## DIY Niskin Bottle Activity

Time
4+ hours

Schedule

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|---|---|
| 15 min | Introduction |
| 30 min | Sampler design exercise |
| 2 hrs | Sampler construction |
| 45 min | Sampler tuning & adjustment |
| 15 min | Clean up |
| 15 min | Discussion |
| Variable | Field deployment |

### Introduction

One of the challenges facing early oceanographers was how to understand the vertical structure of the ocean. Mapping out salinity or temperature gradients at the ocean's surface was simple enough, but determining the characteristics of deeper water required technologies that had not yet been developed. Complicating the matter, many of the methods for characterizing seawater were dependent on lab equipment, requiring samples to be brought up from the depths onto the decks of oceanographic research vessels. Bringing subsurface samples through the water column introduced the possibility of contamination, so the samplers required a means of isolating their contents during the trip to the surface. An early solution was invented by Fridtjof Nansen, and was subsequently improved upon by Shale Niskin in 1966. These days, many oceanographic measurements are made by sensors lowered through the water column, nevertheless, many measurements are still dependent on lab techniques. For these methods, Niskin bottles remain the standard means by which oceanographers acquire their deep-water samples.

### Sampler Design Exercise

Like most technologies, oceanographic sampling tools are developed through an iterative process of design and testing. Ideally, the students would go through a similar process of building a sampler, gathering data, then evaluating those data for accuracy and freedom from bias. To speed things along, we instead use a discussion to simulate the design and testing process, soliciting designs from the students, then providing them with the data that their sampler-design would most likely yield (complete with bias!) This takes a certain degree of artifice, but with a little background you should be able to guide your students to an appropriate design.

Inform your students that they have embarked on an oceanographic research cruise to investigate the characteristics of deep water. Together with your colleagues, you have hypothesized that there may be density differences with depth -- most likely driven by salinity and temperature -- that may provide clues about processing occurring in the open ocean. You have a full team of machinists on board who can build your sampling devices to whatever specifications you desire. How do you proceed?

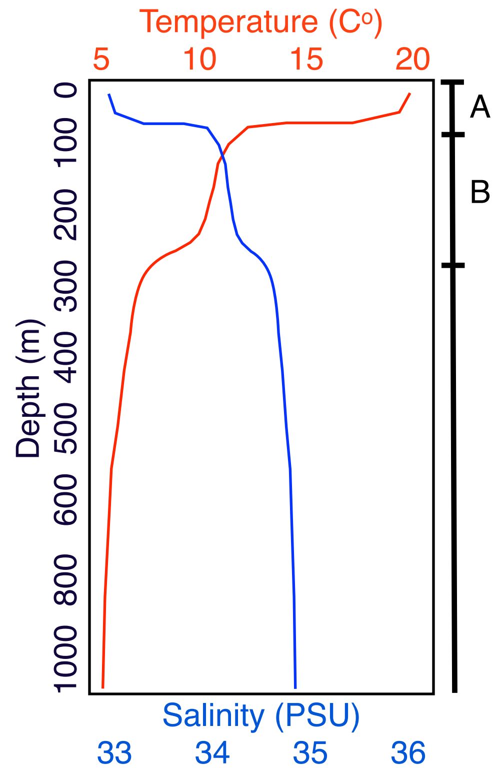


Fig. 1 Actual vertical profiles of salinity and temperature that the students hope to visualize with their samplers.

This exercise makes use of the scientific method. The students propose a sampler design, you then draw the vertical profiles of temperature and salinity that their imaginary sampler generated on deployment, the students generate hypotheses to explain the data you provide, then they test their hypotheses by revising their sampler designs and evaluating the new temperature and salinity profiles that are collected by them.

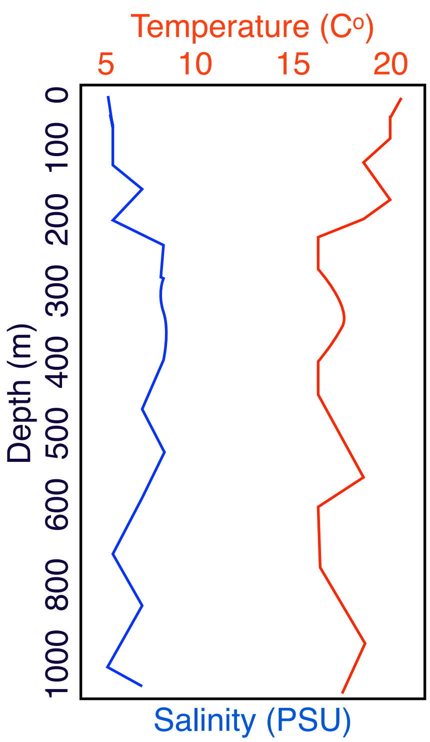


Fig. 2 Vertical profiles of salinity and temperature generated by a bucket-on-a-rope sampler

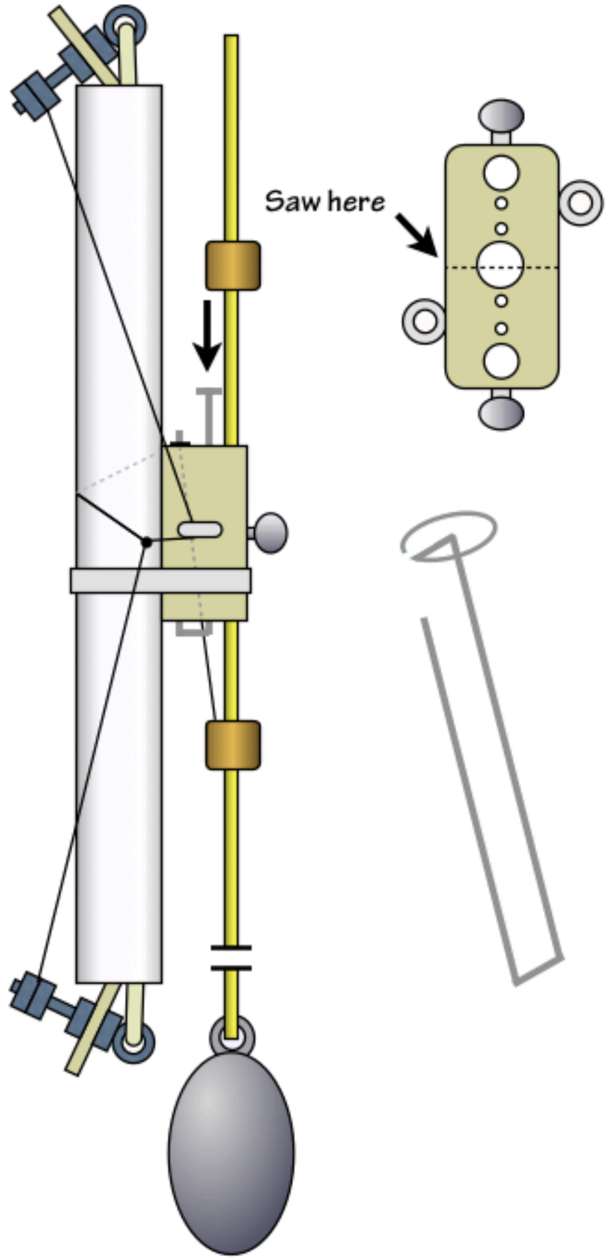
It is impossible to anticipate all the designs students may propose, but the sources of bias with water samplers are somewhat limited, being primarily associated with poorly isolating the samples while they make the journey to the deck of the ship. With a good sampler design that effectively isolates the samples, an oceanographer would generate a profile like that shown in Figure 1. Temperature will be warmer near the surface, and constant down to some depth (A) -- this is the region that is currently being well mixed, primarily by winds. Below that, the temperature declines quickly to another region of relatively constant temperature (B) -- this region is the signature of the previous years' most energetic mixing events, driven by winter storms, and extends much deeper than the summer near-surface thermoclines.

A typical first-try sampler design is a bucket with a rope. Such a device is likely to create mixing between the sample and the adjacent waters as it is hauled up from the sampling depth (did the students remember to include marks on the rope so they could target a particular depth? And did they weight the bucket so it would descend vertically and not be horizontally displaced by the currents?) Because of the mixing, the bucket-on-a-rope sampler might produce profiles like those in Figure 2. In other words, no matter what depth a sample is brought up from, on the deck it tends to look like surface water.

Draw the profile you expect the students' sampler design would produce, and ask the kids if they trust their results. Ask them why they do or don't. This is the place to introduce the concept of bias -- how does the design of their sampler bias the data that they have received? Have the students hypothesize why their sample data look strange, and propose a new sampler design that tests that hypothesis.

Repeat this process, guiding the students (in as subtle a manor as possible) towards the DIY Niskin Bottle design included in this activity. Help the students intuit the most important qualities of a good sampler: accurate readings of depth; a bottle that flushes itself while being transported to the target depth; some sort of trip mechanism that closes the bottle at the target depth; and the ability to keep the sample chemically and thermodynamically isolated during the trip to the deck of the ship. Once they have agreed upon a set of features that will ensure unbiased samples, introduce the DIY Niskin Bottle plans as the technical specs created by the marine technicians. Inform the students that this is what they will build and use in the field!

## DIY Niskin Bottle Plans




Materials
1” PVC pipe (14 inches)
Pine 2x4 (3 inches)
1½ ” wooden disks (2)
2” #22 eye bolts (2)
#22 nuts (8)
#22 wing screw (1)
Heavy nylon monofilament (24”)
Monofilament crimps (4)
¼” Silicone hose (14 inches)
Hose clamp (6 inch diam.)
Heavy wire (10 inches)
Lead weight (~1lb)
¼” Nylon braided line (50’)
#6 washers (8)

Tools
Drill press or hand drill
Tablesaw or hand saw
Sandpaper
Crescent wrench
Electrical tape
Pliers
Files

Instructions
A great deal of time can be saved by preparing as much of the materials ahead of time as possible, leaving the class time reserved for assembly. Cutting, drilling, and sanding the pine mount blocks and PVC pipes, snipping wires and nylon monofilament for the trip mechanism, and drilling the wooden discs can all be completed outside the class. The mount block in particular is time consuming to construct, requiring 7 vertically oriented drilled holes and a saw cut down the middle for each pair. The vertical holes should be drilled with a press, but a hand-held drill may be substituted if you are extremely careful to make the holes straight and parallel to each other. Reducing the length of the mount block makes the drilling easier, but may reduce the stability of the sampler during deployment. The holes drilled

through the centers of the wooden discs should also be straight to facilitate a clean seal when the sampling tube snaps closed.

Step1 - Attach pine mount block to sample tube using the hose connector.
Step 2 - Install eye and wing screws to the mount block.
Step 3 - Bend the trip mechanism wire to form a tall U-shape, being careful to make the width exactly equal to the distance between the two smaller holes in the mount block. The wire should slide easily into and out of the mount block holes.
Step 4 - Insert the trip mechanism wire as far into the block as it will go, then clip the wire closest to the sampling tube about ¼ inch from the top of the mount block, and use a file to smooth and round the end.
Step 5 - Put a 90 degree bend in the other wire about ¾ inch above the block, and continue the bend into a ring, as in the diagram.
Step 6 - Assemble the end caps, attach the rubber hose one cap's eye-bolt, pass the rubber hose through the tube and attach it to the other cap's eye-bolt. Attachment may be achieved using a simple knot, or by inserting an object into the hose to prevent it slipping back through the eye of the eye-bolt (an extra nut does this job nicely). Trim the excess tubing. The hose should hold the end caps tightly against the straight-cut and sanded ends of the sample-tube.
Step 7 - Using the crimps, create loops in the ends of two 12" pieces of monofilament line.
Step 8 - Pull the trigger mechanism into position, and set one of the monofilament loops over the release pin (the wire tip that was smoothed and rounded). Bring the monfilament line around the sampler tube, thread it through the other 12" piece of monofilament line and up through the mount block eye-screw to the top end cap.
Step 9 - Pull the upper end cap into it's cocked position, wrap the monofilament line around the eyebolt between the upper two nuts, then tighten the nuts to hold the line in place.
Step 10 - Pull the second piece of monofilament line down to the lower end cap, and attach it in the same manner used for the upper end cap.
Step 11 - Being careful to avoid getting your fingers pinched by the end caps, cock and trip the sampler to test it's functionality. This should take significant tweaking to get good results. Try adjusting the lengths of the monofilament lines, the arrangement of the endcaps while in the cocked positions, or the distance the eyebolt eyes extend beyond the surfaces of the endcap discs.

<u>Discussion</u>

After the students have cleaned up, have them discuss their experiences tuning the triggers to work well. Did they generate different methods for setting up and triggering their samplers? What problems do they anticipate encountering in the field? What sorts of precautions should they observe when gathering gear for the field deployment? Are there any backup supplies that might be wise to bring?

Deployment

Deploying your samplers requires a few more preparatory steps. First, have your students mark the line you are using to deploy your samplers with. Use one color for every meter, and a second for every five meters. Spray paint works well for this (but be sure to do it outside on a safe surface!) You will also need to assemble the “messenger” -- the weight that descends the line to trip the sampler when it reaches the target depth. For this, stack the eight #6 washers, and wrap them with vinyl electrical tape. Once you are in the field and ready to deploy, thread your line through the messenger, then through the mount block of your sampler, then tie the end to the weights. Adjust the position of the sampler high enough from the weights to avoid bumps, and set in position by tightening the wingnut. Once you are on station, pull the messenger up the rope so that it stays with you and doesn’t go over the side! Lower the sampler, having the students count the meter markers out loud until the target depth is reached (don’t forget to account for the distance of the sampler from the end of your line!) Once your sampler is at depth, have a student release the messenger down the line. You may feel the sampler snapping closed through the line if you are holding it by hand, but don’t count on it! Make sure you give enough time for the mechanism to trigger before you start hauling your sampler up. Once you have your sampler on deck, position it over your sample jar and pull back the lower endcap to release the water.

If the students want an additional challenge, they may want to try and collect multiple samples with one deployment. To do this, you will need to create special messengers that are triggered by the original messenger. These messengers are exactly like the main one, but are tied to a piece of monofilament line that loops around the trigger pin as in the diagram. When the first messenger triggers the release mechanism, it closes the sample tube *and* releases the secondary messenger, which descends the line to trigger a sampler positioned lower down the line. Using this method, you can string together as many samplers along the line as you like. Of course, the more samplers you use, the more chances there are for one of the mechanisms to malfunction. It takes a great deal of skill and experience to effectively utilize these tools -- a fact that is well known to professional marine technicians. How many linked samplers can your students successfully deploy?