

Goal Plan Sampling Requirements by Platform

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This document describes details for the measurements and sampling to be conducted in the EXPORTS Goal Plan implementation.

Ship-Based Sampling Requirements and Operations

CTD/Rosette: Redundant, high quality CTD measurement with high-quality O₂ sensor, ≥24 place rosette system with ≥10 liter bottles, chlorophyll fluorometer and 660 nm, 25 cm-path beam transmissometer. In situ PAR (scalar irradiance) measurements are required with shading minimized along with a mast-mounted PAR sensor integrated into the system. Required inherent optical property measurements include spectral absorption and beam attenuation using a WETLabs ac-s or similar, multi-wavelength backscatter using WETLabs BB-3 or similar, in situ particle size determinations using a LISST-100X, and an aggregate / zooplankton imaging camera system like a UV-P. Must include the ability to accommodate PI instrumentation. Sample upper 1000 m of the water column (IOP instrumentation may have depth limitations). Backup systems are required for each ship. LADCP and Chi-Pod (temperature microstructure) desirable.

Water sampling & minimum analysis set: From each water bottle tripped, samples *should* be collected and archived as appropriate for nutrients, fluorometric Chl, HPLC phytoplankton pigments, POC, DOC, O₂, particulate and phytoplankton absorption spectra ($a_p(\lambda)$ & $a_{ph}(\lambda)$), dissolved absorption spectra ($a_g(\lambda)$), and particulate DNA. Nutrients are analyses for NO₃+NO₂, NO₂, PO₄ and SiO₄. Need the capabilities to analyze dissolved oxygen concentrations at sea. Not all analyses need to be run for all bottles tripped (i.e., costs; ~\$300/sample for all analyses) but ability to retrieve these data from both ships is critical. Protocols for sampling follow standard procedures such as JGOFS, NASA Ocean Optics Protocols, etc.

Underway ship sampling: An underway sampling system will be used to measure near-surface properties at high spatial / temporal resolution from both ships. Priority is to instrument the Survey Ship. Parameters to sample include standard CTD/O₂/Chl-fl/pCO₂/beam_c/meteorology measurements with GPS streams acquired found on nearly all UNOLS vessels. Other required measurements include spectral absorption and beam attenuation using a WETLabs ac-s or similar, multi-wavelength backscatter using WETLabs BB-3 or similar and spectral irradiance and incident PAR fluxes. Meteorology measurements should include true wind speed, true direction, air temperature, relative humidity, barometric pressure, incident solar radiation, and downwelling longwave radiation measurements. A diaphragm pump should be used to reduce particle / aggregate breakup, and the optical measurements should be switchable to be either whole water or 0.2 μm filtered. The underway system must allow water sampling at a reasonable flow rate without markedly affecting flow rates through the other sensors. Other useful underway

measurements include an imaging camera system like a flow-cam or flow-cytobot, O₂/Ar measurements for net community production determinations, acidified/non-acidified light scattering measurements to address PIC concentrations and variable fluorescence measurements kinetics to assess phytoplankton physiological condition. A ship mounted Acoustic Doppler Current Profiler system is needed on both ships to map and monitor horizontal currents.

Sediment trap sampling: Sinking particle fluxes need to be measured from water-following platforms that minimize hydrodynamics biases (Neutrally buoyant sediment trap, PELAGRA, etc.). Duplicate traps will be deployed over 5 depths from base of the euphotic zone to ≥ 500 m. Depending upon the diameter of the collection tube, each trap needs ≥ 3 -6 collection tubes to collect enough material in upper 500m with aspect ratios > 5 . Samples would be wet split and shared for several different geochemical, biological and optical studies, including archiving of samples. Replicate traps would need to be deployed at multiple depths to create vertical profiles of sinking flux.

MOCNESS tows: Depth-stratified mesozooplankton samples need to be collected with a Multiple Opening Closing Net and Environmental Sensing System (MOCNESS), or similar electronic multi-net sampler. Require 10 nets on a 1-m frame, with net mesh size of 200 μm , and cod ends with mesh of same size (or slightly smaller). Sensors on net must include depth, temperature and salinity, with options package for oxygen and fluorescence also useful. Instrument requires enough conducting cable to fish net down to 1000 m. Day/night tow pairs (centered around noon and midnight) should be consecutive, but the order should not matter.

Vertical net tows: Vertical net tows (i.e., single net on the wire) will be required to collect zooplankton for a variety of different experiments, for calibrating acoustics, and for biomass/ abundance measures. Thus, an assortment of single nets will be required. Net mouth diameters are likely to be 0.5 or 1.0 meter, with net mesh sizes ranging from 64 μm to several mm's. Nets require flow meters and both filtering and non-filtering cod ends (the latter for use in collecting live animals). Tow depth and type (vertical, drifting, or oblique) will depend on use, but most tows are expected to be in the epipelagic or upper mesopelagic zones. Wire does not need to be conducting, but portable time-depth recorder for tows is desirable.

In situ large volume filtration: In-situ pumps have been commercially developed to filter seawater over pre-programmed time intervals. Larger filtration volumes ($>1000\text{L}$) allow for sampling of rarer large particles, and typically water is filtered through stacked filter heads to collect material in multiple size classes over ranges from <1 to 100 μm . Independent battery powered units allow for collection at multiple depths which can be chosen at sea and pumps attached to a range of winch/wire configurations. Flow rates are adjustable as well as filter diameter and pore size, resulting in new flow rates of a few up to 5-10 L min^{-1} .

Drifting Experiment Array: Several experiments may require surface floats and subsurface collectors, such as for sinking particles and incubation studies. One example is the RESPIRE trap, that collects sinking particles and then seals sufficiently to follow evolution of oxygen decrease due to respiration on sinking particles. Other arrays examples include Settling Velocity Traps, which capture sinking particles and conduct in situ settling column type separations of the collected particles into different settling velocity fractions. Other systems / experiments may also require variations on these free drifting arrays which can be tracked via satellite positioning systems.

Towed profiling survey vehicle: Undulating towed profiling vehicle (Triaxus, SeaSoar or equivalent) capable of sampling from surface to 200+ m while being towed at 8 knots. Instrument suite to include dual SBE T-C sensors, fast response dissolved oxygen, chlorophyll fluorometer and 660 nm, 25 cm path beam transmissometer, nitrate (SUNA or similar). Inherent optical property measurements include spectral absorption and beam attenuation using a WETLabs ac-s or similar, multi-wavelength backscatter using WETLabs BB-9 or similar. Desirable instruments include temperature microstructure, zooplankton (acoustics, video plankton recorder or other).

Remote sensing reflectance spectra casts: A high spectral resolution (~10 nm), vertically profiling radiometry casts are needed to assess ocean color spectra that are linked to the field sampling. Important for linking the EXPORTS measurements to PACE and other future satellite missions. System must be deployed distant from the ship (≥ 50 m) to minimize the effects of ship shadows. Mast-mounted reference spectral irradiance measurements matched to the profiling spectroradiometry casts are required (shadow-band would be useful). Vertical profiles must go from the surface to the 0.1% PAR depth (≥ 120 m). Multiple casts are needed focused around solar noon.

Bioacoustics: Hull-mounted, multi-frequency or broadband acoustics are required for estimating zooplankton abundance and biomass at high temporal and spatial resolution. Transducers should be mounted in a well in the ship's hull. For multi-frequency, a minimum of 38 and 120 kHz channels are required.

Mesoscale CTD survey: Sample a 50km x 50km area at 5km along-track, 10km cross-track spacing. This is a total of 6 lines, 11 stations per line. Assumes anisotropic target (i.e. frontal feature). 50% collect water, 50% do not. Water is collected only at specific depths.

Mesoscale towed platform survey: Sample a 100km x 100km area with 10 km cross track sampling. Plan is to tow the package for 48 hours straight (@ 8 kts) resulting in 710 km tow. A total of six sections of 100 km fit within this approximately.

Submesoscale towed platform survey: Sample a focused area (50 km on a side) in detail once we find the focal feature.

Autonomous Platform Array

BioArgo Float: Commercially available profiling float with Iridium Rudics communication capability and Lithium primary batteries capable of profiling to near 2000 m depth (to provide reference measurements that control for sensor drift). The float should have a proven operational record better than the Argo fleet average and should be capable of conducting ~250 profiles to near 2000 m depth. Each float should be equipped, on top of the standard T/S measurements, with a fluorescence lifetime optical oxygen sensor that is capable of air oxygen calibration during deployment, an ISFET pH sensors, a UV optical nitrate sensor, chlorophyll fluorescence sensor, and optical backscatter sensor. Downwelling irradiance is also desirable.

Flux Float: Autonomous profiling float carrying sensors for particle abundance, characteristics (i.e., size; composition) and flux. Data volumes generated must be small enough to transmit as the platform is expendable and will not be recovered. The platform should have minimum 6 month endurance while profiling at least every 2 days to 1000 m, ability to record sensor data every 15-20 minutes during the “park” phase of the profile cycle, and capability of maintaining target, sub-mixed layer depths (100-1000 m) with minimal buoyancy adjustments. Sensors should include T, S, oxygen, chlorophyll fluorescence, optical backscatter at two standard wavelengths and a standard angle, a 25-cm path, 650 nm beam transmissometer with standard acceptance angle, and a tilt sensor. The float should be capable of recording optical sensor data at high frequency during ascent for “spike” enumeration. If on-board data reduction/compression is sufficient to allow transmission of measurements, the float should also be equipped with an imaging sediment trap capable of counting and sizing sinking particles in the order 10 μm -1 cm size range.

Lagrangian Float: Lagrangian float capable of following water parcels within the mixed layer and in the stratified region below. Minimum six-month endurance. T, S, oxygen, nitrate, chlorophyll fluorescence, optical backscatter, 660 nm, 25 cm path beam transmissometer, upwelling and downwelling spectral irradiance, microstructure. Desirable capabilities include sensors for pH, zooplankton (acoustics, video plankton recorder or other), velocity and acoustic navigation for subsurface geopositioning.

Long-endurance glider: Autonomous glider with minimum six-month endurance. T, S, oxygen, chlorophyll fluorescence, optical backscatter, downwelling spectral irradiance. Desirable capabilities include sensors for nitrate, microstructure, pH, zooplankton (acoustics, video plankton recorder or other), velocity and acoustic navigation for subsurface geopositioning.

PSD Float: Autonomous profiling float carrying sensors for particle abundance, characteristics (i.e., size; composition) and flux. Sensors may generate data volumes too large to transmit (i.e., imagery) so the platform will require recovery and will be deployed during cruises. Sensors should include T, S, oxygen, chlorophyll fluorescence, optical backscatter at two standard wavelengths and a standard angle, a 25-cm path, 650 nm beam transmissometer with standard acceptance angle, and a particle imaging sensor capable of sizing and counting particles in the order 100 μm – 1 cm size range. The float should be capable of recording optical sensor data at high frequency during profile ascent for “spike” enumeration. If on-board data reduction/compression is sufficient to allow transmission of all measurements, then this platform could be considered “expendable”, allowing its integration into the Autonomous Array.