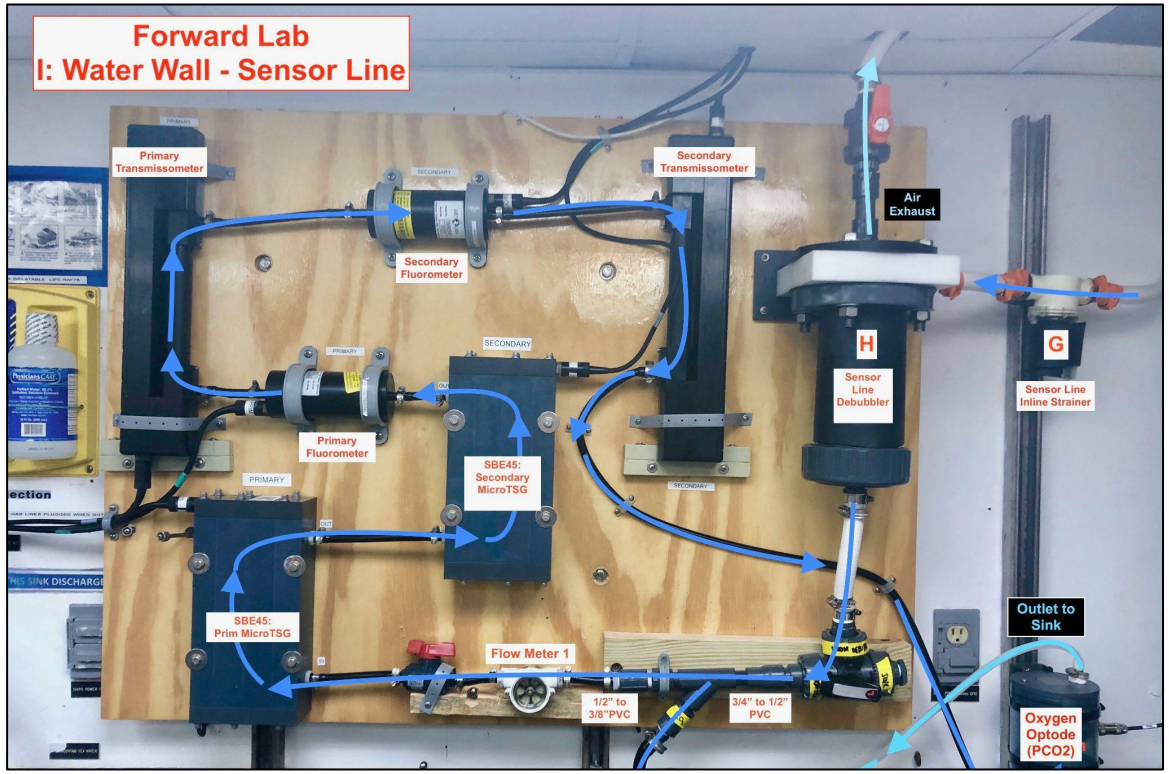
Recommended Practices for Shipboard Flowthrough Systems

Flowthrough System Design, Maintenance & Management, and Data Stewardship

Shawn Smith
Center for Ocean-Atmosphere Prediction Studies at Florida State University
Shipboard Automated Meteorological and Oceanographic System (SAMOS)
Senior Research Associate

Katie Watkins-Brandt
NOAA, Office of Marine and Aviation Operations
Section Chief, Science Services

General Flowthrough Best Practices



Atlantic Explorer flowthrough system with flow direction marked. Photo courtesy of BIOS.

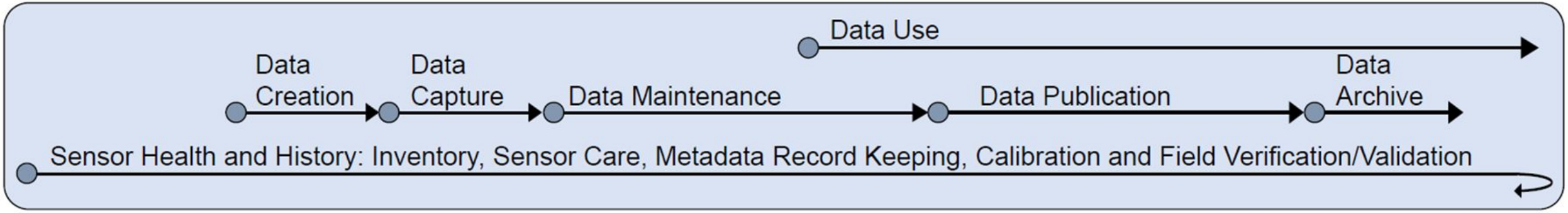
- Group inactive at the moment
  - Workload of in-service techs and group lead makes progress slow
- Primary scope
  - Focus on components of flowthrough system
    - Intakes, sea chest, pipes/tubing, pumps, flow meters, debubblers
  - Will not address specific sensors in system, but may recommend sensor placement, orientation, etc.
- **Working session during RVTEC**
  - **Plan is to collect information on challenge areas**
  - **Discuss how to disseminate content while document is still in draft**

Join us, contact Shawn:
Email: srsmith@fsu.edu

Overview:

- Why should we care about flowthrough systems?
- Interactive Poll #1
- A *Crash Course* on Science Seawater System
- A *Crash Course* on Water Wall Design
- Sensors: Maintenance and Cal/Val Practices
- Interactive Poll #2
- Discussion

Importance of Metadata and Understanding the Data Lifecycle



- Data Capture: one-time event for that point in time and space
- Metadata and Sensor health and history: actively evolving and intricately tied to quality at data capture
- Maintenance and Management: Inventory, Sensor Care, and Record Keeping
- Field Calibration, Validation, and Application
- Factory Calibration

Why should we care about Underway Measurements?
Time and Space: Short Time Scales

AGU ADVANCING EARTH AND SPACE SCIENCE

Global Biogeochemical Cycles

RESEARCH ARTICLE
10.1029/2019GB006518

Diel Measurements of Oxygen- and Carbon-Based Ocean Metabolism Across a Trophic Gradient in the North Pacific

Fernanda Henderikx Freitas[1,2], Angelicque E. White[1,2], and Paul D. Quay[3]

[1]Department of Oceanography, University of Hawai'i at Manoa, Honolulu, HI, USA, [2]Daniel K. Inouye Center for Microbial Oceanography: Research and Education, Honolulu, HI, USA, [3]School of Oceanography, University of Washington, Seattle, WA, USA

[Publication]

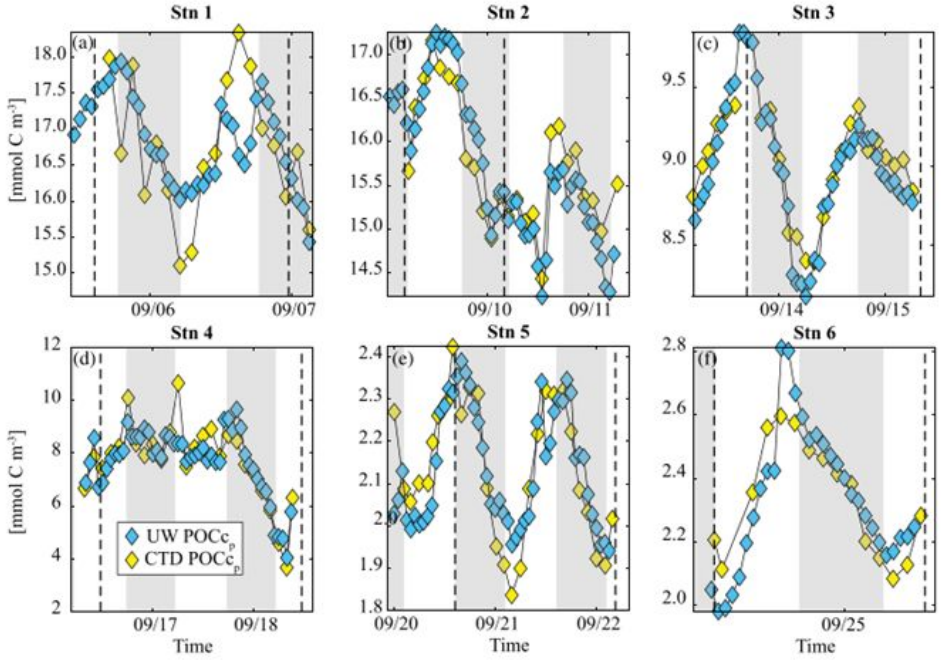


Figure 3. Time series of mixed layer averaged and underway POC-scaled particle beam attenuation. Shaded gray areas denote nighttime periods. The dashed vertical lines mark the period used for calculation of production and respiration rates at each station (same limits as in Figure 2). Note that a clear diurnal cycle was not observed at Stn 4 in the highly dynamic transition zone region.

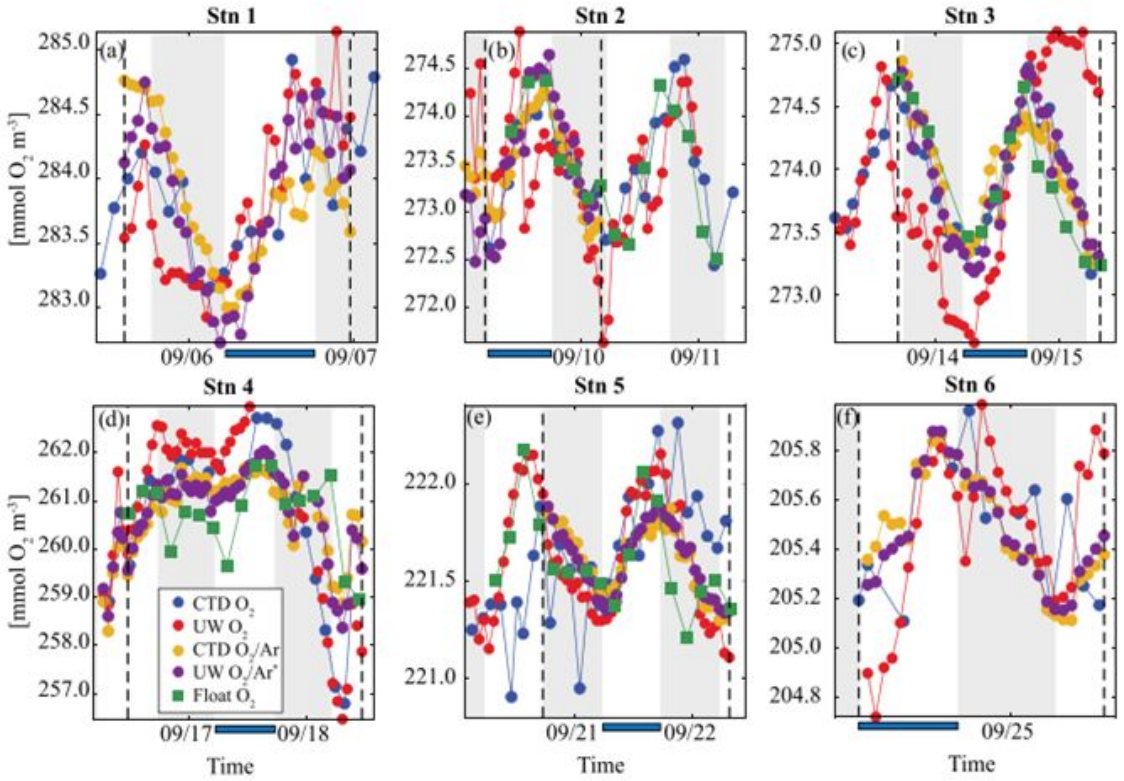
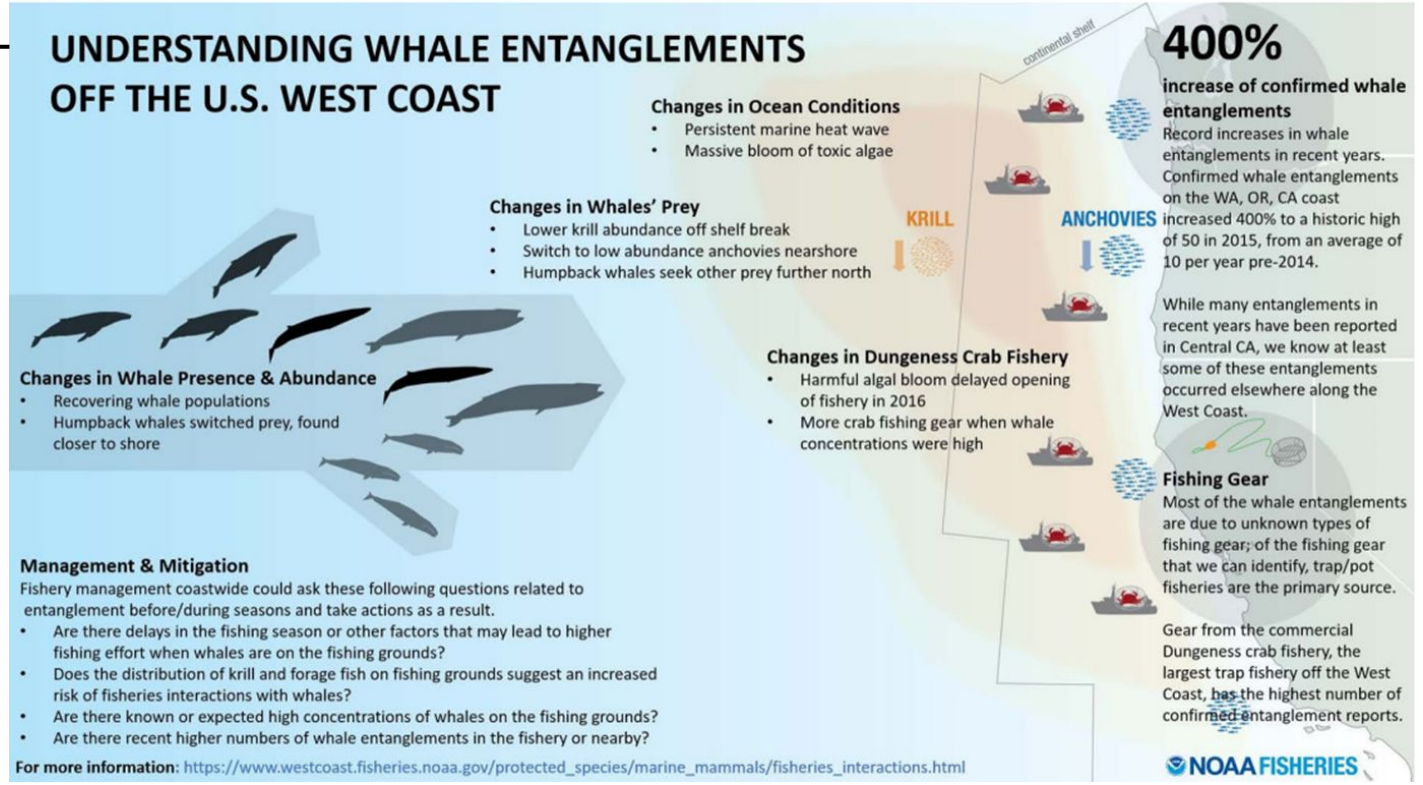
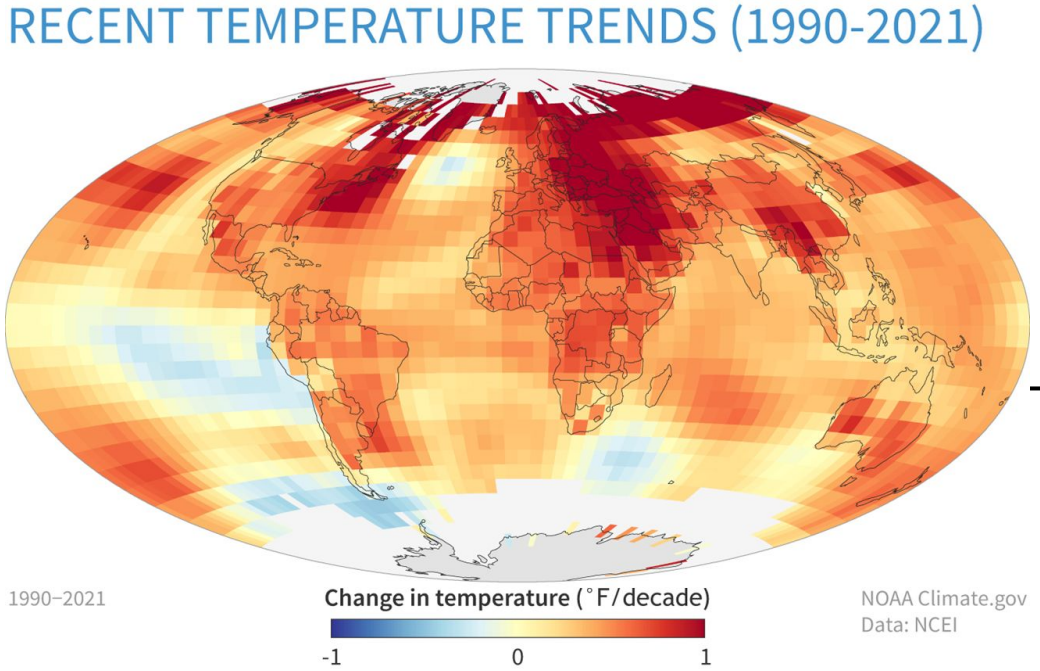


Figure 2. Time series of continuous surface O_2, O_2/Ar, O_2/Ar*, mixed layer averaged O_2 (CTD), and mixed layer float O_2 at each of the six stations. Diel O_2/Ar and O_2/Ar* changes are expressed as O_2 concentrations based on Equation 1, as described in text. Shaded gray areas denote nighttime periods. The dashed vertical lines mark the period used for calculation of production and respiration rates. Horizontal blue lines mark the 12-h ^{14}C, ^{13}C, and ^{18}O incubations periods. Mixed layer averaged float O_2 data for station 6 is shown in Supporting Information S1 since it was retrieved about 2 months prior to sampling at station 6. Note that a clear diurnal cycle was not observed at Stn 4 in the highly dynamic transition zone region.

Why should we care about Underway Measurements?
Time and Space: Long Time Scales

Temperature measurements contributed to understanding “the blob”, where a persistent marine heatwave was a factor in contributing to an increase in whale entanglements off the West Coast. [Publication]





The global average temperature in most locations is warming, sea surface temperature data collected from 1990 to 2021 across the globe has provided us with evidence that our climate is changing. [Publication]

Interactive Poll #1

Scan QR Code

or

Respond to poll here:

PollEv.com/katiewatkinsbrandt709

1. What is your experience/comfort level with flowthrough systems and sensors?
2. What is your biggest concern with flowthrough systems?
3. What issues have you experienced with flowthrough systems?
4. Do you conduct any field verification and/or field calibration on flowthrough sensors?

Interactive Poll #1

Scan QR Code

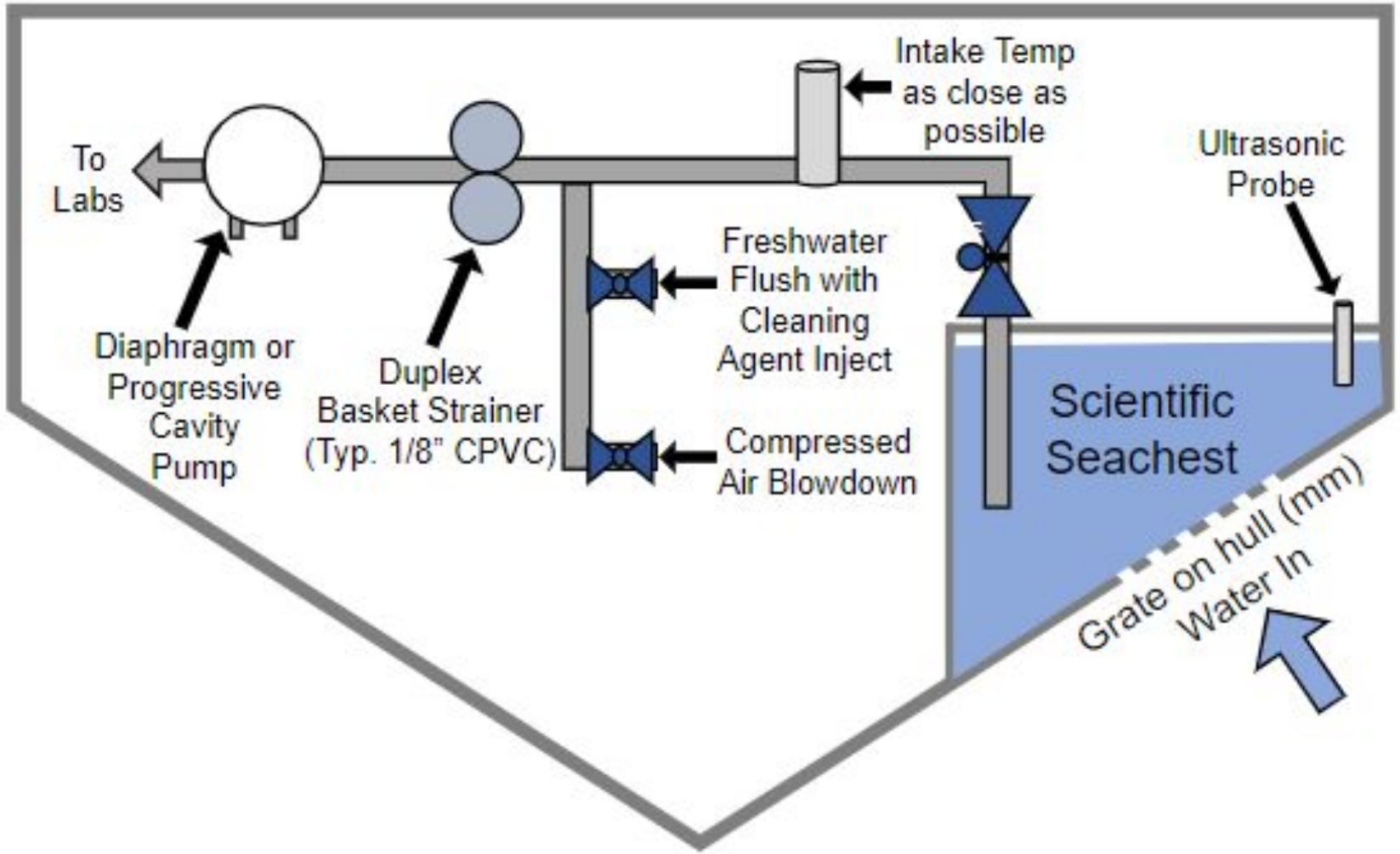
or

Respond to poll here:

PollEv.com/katiewatkinsbrandt709

1. What kind of science seawater pumps does your ship have?
2. What kind of science seawater piping does your ship have?
3. Does the ship regularly clean the scientific seawater system piping?

Flowthrough System:
Crash Course on Science Seawater System Design

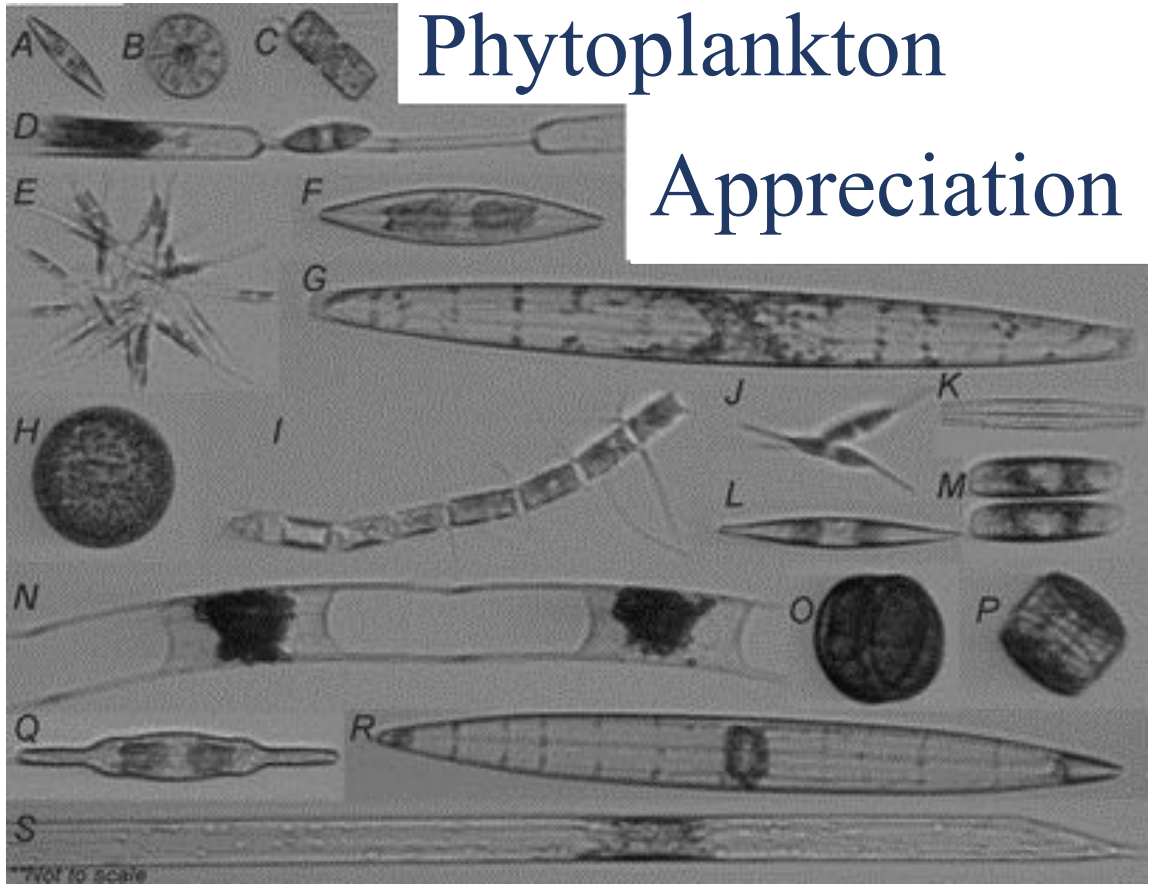


Knowing your system is the first step to ensuring quality data!

Considerations:

- Intake/s Depth
- Intake/s Location
- Seachest coating and/or cleaning capabilities
- Intake Temperature
- Piping and Insulation
- Cleaning mechanisms
- Basket strainers, value of duplex
- Pumps…shift from impeller

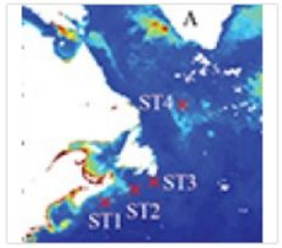
Phytoplankton Appreciation



Katie's Soapbox Moment…

- Take a deep breath
- CO_2 to O_2
- "Particles"
- Type of pump matters, impeller not great for particle integrity
  - If possible, work to integrate change to diaphragm ($) or progressive cavity ($$$) pumps

Optics Express Vol. 24, Issue 18, pp. 20703-20715 (2016) • https://doi.org/10.1364/OE.24.020703



Characterizing the phytoplankton soup: pump and plumbing effects on the particle assemblage in underway optical seawater systems

Ivona Cetinić, Nicole Poulton, and Wayne H. Slade

Author Information ▾ Find other works by these authors ▾

Uncontaminated Science Seawater System Maintenance

Cleaning cycle for scientific seawater system? How often should we run a cleaning cycle?

Full Article

GEOPHYSICAL RESEARCH LETTERS, VOL. 37, L01601, doi:10.1029/2009GL040423, 2010

Evidence of O_2 consumption in underway seawater lines: Implications for air-sea O_2 and CO_2 fluxes

Lauren W. Juranek,[1] Roberta C. Hamme,[2] Jan Kaiser,[3] Rik Wanninkhof,[4] and Paul D. Quay[5]

Work with the Engineers to flush the seachest and science seawater pipes with bleach at *regular intervals*

Regular intervals = depends on ship and where you are sailing, bleach cleaning effective for 45 days following treatment*

Is bleach the right treatment?

Freshwater flush after every cruise, jury out on value of either keeping freshwater in science seawater pipes or drain and dry.

Crash Course on Water Wall Design

- Know your system and sensors
  - To Debubble or Not to Debubble?
  - Order of Operations
  - Sensor Orientation
  - Flow Rate
- Tubing and Fittings
- Other Tips and Tricks

Flowthrough System:
Sensors, Maintenance, and Cal/Val Practices

Supporting infrastructure *briefly* discussed today:

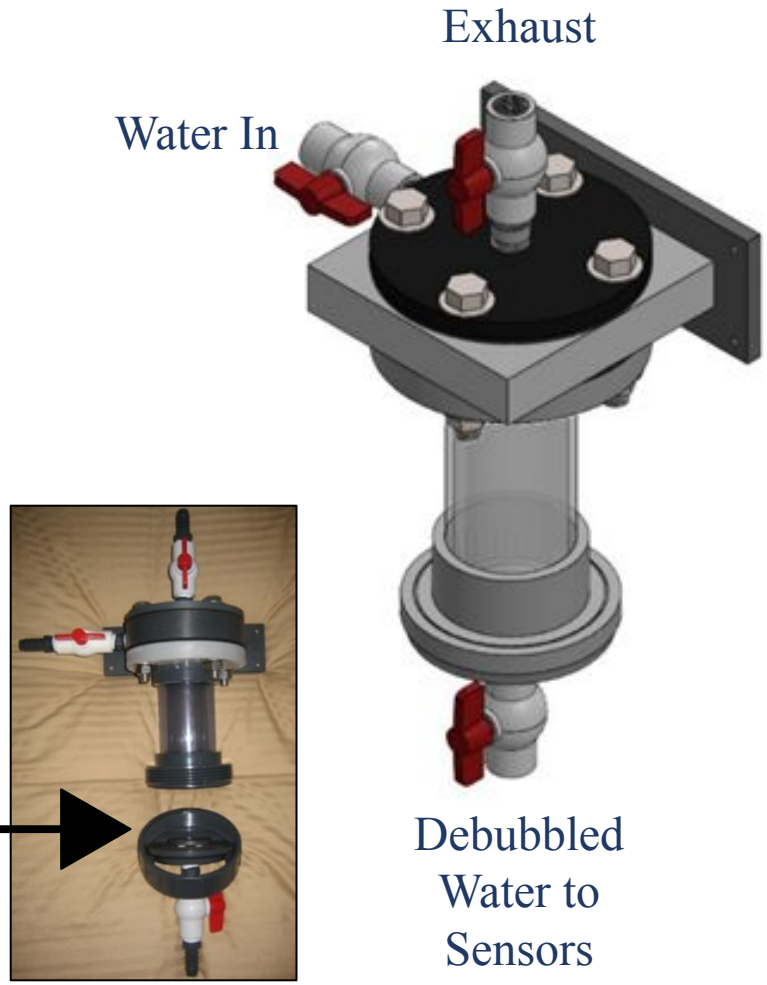
- Debubbler
- Flowmeter

Sensor Summary Table:

- Thermosalinograph
- Single Channel Fluorometer
- Multi-Channel Fluorometer/Scatterometer
- Transmissometer
- Dissolved O_2
- pH
- pCO_2

Debubbler

Vortex debubbler removes bubbles from sensor stream. Available in multiple sizes depending on required flow rate, most common:
2” at 9-12 L/min
3” at 18-24 L/min
Consider 25% exhaust in flow requirements



Maintenance:

- Add velcro neoprene or other black fabric to cover cylinder, reduce biofouling and insulate
- Bottom locking ring easy to remove for cleaning
- Cleaning frequency depends on operating environment but biofilms may build up without cylinder visually appearing dirty, add to end of cruise sensor cleaning practices

Flowmeter and Flow Rates

Flowmeters measure water flow within a system and are critical to monitoring flow and can be used to measure residence times within a system.

Various types available, most commonly used:

- Paddlewheel: Omega FPR Series Low cost (~$400), Accuracy ±1%, typically FPR301 (0.27 to 19 L/min)
- Electromagnetic (magmeter): Higher cost (~$1-3K), Accuracy ±0.5 to 2%, main advantage no moving parts

Flowthrough system general flow recommendation 2 to 10L/min[1]

[1]Great Reference for Best Practices Flowthrough Optical Data: https://ioccg.org/wp-content/uploads/2019/11/inline-protocols-4.0-nov2019.pdf

Sensor Summary

Each sensor has independent cleaning requirements, refer to best practices or SOP's.
PSA: Use lens paper only on optical faces, KimWipes are not good enough!

Sensor	Model/s	Recommended Factory Cal	To Debubble or to not Debubble?	Ideal Flow Rate	Supporting Measurements	Field Verification and/or Calibration Procedure/s
Thermosalinograph	SBE-45, SBE-21	Annual	Debubble	SBE-45: 0.6 to 1.8 L/min SBE-21: 1 L/sec	None	In-situ verification, Comparison to neighboring thermometers and conductivity sensors, Discrete salts sample collection
Intake Thermometer	SBE-38	Annual	Agnostic	None Provided	None	In-situ verification, Comparison to neighboring thermometers
Combination Fluorometer/ Scatterometer	Varied 3 Scattering/ Fluorescence	Annual	Debubble	0.8 to 2.4 L/min, higher better for decreased residence time	None	Dark counts, Fluorescence full-scale verification (when applicable), Discrete sample collection for pigments, Comparison to neighboring fluorometers
Fluorometer	WETStar, Turner 10-AU: Time to Phase Out!	Annual	Debubble	0.6 to 1.8 L/min	None	Dark counts, Fluorescence full-scale verification, Discrete sample collection for chlorophyll, Comparison to neighboring fluorometers
Transmissometer	C-STAR	Annual	Debubble	0.8 to 1.8 L/min	None	Clean water offsets, Dark, air and reference counts, Comparison to neighboring transmissometers
pH	SeaFET V2, Durafet III	Annual	Debubble	0.6 to 1.8 L/min	Temperature, Salinity and Pressure	Discrete pH sample collection, Comparison to neighboring pH sensors
Dissolved Oxygen	SBE-43, Aanderaa 4330	Every 6 to 12 months	Debubble	1.2 to 2.4 L/min	Temperature and Salinity	Discrete Winkler sample collection, Comparison to neighboring oxygen sensors, In-situ calibration for SOC adjustment (discrete samples or neighboring sensor), In-Air Tests
pCO_2	GO-8050/8060, LDEO, AS-P3	None, in-situ	Don't Debubble	Varies depending on sensor	Temperature, Salinity and Pressure	In-situ calibration with certified standards, Discrete samples of TCO2, pH, and/or DIC

To Debubble or Not to Debubble?

- Rule of thumb, if it uses light it's right to debubble (all optical), if it measures gas then pass (pCO_2)
- Others: TSG, O_2, and SeaFET V2 pH debubble to reduce noise in data

Bubbles are optics arch nemesis, when possible always push bubbles up and out with water in through the bottom and out through the top, create the path of least resistance

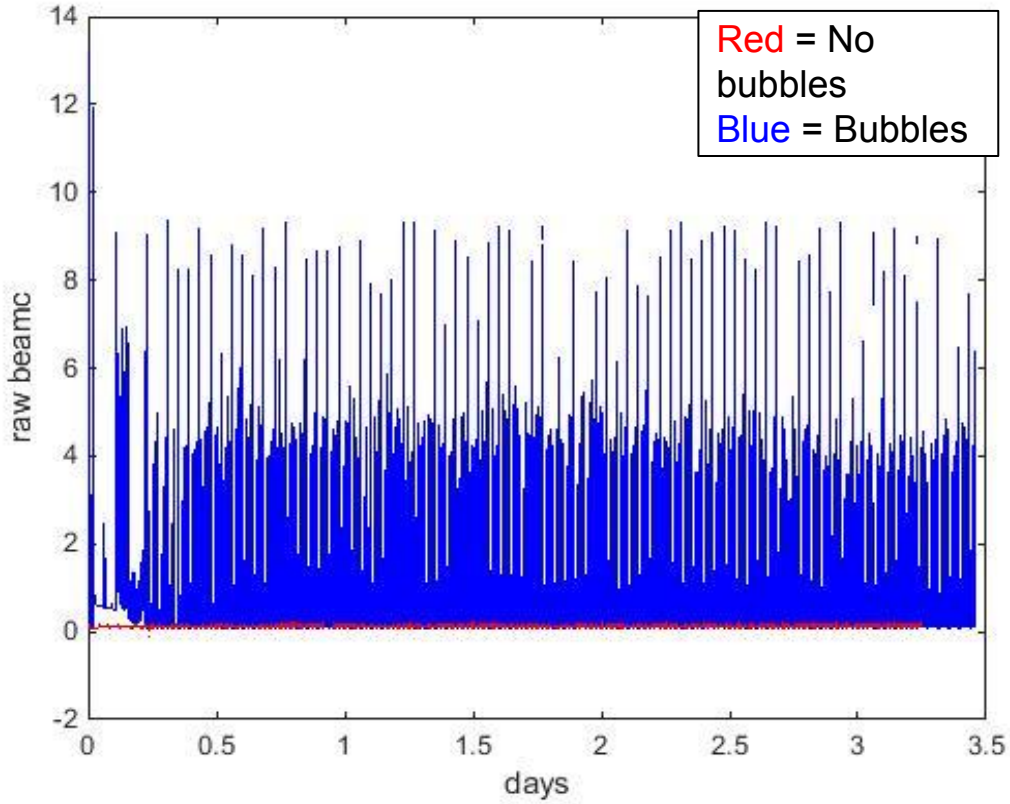
Other trouble with the bubble techniques:

- Backpressure downstream of sensors can be your friend and so can slightly higher flow rates
- Don't over tighten your tubing connections, overtightening hose clamps can introduce air into the stream, also check connections to ensure a seal (C-Star sleeves/faulty O-rings)
- Degassing Y at high point with valve to release air (air bleed)

What does noisy data due to bubbles look like?

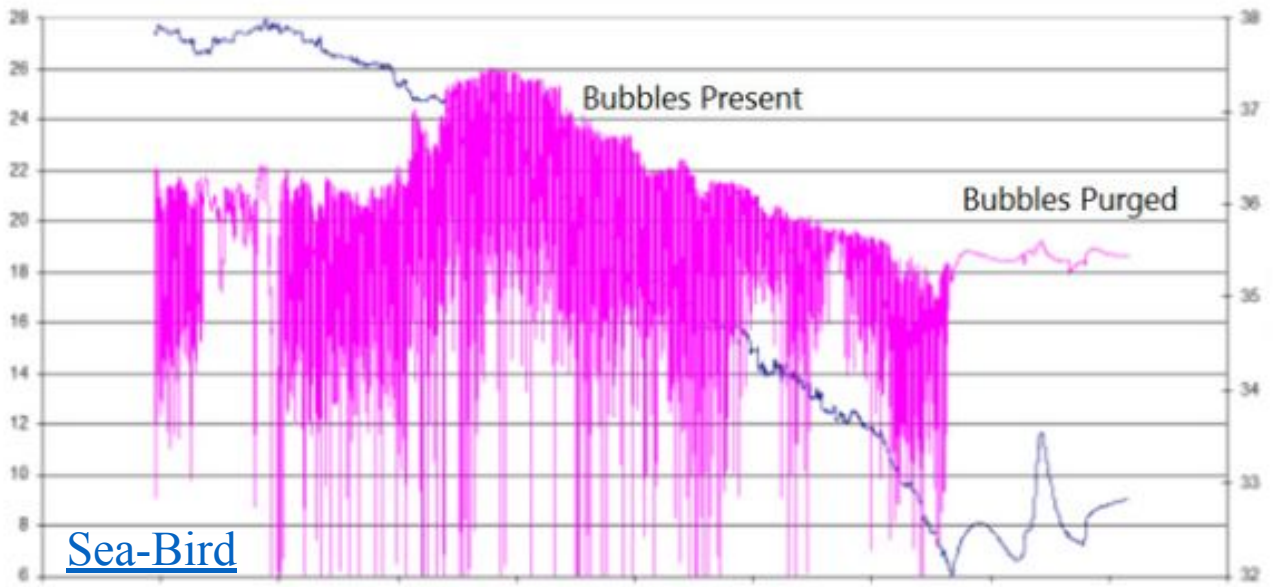
Example: C-STAR

Pretty typical bubble response for all optical sensors



Example: Conductivity Sensor

Pink shows when bubbles present (spikes typically display lower values) and when bubble purged



Tubing and Fittings

- Always maintain a full spare set of sensor tubing to easily swap after every cruise or as needed, do a check by inserting kimwipe into the tubing, see funk then replace
- Minimize tubing lengths but take caution to not create any vertical loops or tight bends in tubing
- Go dark, opaque tubing can help reduce biofouling
- Use quick connect fittings with check valves, where possible, to quickly remove tubing to service sensors
- Tubing type: semi rigid for quick connects like PEX OR Tygon R6303, Excelon 59062, Nalgene™ 180 for barb fittings
- Use Bleach, RBS™ 35 or TERGITOL™ to clean tubing, soak in solution overnight and rinse well with freshwater
- Note cleaning of tubing should not be done in-line, not all sensors are compatible with cleaning products

Order of Operations and Sensor Orientation

Active vs Passive Sensors:
Active: Sensors that may alter the stream and affect the measurements downstream (reagents, light), for fluorometers think ms to sec

Passive: Sensors that do not affect the measurements downstream (thermometer)

Sensor Orientation:

- Sometimes it matters, when at all possible mount sensor so water goes in through the bottom and out through the top
- Pay attention to flow path

Other Tips and Tricks

Light contamination: Pay attention to potential sources of light contamination that could affect your measurements or promote biofouling

Filtered signals for measurement of “particles”

Flowthrough Wall Design (materials/mounts):

- Materials and design to promote ease of maintenance and flexibility to mount (starboard, threaded inserts, etc.)
- Marine Tech 3-D printing repository for sensor mounts
- Flexibility in manifold design for users to easily plug into, union fittings are great

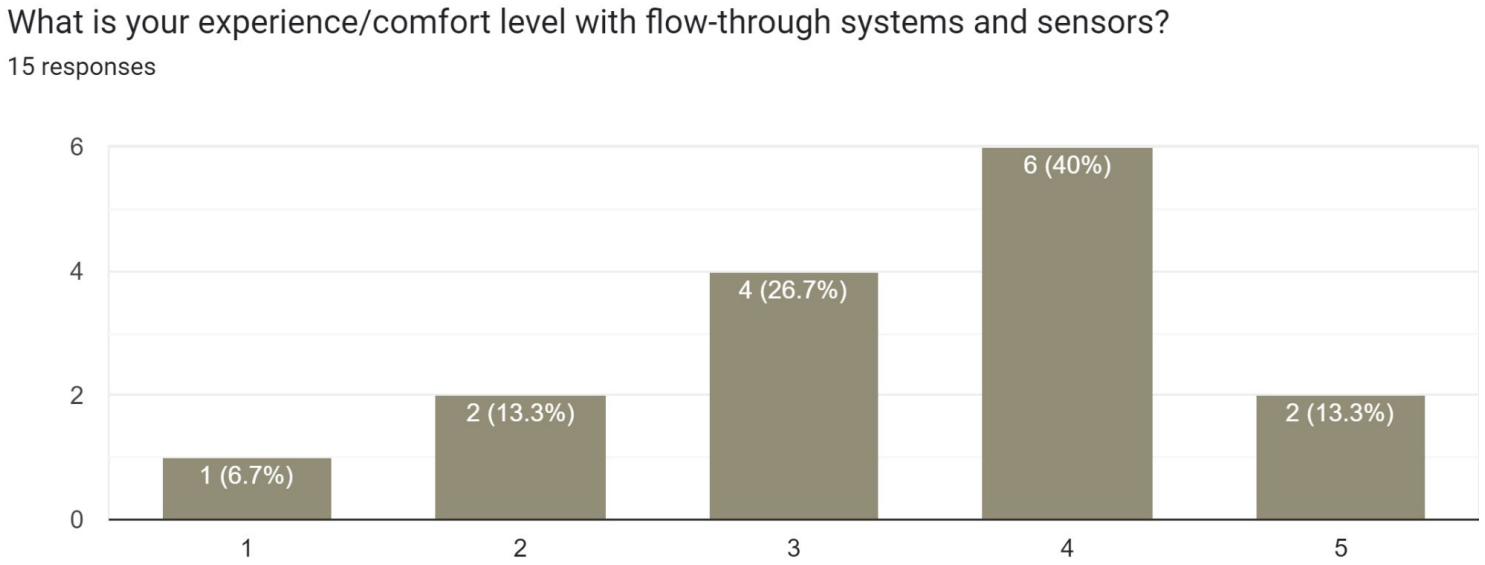
Interactive Poll #2

Scan QR Code
or
Respond to poll here:
PollEv.com/katiewatkinsbrandt709

1. What would you like to see included in the general flowthrough best practices document? You can vote on the different ideas submitted.
2. How would you like to see documents like this get shared to the community?
3. What is your affiliation and position (Tech, Engineer, etc.)?
4. Are you interested in participating in this working group? If yes, please include your email.

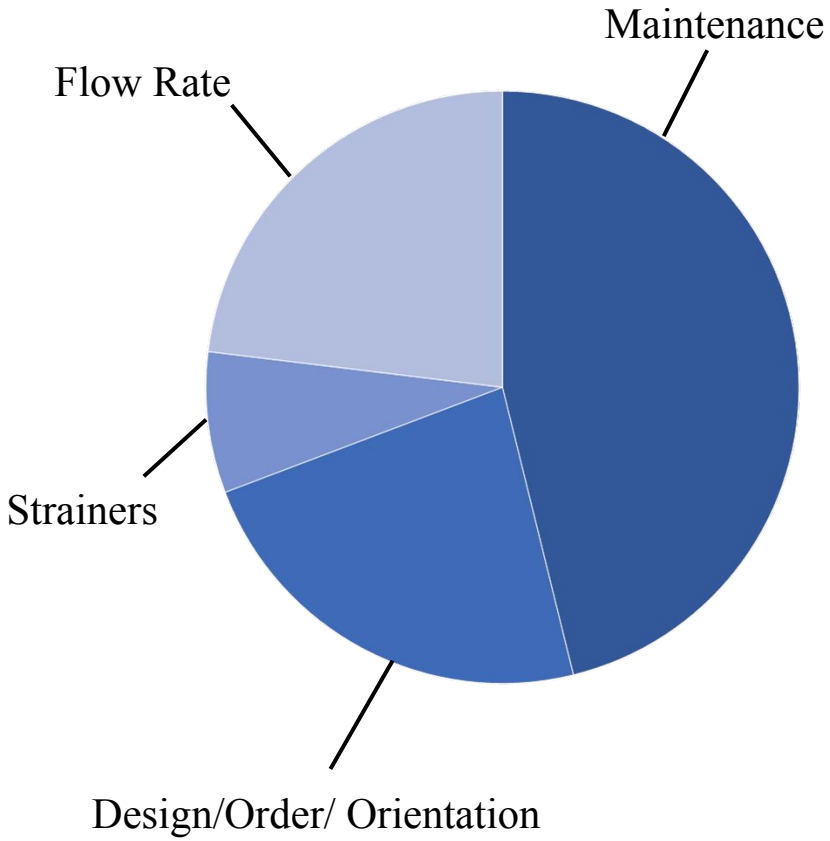
Discussion

WWWW Survey Results: Flowthrough Systems



Note that 1= uncomfortable/little experience to 5 = very comfortable/experienced

Challenges



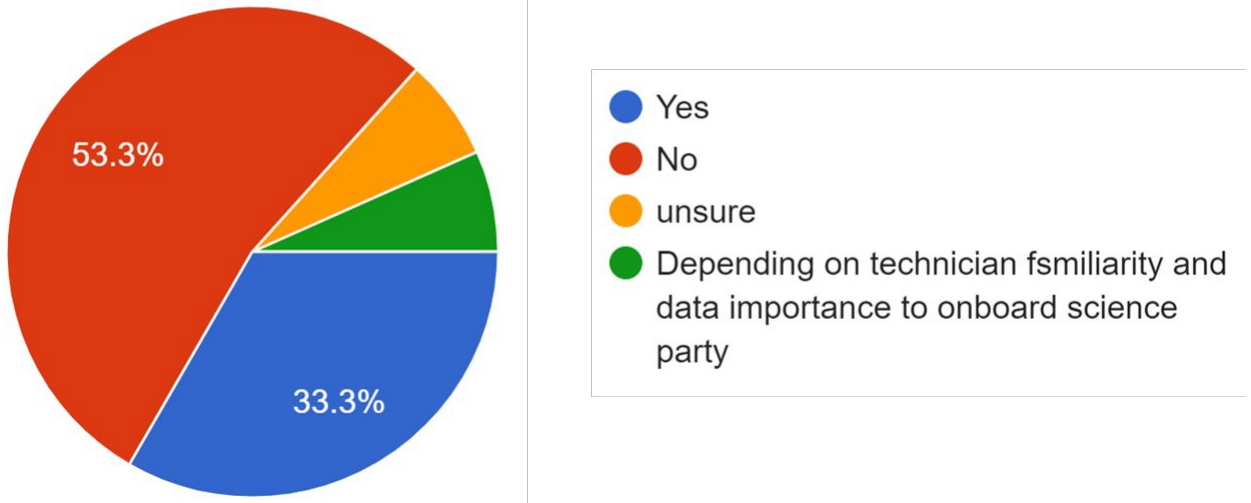
Survey Results: Calibration and Verification

What is your typical calibration timeline for Flowthrough sensors?

14 responses

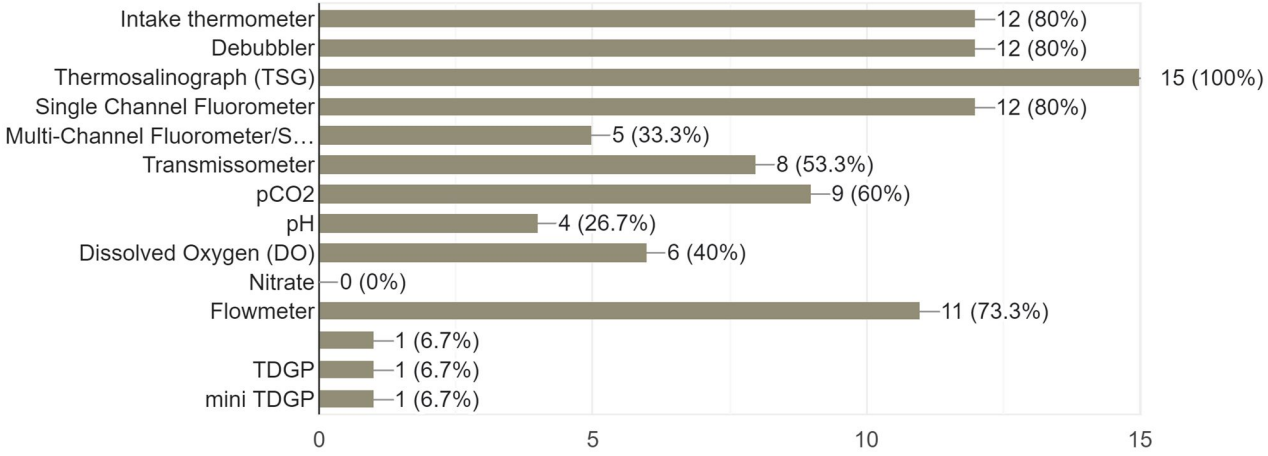
Do you conduct any field verification and/or field calibrations on MET or Flowthrough sensors?

15 responses



What Flowthrough sensors are part of your ship's underway systems? (check all that apply)

15 responses



If Yes, what?

- Regular bottle samples for salinity, pH, regular check on inline DO against handheld sensor
- Field calibration on flowthrough Transmissometer and ECO Fluorometer
- We sometimes do field calibrations of the Transmissometer