The oceanic biological carbon pump transfers atmospheric carbon dioxide to the deep-sea via primary production, particle export and organic matter remineralization. Decades of investigations have shed light on the enormous role marine microorganisms play in solar energy capture, organic matter transformation, and the cycling of bioessential elements including carbon (C), hydrogen (H), nitrogen (N), phosphorus (P) and sulfur (S). To our knowledge, with the exception of only a single published data set three decades ago, the calorific content of sinking particulate matter—the energy available to fuel life processes below the euphotic zone—has eluded direct measurement. Recently, long-term, large-scale collection of sinking particles and optimization of ultra-mini calorimeter sample analysis has enabled direct measurement of the calorific content. Here we will present the first depth-profiles (12 depths, 100-500 m) of the calorific content (and CHNp values) of sinking particulate matter at Station ALOHA, an oligotrophic field station in the North Pacific Subtropical Gyre. This newly formed organic matter provides more comprehensive characterization of sinking particles in the euphotic zone and exported particulate matter. Comparing these data to the CHNp and calorific content of the living planktonic assemblage provides new insight into the consumption and degradation of sinking organic matter. More broadly, this investigation adds to the understanding of energy flux within the ocean.

**Background**

One of the greatest contemporary challenges in microbial oceanography and marine ecology is an improvement to our conceptual understanding and quantitative assessment of energy flow in the open sea (Karl, 2014). Solar radiation is the most abundant form of energy for marine microorganisms and through the process of photosynthesis, solar energy is captured and stored as potential energy in chemical bonds. This newly formed organic matter undergoes transformation as it sinks out of the upper ocean. It is through the coupled processes of photosynthesis and respiration that this potential energy is dissipated through the food web. While many field studies have focused on the flow of carbon and other bioelements to the deep sea, energy flux has never been directly measured. Platt and Irwin (1972) introduced a conceptual framework for indirectly estimating the calorific content (heat of combustion) of phytoplankton. They concluded that “percent carbon in dry phytoplankton should be a good predictor of its calorific value,” and presented these relationships for general use in marine ecology:

\[ \text{calories/dry wt} = 0.632 + 0.886 \times (\% C) \]

and

\[ \text{calories/dry wt} = 0.555 + 0.113 \times (\% C) + 0.054 \times (\% N) \]

These relationships were developed by assessing a spring phytoplankton bloom comprised of mostly living cells in St. Margaret’s Bay, Nova Scotia. Since the vast majority of particulate organic matter in most oligotrophic regions is non-living and may have a chemical composition and elemental stoichiometry distinct from living cells, using a model such as Platt and Irwin may not accurately predict the true calorific value of sinking particulate organic matter. To our knowledge, the only calorific content of sinking particulate organic matter was reported by Honjo (1980) where he used the Platt and Irwin model to calculate the predicted value.

### Measured vs. Predicted

Direct measurements of the calorific value of sinking particulate matter (sPOM) at Station ALOHA reveal a strong decoupling with depth from the Platt and Irwin model using the C and N content. This model is not well suited for sPOM undergoing selective microbial degradation.

### Energy Flux

The energy flux of sinking particulate organic matter at Station ALOHA is dramatically depth dependent. Only 5% of the energy measured at 100 m remains at 500 m, indicating most of the energy is dissipated in the upper 500 m.

### Energy Capture & Flux

Energy captured via photosynthesis at Station ALOHA is estimated at 33,000 J/m³/d (Letelier et al., in press). The exported flux of energy at 100 m is 6.3% of this total, decreasing to 2.8% at 200 m and 0.3% at 500 m.

### Elemental Stoichiometry

**C-specific calorific value**

The cal/mg C ratios of surface plankton and sPOM from 100 m to 130 m are within agreement, suggesting that this sPOM is fresh. The ratios of sPOM from 140 m to 500 m decrease with depth, indicating that the sPOM is losing energy and undergoing selective microbial degradation.

### Elemental Fluxes

All elements show a decrease with depth.