Bermuda Biological Station For Research, Inc.
Bermuda Atlantic Time-series Study

Chapter 20. Trap-Collected Particle Flux with Surface-Tethered Traps

Updated by: K. Gundersen (April 1997, September 1992); N. Bates (April 1991)
Prepared by: M. Tuel and S.E. Lohrenz (October 1989)

1.0 Scope and field of application

This procedure describes a method for the determination of the sinking fluxes of particulate matter and particulate carbon and nitrogen in seawater, expressed as mg $m^{-2}day^{-1}$. The method is suitable for the assay of all levels of sinking flux found in the ocean. This method was developed by Knauer *et al.* (1979) and used extensively in the VERTEX program. As described here, this method does not conform to all of the recommendations of the U.S. JGOFS Planning Report #10 on sediment trap sampling and technology. It is presented as an example of a widely-used technique. There is no consensus in the JGOFS community on the appropriate methods for trapping.

Sediment traps are the only tool for directly collecting the rain of sinking particles in the ocean. They are largely uncalibrated in the field and there are significant unresolved questions on the accuracy and precision of sediment traps. Any investigators that decides to use sediment traps should become aware of all facets of this controversy and make their own decisions about the appropriate methods to use. The U.S. JGOFS Planning Report #10 provides an overview of these issues and there have been significant published papers on trap accuracy since that report.

2.0 Definition

2.1 *Total particulate mass flux* is defined as the amount of sinking particulate matter passing through a depth level as:

Total Mass Flux= mg dry weight m^{-2} day^{-1}

2.2 *Total particulate carbon flux* is defined as the amount of sinking particulate organic carbon passing through a depth level as:

Total Organic Carbon Flux= mg carbon m^{-2} day^{-1}

2.3 *Total nitrogen mass flux* is defined as the amount of sinking particulate organic nitrogen passing through a depth level as:

$$\text{Total Organic Nitrogen Flux} = \text{mg nitrogen } m^{-2}day^{-1}$$

3.0 Principle of Analysis

Fluxes of sinking material are measured using sediment traps (Knauer *et al.* 1979). In the BATS program, these are simple cylinders suspended at various depths from surface and subsurface floats. These cylinders collect sinking particles. It is assumed that the collection of particles is linearly related to the aperture area of the sediment trap and that this collection is an accurate estimate of the mass of sinking particles at that depth and the particle sinking speeds. Hydrodynamic and other biases influence the collection of material by sediment traps and the interpretation of trap data should be approached with caution.

4.0 Apparatus

The design of the array used in the BATS program is shown in Figure 6.

4.1 *Particle Interceptor Traps* (PITs). The particle collection device central to the Multitraps is a polycarbonate cylinder (cross-sectional collection area = 0.0039 m^2). The cylinder is equipped with a base which holds a 90 mm Poretics polycarbonate membrane filter. A drain valve is mounted under the base of the filter holder. At the surface of the cylinder, plastic baffling consisting of circular openings 1.2 cm in diameter provide turbulence reduction at the trap opening.

4.2 *PITs Frame.* A cylindrical stainless steel PITs rack (1 m in diameter) allows for mounting of up to 15 sediment trap cylinders at each depth. The stainless steel frame is attached to the 1/2 inch polypropylene line by stainless steel shackles. The prepared PIT cylinders are held in place on the stainless steel frame by hoseclamps that are protected with Tygon® tubing. Stainless frames with PITs are attached at 3 depths: 150, 200 and 300 meters.

4.3 *Flotation Gear.* At 90 m depth, a polypropylene line is attached to a stainless swivel, which is attached to a stainless steel chain with two 17 inch diameter glass floatation spheres covered by a polyethylene "hard hat" housing. At the surface the polypropylene line is attached to a 10 m double length of 1/2 inch bungi cord connected to a 5/8 inch double braided Duralon line with 8 orange polypropylene A2 floats. The entire flotation array is secured to a surface spar.

4.4 *Surface Spar.* The surface spar consists of a styrofoam core float with a central mast on which is mounted a VHF radio beacon (Novatech), strobelight (Novatech), and ARGOS transmitter.

4.5 *Current Meter.* At BATS we usually deploy an Aanderaa RCM-current meter at 160 m depth. This instrument records time, pressure, temperature, flow speed and flow direction. It records a vector average flow speed and direction at one minute intervals and records the instantaneous measurements every minute for the other parameters. In previous experiments we have deployed a custom-built hydrodynamic sensing package (HDS) that uses microsensing flowmeters based on the hot-wire principle. These packages record flow at four locations on the trap array at 5 Hz plus a variety of other hydrographic parameters (Gust *et al.*, 1994)

5.0 Reagents

5.1 *Hydrochloric acid* (12N, Baker Instra-Analyzed): diluted to make cleaning solutions.

5.2 *Formalin* (reagent grade)

5.3 *Sodium chloride* (reagent grade)

5.4 *Density Gradient Solution.* A density gradient solution is used to reduce advective-diffusive exchange of trap contents with ambient seawater during deployment. The density gradient solution is prepared by adding 1 l formalin and 2.5 kg NaCl to 50 l seawater, yielding a 2% formalin and approximately 86 g l^{-1} NaCl solution. The solution is gravity filtered through a 0.5 µm cartridge membrane filter (Millipore) and used to fill the PITs prior to deployment. A one liter portion of this gradient is saved for subsequent processing steps (see below).

6.0 Sampling

6.1 *Pre-sampling preparation*:

6.1.1 *Filter Preparation.* Poretics polycarbonate membrane filters (90 mm diameter, 0.8 µm pore size) are soaked overnight in 1.2N HCl (Baker Instra-Analyzed), rinsed with further 1.2 N HCl, rinsed three times with Milli-Q water and placed in individual plastic petri dishes. The cleaned filters are oven dried (65° C for a couple of days), allowed to cool in a desiccator, and tared to constant weight on an analytical balance (Sartorius R160P).

6.1.2 *Trap Cleaning Procedure.* The porous polyethylene filter frit is rinsed in Milli-Q, soaked for 24 hours in 1.2 N HCl, and rinsed with Milli-Q three times. All other trap parts are soaked overnight in a dilute Aquet Manostat detergent solution, rinsed thoroughly in tap water to remove the detergent, soaked 24 hours in 0.6 N HCl, and then rinsed in Milli-Q. The PITs are assembled while wearing latex gloves. The prepared Poretics filters are attached to the base of the polycarbonate cylinders together with the porous filter frit and covered by the filter holder with the drain valve. Polyethylene tape is used to provide a seal between the filter holder to the cylinder. The assembled PITs are stored covered with red polyethylene caps.

6.2 *Deployment and Recovery*:

6.2.1 *Deployment.* Prior to deployment, the PITs are filled with density gradient solution and mounted on the frames. Three PITs are mounted on each of three frames, which are deployed at 150, 200 and 300 m. Polyethylene caps are kept on the PITs until each frame is attached to the line and about to be submerged.

The trap array is deployed for a minimum of 72 hours. Generally the array is deployed as the first cruise procedure (see Chapter 2). The location of the trap is checked periodically during the deployment.

6.2.2 *Recovery.* The traps are covered with red polyethylene caps before they are removed from the frame. The seawater at the top of the trap is siphoned off to just above the level of the visible density interface using acid-rinsed (0.6 N HCl) rigid Teflon® tubing. The density gradient solution is drained through the bottom of the trap and discarded. The Poretics filter is removed, returned to its petri dish, sealed with Parafilm and labeled. The filters are stored in the refrigerator until analyzed.

7.0 Sample Processing Procedures

7.1 *Picking Swimmers.* The "swimmers" (recognizable zooplankton) are removed using forceps under a dissecting microscope (12–50 power magnification). The filters are kept wet during this period by adding small volumes of the saved density gradient solution (see above). The zooplankton (down to less than 100 µm in size) are removed with very fine-tipped forceps and placed into small vials with some of the reserve trap preservative. The vial contents can later be used to assess the effectiveness of swimmer removal (see Section 9.2). Manual removal of swimmers is a time-consuming process and still may leave significant swimmer material behind (e.g. see Michaels *et al.*, 1990). It is however superior to screening or other indirect methods.

Screening can remove very large passively sinking particles, but will not remove swimmers that are smaller than the mesh.

Manual picking of swimmers is a subjective exercise. Some labs remove only the largest zooplankton and some attempt to pick the samples at sea where the ship motion can reduce the ability to discern the smaller zooplankton. As there is no absolute standard to compare sediment traps with, there is no absolute way to determine the effectiveness of the swimmer removal by any lab. In the BATS deployments, it generally takes 4-12 hours to remove the swimmers from each PIT tube after a three day deployment in this oligotrophic regime (see Section 9.2 for additional techniques to assess the swimmer problem).

7.2 *Mass Flux.* The material on the filter is scraped into a bolus at the center of the filter with a scalpel and salts are removed by rinsing with Milli-Q water adjusted to pH 9 with ammonium hydroxide. The filter with the sample bolus is oven dried (65 °C), placed in a dessicator and weighed daily until the weight is constant (± 0.01mg) for 2 consecutive weighings.

7.3 *Particulate Carbon and Nitrogen Analysis.* Carbon and nitrogen analyses are performed using a Control Equipment Corporation (CEC) 240 XA elemental analyzer calibrated with acetanilide. The bolus is scraped off the filter with a scalpel and ground in an agate mortar. The whole sample (50-300 µg) is transferred to a silver boat and weighed on a CAHN Electrobalance (Model 4400). The silver boats are put in wells drilled in a Teflon block, and fumed with concentrated HCl for 36 hours to volatilize inorganic carbon. The fumed boats are desiccated overnight and then analyzed for total nitrogen and organic carbon. The results from the CHN analysis yield %C and %N.

8.0 Calculation and expression of results.

8.1 *Mass flux.* The mass flux is calculated as follows: The mass weight minus the tare weight of the filter divided by the number of days deployed and the by the trap cross-sectional area (0.0039 m^2) equals the mass flux (mg m^{-2} d^{-1}).

$$Mass\,flux\ (mg\,m^{-2}day^{-1}) = \frac{(M_w - F_w)}{D \cdot A}$$

Where:

M_w = mass weight
F_w = filter weight
D = days deployed
A = trap area

8.2 *Particle flux.* CHN analysis yields the %C and %N determinants. Particulate flux (mg N or mg C m^{-2} d^{-1}) is then calculated by multiplying the %C or %N by the mass flux.

Particle flux (mg C or mg N) = Mass flux × %C (or %N)

9.0 Quality Control and Assessment

9.1 *Hydrodynamics.* Although there are few field data, published reports indicate that flows above 15 cm s^{-1} at the trap mouth probably cause biases in trap collection. There is a large but insufficient literature on trap hydrodynamics (see U.S.JGOFS Planning Report # 10, Gust *et al.*, 1994).

9.2 *Swimmers.* The effectiveness of swimmer removal can be determined by examining a replicate PIT sample (different tube) with a different technique. The swimmer tube(s) should be deployed in the same way as the mass flux tubes. On recovery, the entire tube contents (after siphoning the upper, exchanged solution) should be transferred to a sample bottle (approximately one liter of liquid). This solution should be allowed to settle for a few days, then the supernatant gently siphoned off. By repeating this process, the sample can be gently concentrated down to a manageable volume (size will depend on the amount of material). This sample can then be counted in much the same way as a plankton tow. The numbers and sizes (values that can be converted to biovolumes or carbon units) of zooplankton can be counted on both a dissecting microscope and an inverted compound microscope using quantitative techniques. The picked swimmers from each of the mass flux traps can then be counted with the same techniques (they are saved after removal from the filters). By comparing the zooplankton in the complete sample(s) with the zooplankton actually removed, the biovolume of unremoved zooplankton can be calculated. Some zooplankton from each of the dominant unremoved swimmer taxa should then be measured for biovolume and carbon content to create a conversion factor for relating the unpicked biovolume to the total measured carbon. This allows a first-order correction for the residual swimmer problem. In practice it is often of similar magnitude as the passive flux in shallow traps (Michaels et al., 1990).

10.0 References and Related Literature

Baker, E. T., Milburn, H. B. and Tennant, D. A. (1988). Field assessment of sediment trap efficiency under varying flow conditions. *J. Mar. Res.* **46**: 573-592.

Coale, K. H. (1990). Labyrinth of doom: A device to minimize the "swimmer" component in sediment trap collections. *Limnol. Oceanogr.* **35**: 1376-1381.

Gust, G., A.F. Michaels, R. Johnson, W. G. Dueser, W. Bowles. (1994). Mooring line motions and sediment trap hydrodynamics: *in-situ* intercomparison of three common deployment designs. *Deep-Sea Research.* **41**: 831-857.

Honjo, S. (1978). Sedimentation of materials in the Sargasso Sea at 5367m deep station. *J. Mar. Res.* **36**: 469-492.

Hurd, D. C. and Spencer, D. W. (1991). Editors; Marine Particles: Analysis and Characterization. *Geophysical Monograph 63*. AGU. Washington DC. 472p.

Knauer, G.A., J.H. Martin and K.W. Bruland. (1979). Fluxes of particulate carbon, nitrogen and phosphorus in the upper water column of the northeast Pacific. *Deep-Sea Research* **26A**:97-108.

Knauer, G. A., Karl, D. M., Martin, J. H. and Hunter, C. N. (1984). In situ effects of selected preservatives on total carbon, nitrogen and metals collected in sediment traps. *J. Mar. Res.* **42**: 445-462.

Lee, C., Hedges, J. I., Wakeham, S. G. and Zhu, N. (1992). The effectiveness of various treatments in retarding bacterial activity in sediment-trap material and their effects on the collection of swimmers. *Limnol. Oceanogr.* **37**:117-130.

Michaels, A. F., Silver, M. W., Gowing, M. M. and Knauer, G. A. (1990). Cryptic zooplankton "swimmers" in upper ocean sediment traps. *Deep Sea Res.* **37**: 1285-1296.

US GOFS Working Group (1989). Sediment Trap Technology and Sampling. Planning Report No. 10. November 1988. WHOI, USA.

Verardo, D. J., Froelich, P. N. and MacIntyre, A. (1990). Determination of organic carbon and nitrogen in marine sediments using the Carlo Erba NA-1500 Analyser. *Deep Sea Res.* **37**: 157-165.

Figure 6. The surface-tethered sediment trap array.