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Technical Note

Best Practices for the SeaFET™ V2: Optimizing pH Data Quality

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Introduction

The SeaFET™ V2 is an upgrade to the Satlantic SeaFET™ pH sensor. It incorporates the same housing and DuraFET as the original SeaFET™ with improved electronics and new operating characteristics for enhanced stability and reliability in long-term deployments. As with the original SeaFET™, an SBE 37-SMP-ODO CTD can be integrated with the SeaFET™ V2 to operate as a SeapHOx™ V2, adding a pumped anti-foul flow path and CTD data corrections to pH data. Accordingly, the Deep SeapHOx™ V2 utilizes the seam Deep-Sea DuraFET® sensor as the original, and has the same upgrades as the shallow versions.

This guide outlines best practices for using, deploying, and interfacing with the SeaFET™ V2.

Description of Sensor Technology

The primary sensing element of the SeaFET V2 is the ISFET, a solid-state sensor that responds to pH in marine environments. It has two different reference electrodes: the internal reference and the external reference. Each provides a separate reference potential to the ISFET, producing separate pH values (Internal pH and External pH). After applying corrections for temperature and salinity, Internal pH and External pH should be similar, allowing the user to verify the validity of the sensor's measurements.

Internal Reference

The internal reference is part of the DuraFET® sensor and consists of an electrode bathed in a saturated KCl solution. Ions in seawater diffuse across a frit on the internal reference gel and propagate charge to the internal reference electrode. The electrode remains isolated from the sensed medium, allowing the Internal pH measurements to remain relatively stable at the expense of some uncertainty. If accurate salinity and temperature data are not available to correct the external cell, the internal cell is generally more accurate.

External Reference

The external reference consists of an Ag/AgCl reference electrode in direct contact with seawater. This sensor responds to both pH and salinity in seawater—if accurate salinity data is available, applying it to pH External data can significantly reduce measurement error, providing the most accurate and stable pH data. If accurate salinity data is not available, the external reference data has a large amount of uncertainty.

Maintenance and Care

Proper maintenance of the SeaFET V2 between deployments is crucial for optimal pH data quality.

Storage

The DuraFET sensor on the SeaFET V2 contains an internal reference electrode bathed in KCl gel. This sensor must be kept wet at all times; if allowed to desiccate, the KCl gel can leak out of the sensor housing. Furthermore, the Ag/AgCl external reference electrode is sensitive to freshwater. **To avoid damaging the sensors, store the SeaFET V2 in clean seawater between uses**, and avoid allowing the sensors to dry for longer than 10 minutes. Failure to do so can result in rapid sensor drift or irreparable damage to the instrument, requiring complete factory replacement and recalibration.

Sea-Bird ships the Shallow SeaFET V2 and SeapHOx V2 with artificial seawater in the flow cell, sealed with plastic plugs. Immediately after recovering the SeaFET V2, fill the flow cell with clean seawater and seal with the plastic plugs. Note that freshwater and artificial seawater are not appropriate storage mediums and will cause the SeaFET V2's sensors to drift—filtered natural seawater is the best storage option.

Batteries

The SeaFET V2 uses 12 D-cell batteries for internal power. If storing for an extended period, remove the batteries from the instrument to prevent leakage.

Replacing batteries generally requires pulling the vent plug. This equalizes the internal pressure, making the battery endcap easier to remove. **Ensure that the vent plug has been re-secured prior to submerging the SeaFET V2.** Failure to do so will result in a flooded instrument.

Cleaning

Remove biofouling with high-purity isopropyl alcohol (90% or higher), lint-free wipes, and lint-free swabs.

- **External Reference**: gently scrub with a lint-free wipe saturated in alcohol. Ensure that all alcohol has dried before storage.
- **ISFET**: gently rinse the ISFET with filtered seawater or isopropyl to remove any sediment from the face. When clear of grit that can scratch the surface, saturate a lint-free swab in alcohol, touch the face of the ISFET, and gently twist to remove any biofouling. After cleaning, the ISFET should appear flat and shiny.

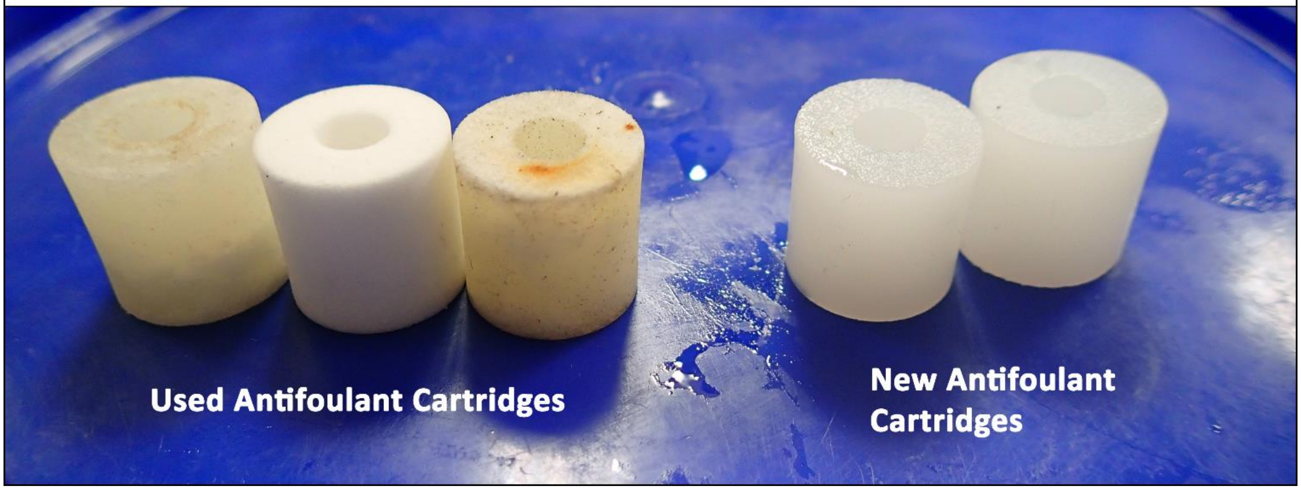
The face of the ISFET on a Deep SeapHOx before and after cleaning.

Before cleaning, biological deposits visible on the face of the ISFET can offset the calibration and sensor response time.

After cleaning, the face of the ISFET should appear flat and shiny. Rinsing and a lint-free swab will prevent scratches.

NOTE: Anti-Fouling Cartridges

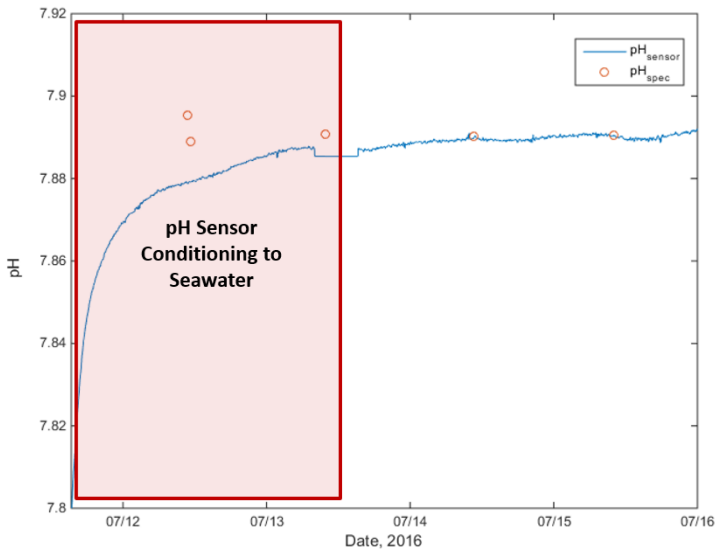
If used as a SeapHOx V2, the accompanying SBE 37 CTD contains two Bis(tributyltin) oxide (aka "TBTO") cartridges that protect from biological growth (SeaFETs without a CTD do not have TBTO protection). These release a small amount of TBTO into the flow path during each sample and eventually lose their effectiveness. Spent cartridges generally have a patchy or bleached appearance as TBTO is depleted. Sea-Bird Scientific recommends replacing these cartridges after every deployment, as it is difficult to estimate the lifespan of the cartridges. These cartridges are located beneath the SBE 37's conductivity cell guard. Wear gloves and eye protection while handling them.



Deployment Considerations

Pre-Deployment

The External Reference requires 24-72 hours to condition to the deployment site's seawater before providing optimal data. If possible, store the SeaFET V2's sensors in filtered seawater from the deployment site prior to deployment to reduce the conditioning time.



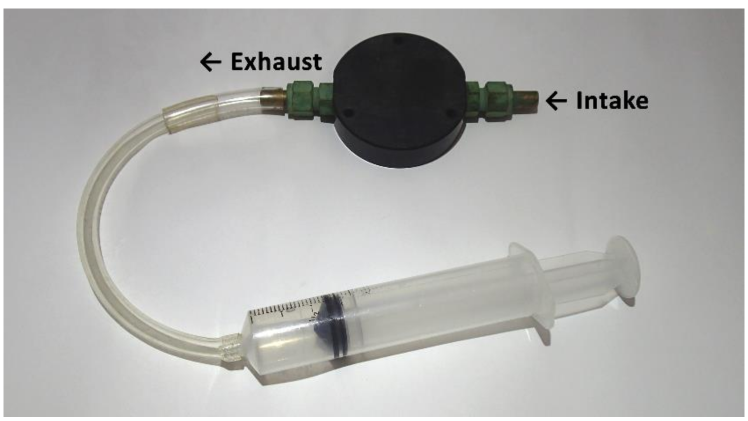
Data from a SeapHOx showing the conditioning period. Red circles represent validation samples processed via a spectrophotometer.

After approximately 48 hours, the SeapHOx data adjusts to within 0.01 pH of the validation sample.

Entering the Water

Bubbles on the sensors will skew data. When deploying with the flow cell and copper tubes (used for the SeapHOx deployments, and SeaFET deployments without the copper guard), deploy the SeaFET vertically with the sensors facing upwards to allow bubbles to escape. Take care to eliminate bubbles before leaving the instrument:

1. Submerge the SeaFET V2 and allow time for the large bubbles to escape.
2. Connect a plastic syringe to the copper tube on the exhaust side, pushing and pulling to purge any remaining bubbles.
3. If possible, collect a few samples (via autonomous data collection or by sending the "TS" command) and verify that pH data is reasonable. If a bubble is present on the face of the ISFET, pH will be clearly lower than expected values for seawater.



The sensing elements are sensitive to light. If deploying the SeaFET V2 near the surface, limit exposure to light during the deployment and consider deploying vertically with the sensing elements facing downwards, taking extra precaution to flush bubbles prior to deployment.

Pumped flow optimizes data from the SeaFET V2. If deploying as a SeaFET without a CTD, Sea-Bird recommends connecting an SBE 5M pump to the intake of the flow cell, and enabling SeaFET pump controls in UCI or a terminal emulator (usepump=y).

Mid-Deployment Checks

The Magnetic Switch and Indicator LED on the SeaFET V2 allow the user to determine the instrument status:

No Flash: **SeaFET V2 batteries/memory are not ready for deployment**	**Red Flash:** **SeaFET V2 has not received a sampling command**	**Green Flash:** **SeaFET V2 is sampling or waiting to begin sampling**
The LED will not flash if any one of the following conditions are true: • The RTC battery is not sufficient (below 2.5 V) • The isolated battery is not sufficient (below 4.0 V) • The main battery or external power supply is not sufficient (below 7.0 V) • The memory is full	The SeaFET V2 batteries and memory are ready to deploy, but the instrument has not received a sampling command. Connect the SeaFET to a computer and click on "Start" in UCI, or send "**startnow**" or "**startlater**" before deploying.	The SeaFET V2 batteries and memory are ready to deploy, and the SeaFET V2 has received the "**startnow**" or "**startlater**" command. It is either sampling or waiting to begin sampling at the time predetermined in UCI or with the "**startdatetime=mmddyyyyhhmmss**" command.

Direct view of the magnetic switch and indicator LED, located on the same side as the bulkhead connector.

The LED responds to a magnet with the strength of a typical refrigerator magnet. If it does not respond immediately, try a stronger magnet if one is available.

If visiting the SeaFET V2 in the field mid-deployment, checking the LED allows the user to identify if the SeaFET V2 is still logging as expected without connecting to a computer. If the LED does not flash, verify that fresh batteries are installed and the memory has been initialized. Engaging the magnetic switch does not change any settings on the SeaFET V2.

When to recalibrate

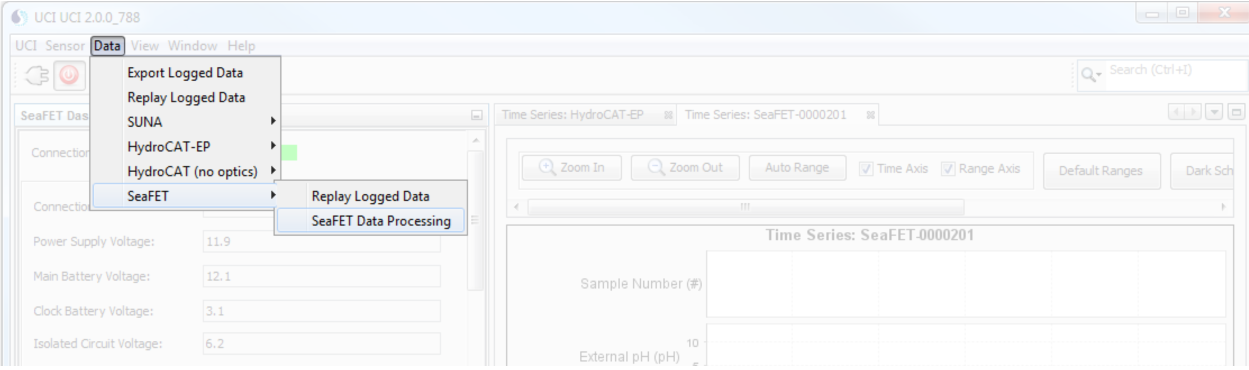
The DuraFET on Shallow SeaFET V2s has an estimated lifespan of 1 year. After 1 year, the internal reference gel and other components are expected to deteriorate. If the SeaFET V2 begins to exhibit the following symptoms, return it to Sea-Bird Scientific for factory repair and recalibration before the next deployment:

- Erratic data, after cleaning and correcting External pH for salinity. This is especially important if only Internal pH is unstable, which could that the internal reference gel is depleted or deteriorated and is no longer providing a stable reference.
- A difference greater than ±0.07 pH from an accurate pure-dye spectrophotometer sample after cleaning. The SeaFET V2's initial accuracy is ±0.05 pH, and the standard spectrophotometer sample is accurate within ±0.01 pH (with pure dye). If the SeaFET V2 is significantly out of spec after cleaning, the sensors have likely drifted.
- A difference of ±0.1 pH from Internal pH and External pH, after cleaning and salinity correction. For the best verification, compare Internal pH and External pH in a seawater bath with stable temperature and salinity, allowing at least 48 hours for the external reference to stabilize upon entering new water.

Note: pH buffer solutions cannot be used to verify data from the SeaFET V2, as the sensors are designed only for seawater use.

Data Analysis Correcting for Salinity

The SeapHOx V2 and Deep SeapHOx V2 will automatically apply a salinity correction to the External pH data. If the SeaFET V2 was deployed without an integrated CTD, the UCI software can process raw .sbsdat files uploaded from the SeaFET V2, allowing users to apply temperature and salinity corrections from a nearby CTD. Navigate to the **Data → SeaFET → SeaFET Data Processing** to access the *SeaFET Data Processing* dashboard:



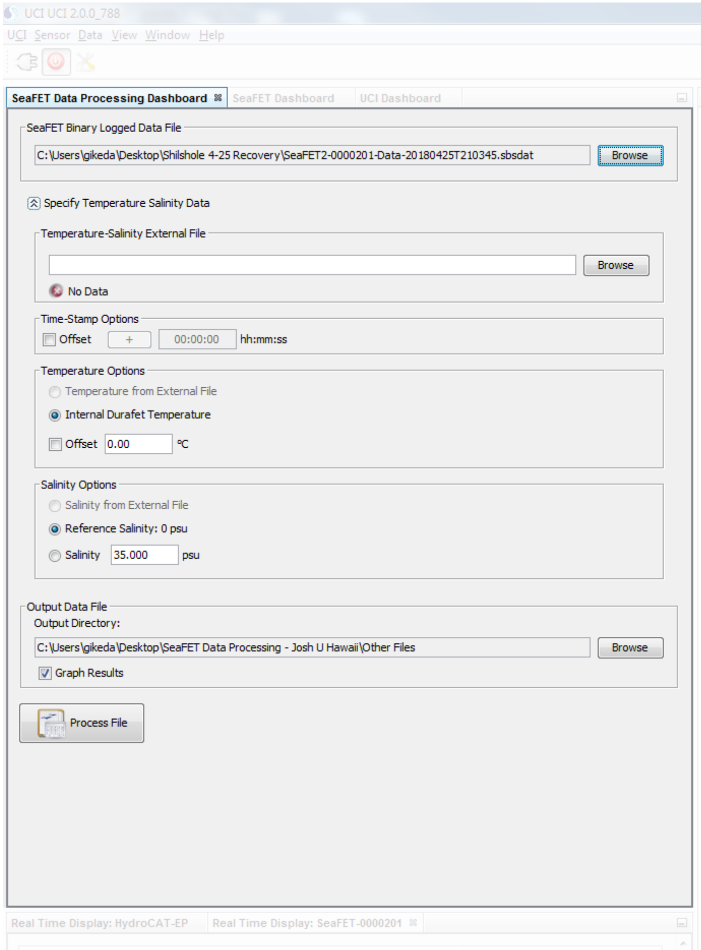
The user can apply temperature and salinity data to calculate a more accurate pH value than the standalone SeaFET V2 sensor, which uses an internal thermistor and a fixed salinity value.

1. Press "Browse" and select a raw .sbsdat data file under "SeaFET Binary Logged Data File"
   a. Multiple files can be processed by holding the Ctrl key while selecting .sbsdata files.
2. Click on the arrow to the left of "Specify Temperature Salinity data" to open the menu.
3. If available, upload an external file containing temperature and salinity data in one of the following formats:
   a. A generic .CSV format:
      YYYY-MM-DD hh:mm:ss, <temperature>, <salinity><CR><LF>
      where:
      - Date and time in UTC
      - Temperature in C°
      - Salinity in PSU
      - <CR><LF> is the carriage return and line feed that is the end of each line.

Example: 2013-04-25 15:22:48, 10.8326,34.8974

   b. A Sea-Bird Electronics .CNV format as made from *SBE Data Processing* with the following output variables:
      - Time, sensor (seconds)
      - Temperature (degrees C)
      - Salinity, practical (PSU)

Example: 388682568 10.8326 34.8974 0.000e+00



If an external file is not available, the user can use the internal DuraFET temperature already recorded to the SeaFET V2 memory and specify a static salinity value to apply to the SeaFET V2's External pH values.