pressure, Digiquartz [db]

name 1 = c0S/m: Conductivity [S/m]
name 2 = t090C: Temperature [ITS-90, deg C]
name 3 = c1S/m: Conductivity, 2 [S/m]
name 4 = t190C: Temperature, 2 [ITS-90, deg C]
name 5 = sbeox0Mm/Kg: Oxygen, SBE 43 [umol/Kg]
name 6 = flag: 0.000e+00

CTD cast 037 was interrupted because of software problems and the data were recorded in two files. The two .cnv files for this cast that were output by Data Convert (AR08037.cnv and AR08037_c.cnv) were converted to ASCII with the Translate module, combined in a text editor, and then converted back to a single binary file (AR08037.cnv).

Fortran program SCRDATA (programmer: Paul Fiedler) was used to exclude pressure values <-5.0 or >1200, temperature values <-1.0 or >33, and conductivity values <2.5 or >7.0. The program first checks the range or span of values from the primary and secondary sensors in the header file. If any span exceeds the above limits, the program writes a new file in which each bad value, and the values in the two scans preceding and the two scans succeeding the bad value are replaced with a missing value of -9.990e-29. The original file is renamed with an "x" prefix. For each edited file, the total number of scans, and for each sensor, the number of values that exceeded the limits and the number of entries replaced with a missing value are summarized in the *ScrData.dat* files in the \\Intermediate\DATCNV folder. Of 91 CTD files, 55 had no outliers, 19 had C0 and C1 outliers, 1 had T0 outliers, 16 had T1 outliers, 15 had pressure outliers, and 27 had DO outliers.

2. Wild Edit Module:

Wild Edit flags outliers in temperature, conductivity, and oxygen data so that they are not used in further processing. Wild Edit's algorithm requires two passes through the data in blocks of *npoint* scans. The first pass computes the mean and standard deviation and temporarily flags values that differ from the mean by more than *pass1_nstd* standard deviations. The second pass recalculates the mean and standard deviation, excluding values flagged in the first pass. Scans that differ from the mean by more than *pass2_nstd* standard deviations are replaced with a bad data flag. The criteria established by *pass2_nstd* can be overridden using *pass2_mindelta*; specifically, if data are within *pass2_mindelta* of the mean, they are not flagged.

The options selected for processing in Wild Edit were as follows for all casts:

wildedit_pass1_nstd = 2.0
wildedit_pass2_nstd = 15.0
wildedit_pass2_mindelta = 0.000e+000
wildedit_npoint = 100
wildedit_vars = c0S/m c1S/m t090C t190C sbox0Mm/Kg

These options are Sea-Bird defaults, except that *pass2_nstd* was changed from 20.0 to 15.0 to identify more outliers.

3. Filter Module:

The Filter module is run to reduce high-frequency noise in the pressure data, which is caused by counting jitter or other unknown sources. It is important to remove this noise before running the Loop Edit module. Loop Edit flags data that exhibit a change in the CTD velocity. Velocity is calculated using only three successive scans; consequently, noisy pressure data can result in erroneously flagged scans. Filter runs a low-pass filter on the data, which smoothes high frequency (rapidly changing) data. To produce zero phase (i.e., no time shift), the filter is first run forward through the data and then run backward through the data. Pressure data is typically filtered with a time constant equal to four times the CTD scan rate. We run a low-pass filter on the pressure data with time constant = 0.15 seconds, as recommended by Sea-Bird Electronics Inc.

The options selected for processing in Filter were as follows for all CTD casts:

```
# filter_low_pass_tc_A = 0.030
# filter_low_pass_tc_B = 0.150
# filter_low_pass_A_vars =
# filter_low_pass_B_vars = prDM
```

4. Align CTD Module:

It is essential that all variables derived from the data, such as salinity, density, and sound speed, use measurements of temperature and conductivity from same parcel of water. Logistically, it is practically impossible to instantaneously measure the same parcel of water with all sensors due to the physical location of the sensors on the unit and the different time delays of the sensors. The typical time delay of conductivity relative to temperature, 0.073 seconds, is automatically corrected by the SBE 11plus Deck Unit during data collection. If spikes are observed in the processed salinity profiles, further alignment of conductivity may be necessary. The Align CTD module can be used to align the conductivity data relative to pressure.

Fortran program TRIALIGN (programmer: Paul Fiedler) was run to find the optimum alignment value for conductivity (i.e., the number of scans by which to shift conductivity relative to temperature). TRIALIGN finds the maximum temperature gradient within a 240-scan window using linear regression; TRIALIGN tests for the gradient using only the first 10,000 scans to ensure data are from the downcast and imposes the criteria that depth must change by at least 5m in the 240-scan window. Conductivity alignments are tested within the region of maximum temperature gradient because misalignment of temperature and conductivity often results in excessive salinity spikes when temperature is changing rapidly. Within the window, conductivity is shifted by -24 to +24 scans. For each shift, salinity is derived from the temperature and conductivity data in each scan and a linear regression is fit to the salinity values. The shift that results in the minimum standard deviation of the regression residuals is selected as the optimal value for that cast. Optimal values for all casts are averaged to obtain a single alignment value for the cruise (one scan is 0.042 seconds).

Inspection of the Mac II 2008 CTD profiles suggested that alignment might improve salinity profiles for the secondary conductivity sensor, although spiking was moderate. TRIALIGN gave

mean optimum advances of 0.000 sec (SE=0.0010) for primary sensor, C3201, and +0.040 sec (SE=0.0018) for secondary sensor, C3353, (see Trialign0 and Trialign1.dat in \FILTER, which have the following columns: CTD file name, pressure (db) at the maximum temperature gradient, maximum temperature gradient (deg C/db), optimal advance (scans), and relative standard deviation of residuals).

Oxygen data are also systematically delayed with respect to pressure due to the long time delay of the oxygen sensor (the SBE 43 ranges from 2 seconds at 25 ºC to approximately 5 seconds at 0 ºC) and the time required for the water to transit through the pumped line. Hysteresis of downcast and upcast oxygen profiles suggested that alignment of the oxygen data relative to pressure was necessary. The Sea-Bird recommended advance of +2 sec was used for the dissolved oxygen sensors.

The options selected for processing in Align CTD were as follows:

```
# alignctd_adv = c1S/m 0.040, sbox0Mm/Kg 2.000
```

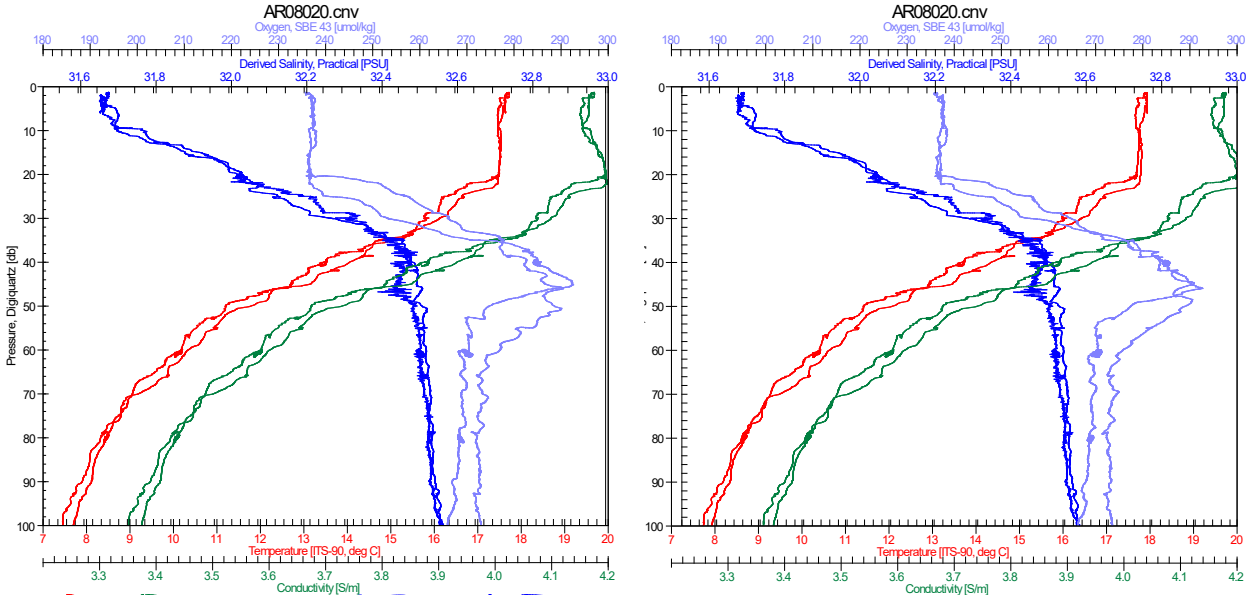


Figure 2. Surface section of CTD cast 020 before (left) and after (right) alignment. The upcast shows salinity spiking in the thermocline and also noise at bottle depths. Alignment slightly reduces salinity spikes and brings the oxygen downcast and upcast profiles closer together.

5. Cell Thermal Mass Module:

Cell Thermal Mass uses a recursive filter to remove conductivity cell thermal mass effects from the measured conductivity. In areas with large temperature gradients, the thermal mass correction

is on the order of 0.005 psu. In areas with small temperature gradients, the correction is negligible.

The following Sea-Bird Electronics Inc. recommendations for Cell Thermal Mass when processing SBE 9plus data, with TC duct, were used:

celltm_alpha = 0.0300, 0.0300
celltm_tau = 7.0000, 7.0000
celltm_temp_sensor_use_for_cond = primary, secondary

6. Loop Edit Module:

Loop Edit flags data that exhibit a change in the mean CTD ascent or descent rate (e.g., pressure reversals or slowdowns). Such changes in ascent or descent rates are usually created by ship heave as the CTD unit is lowered or raised, and indicate unreliable data. Data that have been flagged are documented in the *.cnv header.

The options selected for processing in Loop Edit follow the recommendations of Sea-Bird Electronics Inc. for casts in which data collection begins after the surface soak:

loopedit_minVelocity = 0.250
loopedit_surfaceSoak: minDepth = 5.0, maxDepth = 20, useDeckPress = 0
loopedit_excl_bad_scans = no

Examination of pressure vs. scan count in Sea Plot showed that data collection for only some casts was started before the CTD had been returned to near the surface after the 10m surface soak (i.e., data collected began either on deck or during the soak): 012, 013, 017, 018, 020, 021, 026, 027, 029, 030, 031, 033, 035, 036, 038, 039, 040, 041, 042, 044 – 049, 053, 055 – 069, 055T, and 079.

7. Derive Module:

Derive uses pressure, temperature, and conductivity from the input *.cnv file to compute the following oceanographic variables, which are routinely used in the assessment of protected species:

- Salinity
- Density (density, sigma-theta, sigma-t, sigma-1, sigma-2, sigma-4)
- Depth (salt water, fresh water)
- Sound velocity (which can be calculated using the Chen-Millero, DelGrosso or Wilson equation)
- Average sound velocity (the harmonic mean from the surface to the current CTD depth, which is calculated on the downcast only)

The following derived variables were calculated in this module for all CTD casts:

name 5 = sbox0Mm/Kg: Oxygen, SBE 43 [umol/kg]
name 6 = depSM: Depth [salt water, m], lat = 30.7997

name 7 = potemp090C: Potential Temperature [ITS-90, deg C]
name 8 = sal00: Salinity, Practical [PSU]
name 9 = sigma-é00: Density [sigma-theta, kg/m^3]
name 10 = svCM: Sound Velocity [Chen-Millero, m/s]
name 11 = avgsvCM: Average Sound Velocity [Chen-Millero, m/s], minP = 2, minS = 20
name 12 = svCM1: Sound Velocity, 2 [Chen-Millero, m/s]
name 13 = potemp190C: Potential Temperature, 2 [ITS-90, deg C]
name 14 = sal11: Salinity, Practical, 2 [PSU]
name 15 = sigma-é11: Density, 2 [sigma-theta, kg/m^3]

Note that there is no option in Sea-Bird's SBE Data Processing to calculate Average Sound Velocity from secondary sensor data.

To calculate average sound velocity, the following values were used:

# minimum pressure = 2 db	[average depth of the acoustic array]
# minimum salinity = 20 psu	[recommended by Sea-Bird Electronics Inc.]
# Latitude = 38 °N	[this value is used only if NMEA latitude is not available in the header]

The profiles output by the Derive module were inspected by the Senior Oceanographer for bad data caused by sensor failure, temperature inversions, low surface salinity measurements (likely the result of rain), and spikes in salinity. Comments about each cast are in ORCAWALE 2008 MAC II CTD Cast info.xls in the \Documentation folder. Comment codes are:

A – acceptable
N – acceptable for assessments of protected species but not for a national archive
R – reject cast

8. Bin Average Module:

The Bin Average module averages temperature, conductivity, pressure, and derived variables in user-selected intervals; the intervals may be defined using pressure, depth, scan number, or time range. We use 1m bins, with no surface bin. In this module, we exclude scans that we flagged as bad in previous modules.

The following processing options were selected in this module for all casts:

binavg_bintype = meters
binavg_binsize = 1
binavg_excl_bad_scans = yes
binavg_skipover = 0
binavg_surface_bin = no, min = 0.000, max = 5.000, value = 0.000

9. Split Module:

Split separates the data from an input *.cnv file into upcast (pressure decreasing) and downcast (pressure increasing) *.cnv files. Downcast only files are output because they do not contain the

data collected when the bottles are fired (e.g., repetitive sampling at the same pressure). Consequently, they are used to derive variables such as thermocline depth and strength.

The following options were selected in this module for all casts:

split_excl_bad_scans = no
output the downcast only (into the \Split folder). This command adds a 'd' at the beginning of the filenames.

10. ASCII Out Module:

ASCII Out outputs the header and/or the data from a binary data file (*.cnv). Data are written to an ASCII file (*.asc), while the header information, which lists each processing module and the variables applied, is written to a separate ASCII file (*.hdr).

This module was run twice. First, to convert the complete cast; second, to convert the downcast-only files created with the SPLIT module.

The following options were selected in this module for all casts:

Output Header and Data files
Label Column at top of the file
Column separator = space

FINAL PRODUCT

ASCII Out outputs the header and/or the data from a binary data file (*.cnv). Data are written to an ASCII file (*.asc), while the header information, which lists each processing module and the variables applied, is written to a separate ASCII file (*.hdr).

ASCII down-cast output files, containing only data recorded by the secondary sensors and no error flags, can be found in the \Final\ASCII_Down_cast folder.

The file headers have been saved separately from the final ASCII data files in both directories. The header files contain time in two separate fields: "System UpLoad Time" and "NMEA UTC (Time)". The time in the "System UpLoad Time" field is taken from the PC used to the collect the data and may not be accurate (e.g., this field may be recorded in local time, rather than Coordinated Universal Time, and may not have been adjusted for local time zone changes). The Coordinated Universal Time in the "NMEA UTC (Time)" field is taken from the GPS unit and is accurate as long as the GPS functioned properly.

The downcast profile is used to derive variables commonly used in protected species assessments, such as thermocline depth and strength. Plots of complete casts show hysteresis, or depth offsets, of 5-8 m. The error in the depth, as indicated by the offsets, are expected to occur primarily in the upcasts due to "package wake" (i.e., the "shadowing" of the sensors by the rosette and frame as the CTD is pulled up through the water column). Additionally, the upcasts include repetitive sampling of the same depth when bottles are fired to collect water samples.

In total, 91 CTD casts were conducted during ORCAWALE 2008 on the McArthur II. The data set is comprised of 86 normal station casts and 5 test casts in which all bottles are tripped at 500m. The test cast typically precedes the first regular cast of each leg of the cruise. The output format for the combined up and down casts is shown below.

```
    PrDM    C0S/m    C1S/m    T090C    T190C Sbox0Mm/Kg  DepSM Potemp090C  Sal00 Sigma-é00…
   SvCM  AvgsvCM    SvCM1 Potemp190C  Sal11 Sigma-é11    Nbin       Flag
   2.014 4.217121 4.217384  16.2672  16.2694  243.704    2.000  16.2668  33.2333  24.3284…
1508.61  1508.67  1508.62  16.2691  33.2337  24.3282       50 0.0000e+00
   3.021 4.217813 4.218071  16.2729  16.2752  242.509    3.000  16.2724  33.2342  24.3278…
1508.64  1508.67  1508.65  16.2747  33.2346  24.3276       51 0.0000e+00
   4.028 4.217882 4.218055  16.2731  16.2747  242.462    4.000  16.2725  33.2342  24.3278…
1508.66  1508.67  1508.67  16.2741  33.2344  24.3276       52 0.0000e+00
```

The output format for the down casts only is shown below.

```
   PrDM     C0S/m    T090C Sbox0Mm/Kg DepSM Potemp090C  Sal00 Sigma-é00    SvCM AvgsvCM   Nbin
  2.014  4.217121  16.2672   243.704  2.000    16.2668 33.2333  24.3284 1508.61 1508.67     50
  3.021  4.217813  16.2729   242.509  3.000    16.2724 33.2342  24.3278 1508.64 1508.67     51
  4.028  4.217882  16.2731   242.462  4.000    16.2725 33.2342  24.3278 1508.66 1508.67     52
```

Column descriptions are as follows (only the bolded variables are included in the final downcast files):

PrDM = Digiquartz pressure in decibars (db)

C0S/m = Primary conductivity in Siemens per meter (S/m)

T090C = Primary temperature, in degrees Celsius (ºC), calculated using the ITS-90 standard

C1S/m = Secondary conductivity in Siemens per meter (S/m)

T190C = Secondary temperature, in degrees Celsius (ºC), calculated using the ITS-90 standard

Sbox0Mm/Kg = Oxygen, SBE 43 (µmol/Kg)

DepSM = Salt water depth in meters (m)

Potemp090C = Potential temperature (reference pressure = 0.0 decibars), derived from the primary temperature sensor

Sal00 = Salinity, in practical salinity units (psu), derived from the primary temperature and conductivity sensors

Sigma-é00 = Density [sigma-theta], in kilograms per cubic meter (kg/m^3), calculated from the primary temperature sensor and the salinity data derived from the primary conductivity sensor

SvCM = Chen-Millero's sound velocity in meters per second (m/s) calculated from the primary temperature sensor and the salinity data derived from the primary conductivity sensor

AvgsvCM = Chen-Millero's average sound velocity in meters per second (m/s) calculated from the primary temperature sensor and the salinity data derived from the primary conductivity sensor

SvCM1 = Chen-Millero's sound velocity in meters per second (m/s) calculated from the secondary temperature sensor and the salinity data derived from the secondary conductivity sensor

Potemp090C = Potential temperature (reference pressure = 0.0 decibars), derived from the secondary temperature sensor

Sal11 = Salinity, in practical salinity units (psu), derived from the secondary temperature and conductivity sensors

Sigma-é11 = Density [sigma-theta], in kilograms per cubic meter (kg/m^3), calculated from the secondary temperature sensor and the salinity data derived from the secondary conductivity sensor

Nbin = number of scans used to calculate the bin average

Perl program CTDPositionCheck (programmer: Dan Prosperi) was used to check the CTD cast date/times and positions recorded in the header files against the edited TSG file for the survey. All 91 files had matching TSG records; no corrections were necessary.

Paul Fiedler, 16 June 2021

Appendix 1. ORCAWALE 2008 MACII Sea-Bird Data Processing Configuration Files

ORCAWALE2008 MACII Casts 001_021.con

```
Configuration report for SBE 911plus/917plus
       CTD
-----------------------------------------

Frequency channels suppressed : 0
Voltage words suppressed      : 0
Computer interface            : RS-232C
Deck unit                     : SBE11plus
       Firmware Version >= 5.0
Scans to average              : 1
NMEA position data added      : Yes
NMEA depth data added         : No
NMEA time added               : No
NMEA device connected to      : deck unit
Surface PAR voltage added     : No
Scan time added               : No

1) Frequency 0, Temperature

   Serial number : 4667
   Calibrated on : 08 Jan 08
   G             : 4.39706498e-003
   H             : 6.45677269e-004
   I             : 2.20112076e-005
   J             : 1.79646176e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0019

2) Frequency 1, Conductivity

   Serial number : 3201
   Calibrated on : 08 Jan 08
   G             : -1.01913049e+001
   H             : 1.44753322e+000
   I             : 8.08946171e-006
   J             : 8.87076429e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 0.99970000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 0405
   Calibrated on : 29 Jan 08
   C1            : -4.505278e+004
   C2            : -9.372496e-001
   C3            : 1.416440e-002
   D1            : 3.852400e-002
   D2            : 0.000000e+000
   T1            : 3.024202e+001
   T2            : -5.890827e-004
   T3            : 4.036660e-006
   T4            : 2.914400e-009
   T5            : 0.000000e+000
   Slope         : 0.99986000
   Offset        : -0.61000
   AD590M        : 1.111000e-002
   AD590B        : -8.834520e+000

4) Frequency 3, Temperature, 2

   Serial number : 4803
   Calibrated on : 12-Feb-08
   G             : 4.33023175e-003
   H             : 6.36139215e-004
   I             : 2.03174160e-005
   J             : 1.62827107e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : -0.0016

5) Frequency 4, Conductivity, 2

   Serial number : 3353
   Calibrated on : 22-Feb-08
   G             : -9.72474259e+000
   H             : 1.49018932e+000
   I             : -1.74455309e-003
   J             : 2.14776238e-004
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00035000
   Offset        : 0.00000

6) A/D voltage 0, Oxygen, SBE 43

   Serial number : 1294
   Calibrated on : 21-Mar-08p
   Equation      : Owens-Millard
   Soc           : 4.2740e-001
   Boc           : 0.0000
   Offset        : -0.4854
   Tcor          : 0.0017
   Pcor          : 1.35e-004
   Tau           : 0.0

7) A/D voltage 1, Free

8) A/D voltage 2, Free

9) A/D voltage 3, Free

10) A/D voltage 4, Free

11) A/D voltage 5, Free

12) A/D voltage 6, Altimeter

    Serial number : 42648
    Calibrated on :
    Scale factor  : 15.000
    Offset        : 0.000

13) A/D voltage 7, Free

Scan length                   : 37
```

ORCAWALE2008 MACII Casts 022_034.con

```
Configuration report for SBE 911plus/917plus
       CTD
-----------------------------------------

Frequency channels suppressed : 0
Voltage words suppressed      : 0
Computer interface            : RS-232C
Deck unit                     : SBE11plus
       Firmware Version >= 5.0
Scans to average              : 1
NMEA position data added      : Yes
NMEA depth data added         : No
NMEA time added               : No
NMEA device connected to      : deck unit
Surface PAR voltage added     : No
Scan time added               : No

1) Frequency 0, Temperature

   Serial number : 4667
   Calibrated on : 08 Jan 08
   G             : 4.39706498e-003
   H             : 6.45677269e-004
   I             : 2.20112076e-005
   J             : 1.79646176e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0019

2) Frequency 1, Conductivity

   Serial number : 3201
   Calibrated on : 08 Jan 08
   G             : -1.01913049e+001
   H             : 1.44753322e+000
   I             : 8.08946171e-006
   J             : 8.87076429e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 0.99970000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 0405
   Calibrated on : 29 Jan 08
   C1            : -4.505278e+004
   C2            : -9.372496e-001
   C3            : 1.416440e-002
   D1            : 3.852400e-002
   D2            : 0.000000e+000
   T1            : 3.024202e+001
   T2            : -5.890827e-004
   T3            : 4.036660e-006
   T4            : 2.914400e-009
   T5            : 0.000000e+000
   Slope         : 0.99986000
   Offset        : -0.61000
   AD590M        : 1.111000e-002
   AD590B        : -8.834520e+000

4) Frequency 3, Temperature, 2

   Serial number : 4803
   Calibrated on : 12-Feb-08
   G             : 4.33023175e-003
   H             : 6.36139215e-004
   I             : 2.03174160e-005
   J             : 1.62827107e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : -0.0016

5) Frequency 4, Conductivity, 2

   Serial number : 3353
   Calibrated on : 22-Feb-08
   G             : -9.72474259e+000
   H             : 1.49018932e+000
   I             : -1.74455309e-003
   J             : 2.14776238e-004
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00035000
   Offset        : 0.00000

6) A/D voltage 0, Oxygen, SBE 43

   Serial number : 1294
   Calibrated on : 21-Mar-08p
   Equation      : Owens-Millard
   Soc           : 4.3290e-001
   Boc           : 0.0000
   Offset        : -0.4844
   Tcor          : 0.0017
   Pcor          : 1.35e-004
   Tau           : 0.0

7) A/D voltage 1, Free

8) A/D voltage 2, Free

9) A/D voltage 3, Free

10) A/D voltage 4, Free

11) A/D voltage 5, Free

12) A/D voltage 6, Altimeter

    Serial number : 42648
    Calibrated on :
    Scale factor  : 15.000
    Offset        : 0.000

13) A/D voltage 7, Free

Scan length                   : 37
```

ORCAWALE2008 MACII Casts 035_054.con

```
Configuration report for SBE 911plus/917plus
       CTD
-----------------------------------------

Frequency channels suppressed : 0
Voltage words suppressed      : 0
Computer interface            : RS-232C
Deck unit                     : SBE11plus
       Firmware Version >= 5.0
Scans to average              : 1
NMEA position data added      : Yes
NMEA depth data added         : No
NMEA time added               : No
NMEA device connected to      : deck unit
Surface PAR voltage added     : No
Scan time added               : No

1) Frequency 0, Temperature

   Serial number : 4667
   Calibrated on : 08 Jan 08
   G             : 4.39706498e-003
   H             : 6.45677269e-004
   I             : 2.20112076e-005
   J             : 1.79646176e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0019

2) Frequency 1, Conductivity

   Serial number : 3201
   Calibrated on : 08 Jan 08
   G             : -1.01913049e+001
   H             : 1.44753322e+000
   I             : 8.08946171e-006
   J             : 8.87076429e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 0.99970000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 0405
   Calibrated on : 29 Jan 08
   C1            : -4.505278e+004
   C2            : -9.372496e-001
   C3            : 1.416440e-002
   D1            : 3.852400e-002
   D2            : 0.000000e+000
   T1            : 3.024202e+001
   T2            : -5.890827e-004
   T3            : 4.036660e-006
   T4            : 2.914400e-009
   T5            : 0.000000e+000
   Slope         : 0.99986000
   Offset        : -0.61000
   AD590M        : 1.111000e-002
   AD590B        : -8.834520e+000

4) Frequency 3, Temperature, 2

   Serial number : 4803
   Calibrated on : 12-Feb-08
   G             : 4.33023175e-003
   H             : 6.36139215e-004
   I             : 2.03174160e-005
   J             : 1.62827107e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : -0.0016

5) Frequency 4, Conductivity, 2

   Serial number : 3353
   Calibrated on : 22-Feb-08
   G             : -9.72474259e+000
   H             : 1.49018932e+000
   I             : -1.74455309e-003
   J             : 2.14776238e-004
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00035000
   Offset        : 0.00000

6) A/D voltage 0, Oxygen, SBE 43

   Serial number : 1294
   Calibrated on : 21-Mar-08p
   Equation      : Owens-Millard
   Soc           : 4.3290e-001
   Boc           : 0.0000
   Offset        : -0.4844
   Tcor          : 0.0017
   Pcor          : 1.35e-004
   Tau           : 0.0

7) A/D voltage 1, Free

8) A/D voltage 2, Free

9) A/D voltage 3, Free

10) A/D voltage 4, Free

11) A/D voltage 5, Free

12) A/D voltage 6, Altimeter

    Serial number : 42648
    Calibrated on :
    Scale factor  : 15.000
    Offset        : 0.000

13) A/D voltage 7, Free

Scan length                   : 37
```

ORCAWALE2008 MACII Casts 055_069.con

```
Configuration report for SBE 911plus/917plus
       CTD
-----------------------------------------

Frequency channels suppressed : 0
Voltage words suppressed      : 0
Computer interface            : RS-232C
Deck unit                     : SBE11plus
       Firmware Version >= 5.0
Scans to average              : 1
NMEA position data added      : Yes
NMEA depth data added         : No
NMEA time added               : No
NMEA device connected to      : deck unit
Surface PAR voltage added     : No
Scan time added               : No

1) Frequency 0, Temperature

   Serial number : 4667
   Calibrated on : 08 Jan 08
   G             : 4.39706498e-003
   H             : 6.45677269e-004
   I             : 2.20112076e-005
   J             : 1.79646176e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0019

2) Frequency 1, Conductivity

   Serial number : 3201
   Calibrated on : 08 Jan 08
   G             : -1.01913049e+001
   H             : 1.44753322e+000
   I             : 8.08946171e-006
   J             : 8.87076429e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 0.99970000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 0405
   Calibrated on : 29 Jan 08
   C1            : -4.505278e+004
   C2            : -9.372496e-001
   C3            : 1.416440e-002
   D1            : 3.852400e-002
   D2            : 0.000000e+000
   T1            : 3.024202e+001
   T2            : -5.890827e-004
   T3            : 4.036660e-006
   T4            : 2.914400e-009
   T5            : 0.000000e+000
   Slope         : 0.99986000
   Offset        : -0.61000
   AD590M        : 1.111000e-002
   AD590B        : -8.834520e+000

4) Frequency 3, Temperature, 2

   Serial number : 4803
   Calibrated on : 12-Feb-08
   G             : 4.33023175e-003
   H             : 6.36139215e-004
   I             : 2.03174160e-005
   J             : 1.62827107e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : -0.0016

5) Frequency 4, Conductivity, 2

   Serial number : 3353
   Calibrated on : 22-Feb-08
   G             : -9.72474259e+000
   H             : 1.49018932e+000
   I             : -1.74455309e-003
   J             : 2.14776238e-004
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00035000
   Offset        : 0.00000

6) A/D voltage 0, Oxygen, SBE 43

   Serial number : 1294
   Calibrated on : 21-Mar-08p
   Equation      : Owens-Millard
   Soc           : 4.4320e-001
   Boc           : 0.0000
   Offset        : -0.4825
   Tcor          : 0.0017
   Pcor          : 1.35e-004
   Tau           : 0.0

7) A/D voltage 1, Free

8) A/D voltage 2, Free

9) A/D voltage 3, Free

10) A/D voltage 4, Free

11) A/D voltage 5, Free

12) A/D voltage 6, Altimeter

    Serial number : 42648
    Calibrated on :
    Scale factor  : 15.000
    Offset        : 0.000

13) A/D voltage 7, Free

Scan length                   : 37
```

ORCAWALE2008 MACII Casts 070_071.con

```
Configuration report for SBE 911plus/917plus
       CTD
-----------------------------------------

Frequency channels suppressed : 0
Voltage words suppressed      : 0
Computer interface            : RS-232C
Deck unit                     : SBE11plus
       Firmware Version >= 5.0
Scans to average              : 1
NMEA position data added      : Yes
NMEA depth data added         : No
NMEA time added               : No
NMEA device connected to      : deck unit
Surface PAR voltage added     : No
Scan time added               : No

1) Frequency 0, Temperature

   Serial number : 4667
   Calibrated on : 08 Jan 08
   G             : 4.39706498e-003
   H             : 6.45677269e-004
   I             : 2.20112076e-005
   J             : 1.79646176e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0019

2) Frequency 1, Conductivity

   Serial number : 3201
   Calibrated on : 08 Jan 08
   G             : -1.01913049e+001
   H             : 1.44753322e+000
   I             : 8.08946171e-006
   J             : 8.87076429e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 0.99970000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 0405
   Calibrated on : 29 Jan 08
   C1            : -4.505278e+004
   C2            : -9.372496e-001
   C3            : 1.416440e-002
   D1            : 3.852400e-002
   D2            : 0.000000e+000
   T1            : 3.024202e+001
   T2            : -5.890827e-004
   T3            : 4.036660e-006
   T4            : 2.914400e-009
   T5            : 0.000000e+000
   Slope         : 0.99986000
   Offset        : -0.61000
   AD590M        : 1.111000e-002
   AD590B        : -8.834520e+000

4) Frequency 3, Temperature, 2

   Serial number : 4803
   Calibrated on : 12-Feb-08
   G             : 4.33023175e-003
   H             : 6.36139215e-004
   I             : 2.03174160e-005
   J             : 1.62827107e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : -0.0016

5) Frequency 4, Conductivity, 2

   Serial number : 3353
   Calibrated on : 22-Feb-08
   G             : -9.72474259e+000
   H             : 1.49018932e+000
   I             : -1.74455309e-003
   J             : 2.14776238e-004
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00035000
   Offset        : 0.00000

6) A/D voltage 0, Oxygen, SBE 43

   Serial number : 1294
   Calibrated on : 21-Mar-08p
   Equation      : Owens-Millard
   Soc           : 4.4600e-001
   Boc           : 0.0000
   Offset        : -0.4820
   Tcor          : 0.0017
   Pcor          : 1.35e-004
   Tau           : 0.0

7) A/D voltage 1, Free

8) A/D voltage 2, Free

9) A/D voltage 3, Free

10) A/D voltage 4, Free

11) A/D voltage 5, Free

12) A/D voltage 6, Altimeter

    Serial number : 42648
    Calibrated on :
    Scale factor  : 15.000
    Offset        : 0.000

13) A/D voltage 7, Free

Scan length                   : 37
```

ORCAWALE2008 MACII Casts 072.con

```
Configuration report for SBE 911plus/917plus
       CTD
-----------------------------------------

Frequency channels suppressed : 0
Voltage words suppressed      : 0
Computer interface            : RS-232C
Deck unit                     : SBE11plus
       Firmware Version >= 5.0
Scans to average              : 1
NMEA position data added      : Yes
NMEA depth data added         : No
NMEA time added               : No
NMEA device connected to      : deck unit
Surface PAR voltage added     : No
Scan time added               : No

1) Frequency 0, Temperature

   Serial number : 4667
   Calibrated on : 08 Jan 08
   G             : 4.39706498e-003
   H             : 6.45677269e-004
   I             : 2.20112076e-005
   J             : 1.79646176e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0019

2) Frequency 1, Conductivity

   Serial number : 3201
   Calibrated on : 08 Jan 08
   G             : -1.01913049e+001
   H             : 1.44753322e+000
   I             : 8.08946171e-006
   J             : 8.87076429e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 0.99970000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 0405
   Calibrated on : 29 Jan 08
   C1            : -4.505278e+004
   C2            : -9.372496e-001
   C3            : 1.416440e-002
   D1            : 3.852400e-002
   D2            : 0.000000e+000
   T1            : 3.024202e+001
   T2            : -5.890827e-004
   T3            : 4.036660e-006
   T4            : 2.914400e-009
   T5            : 0.000000e+000
   Slope         : 0.99986000
   Offset        : -0.61000
   AD590M        : 1.111000e-002
   AD590B        : -8.834520e+000

4) Frequency 3, Temperature, 2

   Serial number : 4803
   Calibrated on : 12-Feb-08
   G             : 4.33023175e-003
   H             : 6.36139215e-004
   I             : 2.03174160e-005
   J             : 1.62827107e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : -0.0016

5) Frequency 4, Conductivity, 2

   Serial number : 3353
   Calibrated on : 22-Feb-08
   G             : -9.72474259e+000
   H             : 1.49018932e+000
   I             : -1.74455309e-003
   J             : 2.14776238e-004
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00035000
   Offset        : 0.00000

6) A/D voltage 0, Free

7) A/D voltage 1, Free

8) A/D voltage 2, Oxygen, SBE 43

   Serial number : 1295
   Calibrated on : 20-Feb-08p
   Equation      : Owens-Millard
   Soc           : 4.0560e-001
   Boc           : 0.0000
   Offset        : -0.5091
   Tcor          : 0.0023
   Pcor          : 1.35e-004
   Tau           : 0.0

9) A/D voltage 3, Free

10) A/D voltage 4, Free

11) A/D voltage 5, Free

12) A/D voltage 6, Altimeter

    Serial number : 42648
    Calibrated on :
    Scale factor  : 15.000
    Offset        : 0.000

13) A/D voltage 7, Free

Scan length                   : 37
```

ORCAWALE2008 MACII Casts 073.con

```
Configuration report for SBE 911plus/917plus
       CTD
-----------------------------------------

Frequency channels suppressed : 0
Voltage words suppressed      : 0
Computer interface            : RS-232C
Deck unit                     : SBE11plus
Firmware Version >= 5.0
Scans to average              : 1
NMEA position data added      : Yes
NMEA depth data added         : No
NMEA time added               : No
NMEA device connected to      : deck unit
Surface PAR voltage added     : No
Scan time added               : No

1) Frequency 0, Temperature

   Serial number : 4667
   Calibrated on : 08 Jan 08
   G             : 4.39706498e-003
   H             : 6.45677269e-004
   I             : 2.20112076e-005
   J             : 1.79646176e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0019

2) Frequency 1, Conductivity

   Serial number : 3201
   Calibrated on : 08 Jan 08
   G             : -1.01913049e+001
   H             : 1.44753322e+000
   I             : 8.08946171e-006
   J             : 8.87076429e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 0.99970000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 0405
   Calibrated on : 29 Jan 08
   C1            : -4.505278e+004
   C2            : -9.372496e-001
   C3            : 1.416440e-002
   D1            : 3.852400e-002
   D2            : 0.000000e+000
   T1            : 3.024202e+001
   T2            : -5.890827e-004
   T3            : 4.036660e-006
   T4            : 2.914400e-009
   T5            : 0.000000e+000
   Slope         : 0.99986000
   Offset        : -0.61000
   AD590M        : 1.111000e-002
   AD590B        : -8.834520e+000

4) Frequency 3, Temperature, 2

   Serial number : 4803
   Calibrated on : 12-Feb-08
   G             : 4.33023175e-003
   H             : 6.36139215e-004
   I             : 2.03174160e-005
   J             : 1.62827107e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : -0.0016

5) Frequency 4, Conductivity, 2

   Serial number : 3353
   Calibrated on : 22-Feb-08
   G             : -9.72474259e+000
   H             : 1.49018932e+000
   I             : -1.74455309e-003
   J             : 2.14776238e-004
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00035000
   Offset        : 0.00000

6) A/D voltage 0, Oxygen, SBE 43

   Serial number : 1294
   Calibrated on : 21-Mar-08p
   Equation      : Owens-Millard
   Soc           : 4.4600e-001
   Boc           : 0.0000
   Offset        : -0.4820
   Tcor          : 0.0017
   Pcor          : 1.35e-004
   Tau           : 0.0

7) A/D voltage 1, Free

8) A/D voltage 2, Free

9) A/D voltage 3, Free

10) A/D voltage 4, Free

11) A/D voltage 5, Free

12) A/D voltage 6, Altimeter

    Serial number : 42648
    Calibrated on :
    Scale factor  : 15.000
    Offset        : 0.000

13) A/D voltage 7, Free

Scan length                   : 37
```

ORCAWALE2008 MACII Casts 074.con

```
Configuration report for SBE 911plus/917plus
       CTD
-------------------------------------------

Frequency channels suppressed : 0
Voltage words suppressed      : 0
Computer interface            : RS-232C
Deck unit                     : SBE11plus
       Firmware Version >= 5.0
Scans to average              : 1
NMEA position data added      : Yes
NMEA depth data added         : No
NMEA time added               : No
NMEA device connected to      : deck unit
Surface PAR voltage added     : No
Scan time added               : No

1) Frequency 0, Temperature

   Serial number : 4667
   Calibrated on : 08 Jan 08
   G             : 4.39706498e-003
   H             : 6.45677269e-004
   I             : 2.20112076e-005
   J             : 1.79646176e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0019

2) Frequency 1, Conductivity

   Serial number : 3201
   Calibrated on : 08 Jan 08
   G             : -1.01913049e+001
   H             : 1.44753322e+000
   I             : 8.08946171e-006
   J             : 8.87076429e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 0.99970000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 0405
   Calibrated on : 29 Jan 08
   C1            : -4.505278e+004
   C2            : -9.372496e-001
   C3            : 1.416440e-002
   D1            : 3.852400e-002
   D2            : 0.000000e+000
   T1            : 3.024202e+001
   T2            : -5.890827e-004
   T3            : 4.036660e-006
   T4            : 2.914400e-009
   T5            : 0.000000e+000
   Slope         : 0.99986000
   Offset        : -0.61000
   AD590M        : 1.111000e-002
   AD590B        : -8.834520e+000

4) Frequency 3, Temperature, 2

   Serial number : 4803
   Calibrated on : 12-Feb-08
   G             : 4.33023175e-003
   H             : 6.36139215e-004
   I             : 2.03174160e-005
   J             : 1.62827107e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : -0.0016

5) Frequency 4, Conductivity, 2

   Serial number : 3353
   Calibrated on : 22-Feb-08
   G             : -9.72474259e+000
   H             : 1.49018932e+000
   I             : -1.74455309e-003
   J             : 2.14776238e-004
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00035000
   Offset        : 0.00000

6) A/D voltage 0, Free

7) A/D voltage 1, Free

8) A/D voltage 2, Oxygen, SBE 43

   Serial number : 1294
   Calibrated on : 21-Mar-08p
   Equation      : Owens-Millard
   Soc           : 4.4600e-001
   Boc           : 0.0000
   Offset        : -0.4820
   Tcor          : 0.0017
   Pcor          : 1.35e-004
   Tau           : 0.0

9) A/D voltage 3, Free

10) A/D voltage 4, Free

11) A/D voltage 5, Free

12) A/D voltage 6, Altimeter

    Serial number : 42648
    Calibrated on :
    Scale factor  : 15.000
    Offset        : 0.000

13) A/D voltage 7, Free

Scan length                   : 37
```

ORCAWALE2008 MACII Casts 075.con

```
Configuration report for SBE 911plus/917plus
       CTD
-----------------------------------------

Frequency channels suppressed : 0
Voltage words suppressed      : 0
Computer interface            : RS-232C
Deck unit                     : SBE11plus
       Firmware Version >= 5.0
Scans to average              : 1
NMEA position data added      : Yes
NMEA depth data added         : No
NMEA time added               : No
NMEA device connected to      : deck unit
Surface PAR voltage added     : No
Scan time added               : No

1) Frequency 0, Temperature

   Serial number : 4667
   Calibrated on : 08 Jan 08
   G             : 4.39706498e-003
   H             : 6.45677269e-004
   I             : 2.20112076e-005
   J             : 1.79646176e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0019

2) Frequency 1, Conductivity

   Serial number : 3201
   Calibrated on : 08 Jan 08
   G             : -1.01913049e+001
   H             : 1.44753322e+000
   I             : 8.08946171e-006
   J             : 8.87076429e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 0.99970000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 0405
   Calibrated on : 29 Jan 08
   C1            : -4.505278e+004
   C2            : -9.372496e-001
   C3            : 1.416440e-002
   D1            : 3.852400e-002
   D2            : 0.000000e+000
   T1            : 3.024202e+001
   T2            : -5.890827e-004
   T3            : 4.036660e-006
   T4            : 2.914400e-009
   T5            : 0.000000e+000
   Slope         : 0.99986000
   Offset        : -0.61000
   AD590M        : 1.111000e-002
   AD590B        : -8.834520e+000

4) Frequency 3, Temperature, 2

   Serial number : 4803
   Calibrated on : 12-Feb-08
   G             : 4.33023175e-003
   H             : 6.36139215e-004
   I             : 2.03174160e-005
   J             : 1.62827107e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : -0.0016

5) Frequency 4, Conductivity, 2

   Serial number : 3353
   Calibrated on : 22-Feb-08
   G             : -9.72474259e+000
   H             : 1.49018932e+000
   I             : -1.74455309e-003
   J             : 2.14776238e-004
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00035000
   Offset        : 0.00000

6) A/D voltage 0, Free

7) A/D voltage 1, Free

8) A/D voltage 2, Oxygen, SBE 43

   Serial number : 1295
   Calibrated on : 20-Feb-08p
   Equation      : Owens-Millard
   Soc           : 4.0560e-001
   Boc           : 0.0000
   Offset        : -0.5091
   Tcor          : 0.0023
   Pcor          : 1.35e-004
   Tau           : 0.0

9) A/D voltage 3, Free

10) A/D voltage 4, Free

11) A/D voltage 5, Free

12) A/D voltage 6, Altimeter

    Serial number : 42648
    Calibrated on :
    Scale factor  : 15.000
    Offset        : 0.000

13) A/D voltage 7, Free

Scan length                   : 37
```

ORCAWALE2008 MACII Casts 076_086.con

```
Configuration report for SBE 911plus/917plus
       CTD
```

```
Frequency channels suppressed : 0
Voltage words suppressed      : 0
Computer interface            : RS-232C
Deck unit                     : SBE11plus
       Firmware Version >= 5.0
Scans to average              : 1
NMEA position data added      : Yes
NMEA depth data added         : No
NMEA time added               : No
NMEA device connected to      : deck unit
Surface PAR voltage added     : No
Scan time added               : No

1) Frequency 0, Temperature

   Serial number : 4667
   Calibrated on : 08 Jan 08
   G             : 4.39706498e-003
   H             : 6.45677269e-004
   I             : 2.20112076e-005
   J             : 1.79646176e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : 0.0019

2) Frequency 1, Conductivity

   Serial number : 3201
   Calibrated on : 08 Jan 08
   G             : -1.01913049e+001
   H             : 1.44753322e+000
   I             : 8.08946171e-006
   J             : 8.87076429e-005
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 0.99970000
   Offset        : 0.00000

3) Frequency 2, Pressure, Digiquartz with TC

   Serial number : 3001
   Calibrated on : 11-Feb-08
   C1            : -3.911989e+004
   C2            : -1.960405e+000
   C3            : 9.871570e-003
   D1            : 3.178100e-002
   D2            : 0.000000e+000
   T1            : 2.933918e+001
   T2            : -9.729668e-004
   T3            : 3.817570e-006
   T4            : 0.000000e+000
   T5            : 0.000000e+000
   Slope         : 0.99995000
   Offset        : 10.79700
   AD590M        : 1.135000e-002
   AD590B        : -8.643200e+000

4) Frequency 3, Temperature, 2

   Serial number : 4803
   Calibrated on : 12-Feb-08
   G             : 4.33023175e-003
   H             : 6.36139215e-004
   I             : 2.03174160e-005
   J             : 1.62827107e-006
   F0            : 1000.000
   Slope         : 1.00000000
   Offset        : -0.0016

5) Frequency 4, Conductivity, 2

   Serial number : 3353
   Calibrated on : 22-Feb-08
   G             : -9.72474259e+000
   H             : 1.49018932e+000
   I             : -1.74455309e-003
   J             : 2.14776238e-004
   CTcor         : 3.2500e-006
   CPcor         : -9.57000000e-008
   Slope         : 1.00035000
   Offset        : 0.00000

6) A/D voltage 0, Free

7) A/D voltage 1, Free

8) A/D voltage 2, Oxygen, SBE 43

   Serial number : 1295
   Calibrated on : 20-Feb-08p
   Equation      : Owens-Millard
   Soc           : 4.0560e-001
   Boc           : 0.0000
   Offset        : -0.5091
   Tcor          : 0.0023
   Pcor          : 1.35e-004
   Tau           : 0.0

9) A/D voltage 3, Free

10) A/D voltage 4, Free

11) A/D voltage 5, Free

12) A/D voltage 6, Altimeter

    Serial number : 42648
    Calibrated on :
    Scale factor  : 15.000
    Offset        : 0.000

13) A/D voltage 7, Free

Scan length                   : 37
```

Appendix 2. Bottle Salinity Analyses

Bottle salinity samples were analyzed to validate CTD sensor calibration and to detect evidence of Niskin bottle leakage. Samples were collected from bottles tripped at depth and analyzed with a Guildline Portasal 8410A salinometer using standard methods (Guildline Technical Manual TM 8410A-F-00). The salinity data from the Portasal and CTD can be found in \Oceanographic\Salinity. The results summarized below can also be found in ORCAWALE 2008 Salts.xls in \Documentation.

Portasal data were collected during salts runs at sea by the program PSAL9709 (Oceanographic Data Facility, Scripps Institution of Oceanography). The raw data files, which are the files without a filename extension in each of the leg subfolders in \\Stenella\Ecology \Survey_Data\CA_Current\2008_ORCAWALE\Oceanographic\Salinity\Raw\MACII, were copied with a text editor into a single file named *salts08m.raw*.

Fortran program CR2SAL.EXE (programmer: Fiedler) calculated salinities from the recorded conductivity ratios and bath temperatures in *salts08m.raw* using the Sea-Bird salinity algorithm. The two output files, *salts08m.sal* and *salts08m.sta*, are identical except that the sample records in the *.sta* file are truncated. Output file *salts08m.sal* lists four salinity values for each sample, calculated from the listed value and three adjusted values of the sample conductivity ratio, as discussed below.

File *salts08m.sta* was edited to list the raw CTD file and Niskin bottle number corresponding to each sample. FORTRAN program SALTS.EXE (programmer: Fiedler) called Sea-Bird program SBEBATCH to process each raw CTD file. Specifically, the batch program creates a temporary water bottle *.ros* file from the Data Conversion module and outputs a bottle data summary *.btl* file from the Bottle Summary module. The *.ros* file contains data for each scan associated with a bottle firing, which by default are all scans within a 1.5-second duration after a bottle firing confirmation is received from the water sampler. The *.btl* file contains means and standard deviations of the CTD data for each bottle. SALTS then reads the *.btl* file to find CTD salinity values corresponding to the bottle samples in *salts08m.sal*. Two files are output for each pair of temperature/conductivity sensors (1 = primary, 2 = secondary): *salts08m1.dat* and *salts08m2.dat* contain the CTD salinity and depth for each bottle sample and the differences between each of the four alternative bottle salinity values and the CTD salinity; *salts08m1.sum* and *salts08m2.sum* contain means and standard deviations of the differences within each salts run. One cast number was changed to obtain reasonable (Bottle – CTD) differences (see *salts08m.sta* for details).

Conductivity Ratio Adjustment for Bottle Salinities

When analyzing samples on the Portasal, the initial salinity standard reading should be equal to 2x the actual conductivity ratio of the standard (K_{15} on the ampule label) after correct initialization of the instrument. Referencing sample conductivity ratios to the initial standard reading may not give the best results for several reasons; for example, the initial standard reading may be erroneous (e.g., the Portasal was not sufficiently warmed up with standard water before samples are read) or the sensitivity of the Portasal may drift during the run. Adjusting the

reference for sample conductivity ratios will change both the mean and the standard deviation of Bottle - CTD salinity differences if the initial and final standard readings differ. Selection of an adjustment alternative should be based on minimizing the standard deviation.

CR2SAL calculates four alternative salinity values from sample conductivity ratios adjusted relative to:

(0) the initial standard reading (no adjustment),
(1) the final standard reading,
(2) the average of the initial and final readings, and
(3) a standard reading interpolated between the initial and final readings.

Salinities calculated from sample conductivity ratios adjusted by method (2) resulted in bottle–CTD differences with the smallest means (biases) and standard deviations (RMSE) overall:

	Mean (Bottle – CTD)		St. dev. (Bottle – CTD)	
Adjustment	primary	secondary	primary	secondary
None:	**+0.001930**	-0.004449	0.006021	0.007287
(1):	+0.008409	+0.002031	0.006485	**0.004996**
(2):	+0.005169	**-0.001210**	**0.005269**	0.005256
(3):	+0.005092	-0.001287	0.005438	0.005682

Therefore, bottle salinities calculated from sample conductivity ratios adjusted by method (2) were used in subsequent analyses.

Precision of Bottle Salinity Measurements

Three replicate samples collected from 17 deep bottles on selected CTD casts allow an assessment of the precision of our bottle salinity sampling and analysis methods (see Replicates worksheet in ORCAWALE 2008 Salts.xls). An ANOVA gives a "mean squares within" of 8.302e-06, which is equivalent to the variance of replicate salinity values within bottles. The square root of this value gives a precision of ±0.0029 psu, approximately equal to the accuracy of ±0.003 specified by Guildline, but greater than the ±0.001 precision that can be achieved under ideal laboratory conditions (Sea-Bird, personal communication).

The standard deviation of Bottle - CTD salinity differences for all samples was 0.0053 (above table, Adjustment 2), about two times greater than the precision of bottle salinity replicates. A larger error is expected because of the additional errors of the CTD sensors and the mismatch of waters pumped through CTD sensors and sampled by Niskin bottles.

Bottle – CTD Salinity Differences

Figure 3 shows Bottle – CTD salinity differences for all samples. CTD values are from primary (S1) and secondary (S2) sensors, both before and after calibration adjustments based on post-cruise calibrations. The trend lines without calibration adjustment show the positive drift of the primary sensors (decreasing Bottle – CTD differences) and the negative drift of the secondary sensors, consistent with the data in the calibration spreadsheet, \\Stenella\Ecology\Survey_Data\CA_Current\2008_ORCAWALE\Oceanographic\CTD\Data\MACII\Documents\CTDcalibrations ORCAWALE 2008_MACII.xls. The adjustment of sensor calibrations for drift, based on the post-cruise calibration, tended to bring the biases of both sensors back towards zero. However, the calibration adjustment tends to over-correct for the drift. In addition, there is a bias at the start of the cruise, as if these sensors had been used between the pre-cruise calibration and the start of the cruise.

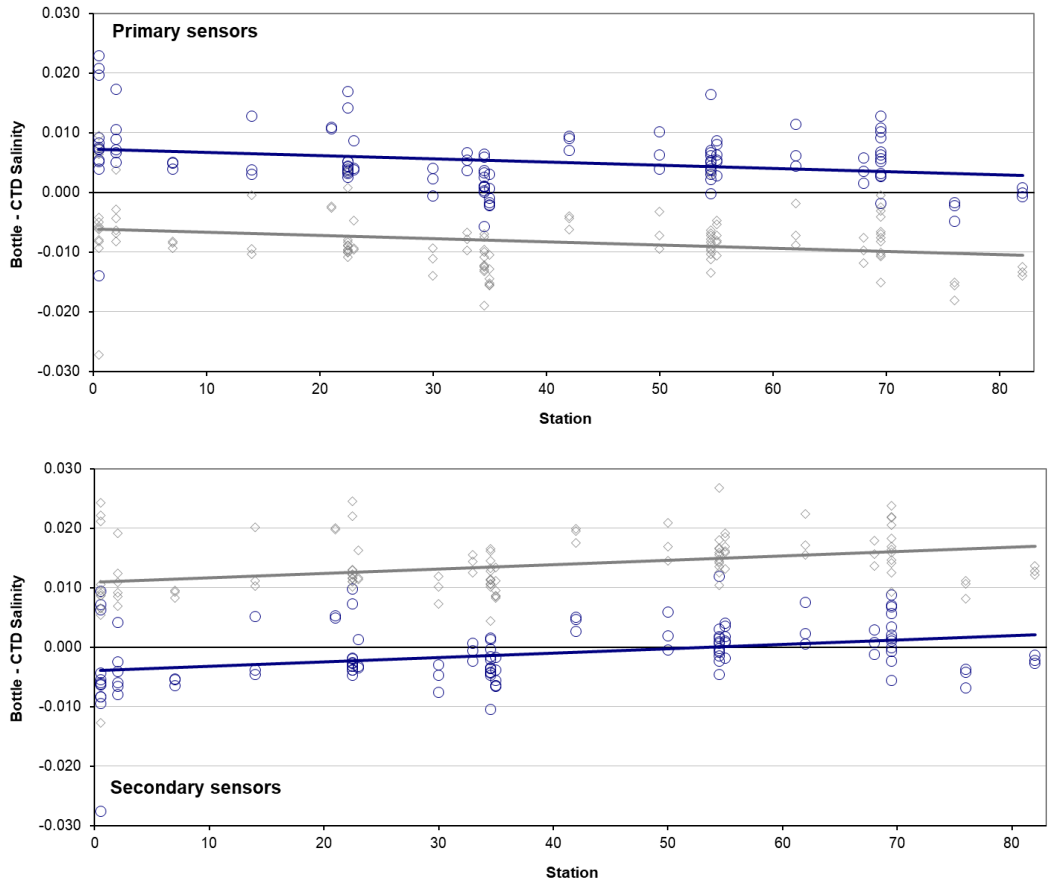


Figure 3. Bottle – CTD salinity differences for ORCAWALE 2008, McArthur II, using pre-cruise sensor calibrations (gray diamonds) and post-cruise adjustments (dark blue circles).

Overall, the Bottle – CTD salinity differences indicate that the CTD secondary sensors were more accurate than the primary sensors after calibration adjustment. Consequently, *temperature and salinity values from the secondary sensors should be included in the final CTD data files*.

Test Cast Bottle vs. CTD Salinities

The following table summarizes bottle salinities and corresponding CTD salinities (mean ±sd) from the five test casts, when all 12 bottles were tripped sequentially at 500m. Although values are listed to four decimal places, the precision of the salinometer is ±0.003 and the precision of the CTD sensors is ±0.0004 psu.

	CTD S1	CTD S2	Bottle
Leg 1	34.1391 ±0.0003	34.1306 ±0.0003	34.1375 ±0.0096
Leg 2	34.1599 ±0.0002	34.1499 ±0.0002	34.1576 ±0.0048
Leg 3	34.1289 ±0.0005	34.1218 ±0.0005	34.1245 ±0.0031
Leg 4	34.3072 ±0.0010	34.3049 ±0.0011	34.3083 ±0.0038
Leg 5	34.1068 ±0.0010	34.1095 ±0.0011	34.1118 ±0.0039

For legs 2-5, the salinity of the bottle samples collected at the same depth (column labeled "Bottle" above) vary by slightly more than the precision of replicates (i.e., ±0.0029 psu) and the precision of the salinometer; consequently, the measured bottle salinity values are essentially identical. On the first leg, the salinity measurement from bottle 12 was much lower than the CTD salinity from either sensor (Fig. 4), which resulted in a larger standard deviation.

Salinities derived from the secondary CTD sensors, after temperature and conductivity calibration adjustments, are plotted as deviations from the Portasal bottle salinities in Figure 4.

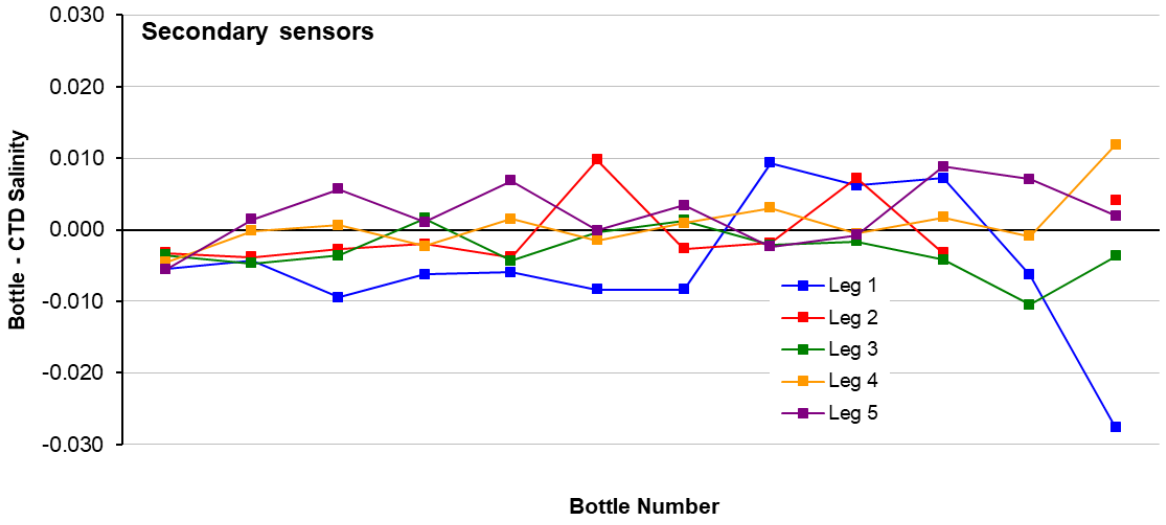


Figure 4. Bottle - CTD salinity differences, derived from secondary sensor data, for test casts on ORCAWALE 2008, McArthur II, Legs 1-5.

There are no bottles with consistently large negative differences that might indicate leakage of a Niskin bottle as it is brought up from depth to the surface through lower-salinity waters.

Appendix 3. Surface Oxygen Saturation

Surface waters are normally close to saturated with dissolved oxygen. Air-sea exchange due to wind-driven turbulence will saturate surface waters. Local addition of oxygen by photosynthesis can result in oversaturation. Uptake of oxygen by net community respiration below the mixed layer often results in undersaturation (Lazarevich, P., T. Rossby, and C. McNeil. 2004. Oxygen variability in the near-surface waters of the northern North Atlantic: Observations and a model. Journal of Marine Research 62:663-683). Oxygen saturation at the sea surface during summer in the northeast Pacific Ocean has been observed to vary between 90 and 110%. Winter values are closer to 100% (Kester, D. R., and R. M. Pytkowicz. 1968. Oxygen saturation in the surface waters of the northeast Pacific Ocean. Journal of Geophysical Research 73:5421-5424).

As a quick check on oxygen sensor calibration and function, Fortran program XO2SAT.EXE (programmer: Paul Fiedler) extracted near-surface (to 10m) CTD data from the final ASCII data files. Observed dissolved oxygen concentration was compared to an oxygen saturation value calculated from observed temperature and salinity using a Sea-Bird equation (Derived Parameter Formulas in SBE Data Processing) in output file \\Stenella\Ecology\Survey_Data\ CA_Current\2008_ORCAWALE\Oceanographic\CTD\Data\MACII\Intermediate*o2sat08m.dat*.

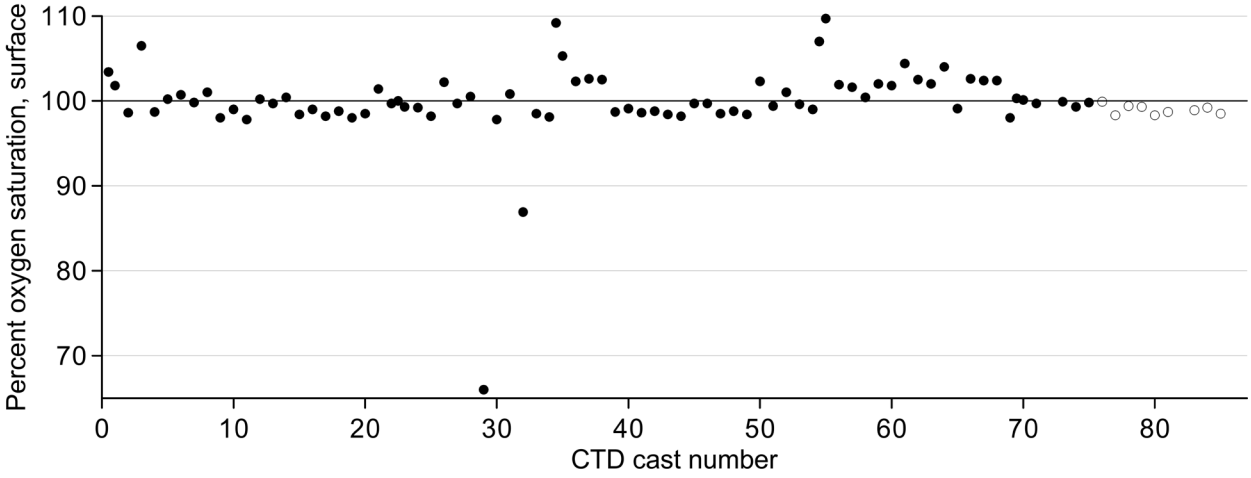


Figure 5. Percent oxygen saturation at the surface for ORCAWALE 2008 CTD casts: oxygen sensors 1294 (●) and 1295 (○). Oxygen saturation values range from 227.9 to 282.1 μmoles kg^{-1}.

Most of the oxygen saturation values (Fig. 5) are within the expected range for surface waters. The low values in Fig. 5 are for casts 029 (66.0%) and 032 (86.9%), These stations were adjacent to the coast in southern Oregon and northern California, where oxygen-depleted water has been upwelled onto the shelf in recent years (Chan, et al. 2008. Emergence of anoxia in the California Current large marine ecosystem. Science 319(5865):920).

No oxygen data were recorded on cast 072, because the sensor was exchanged and not connected properly, and on cast 082, for an unknown reason.