**The roles of suspension-feeding and flux-feeding zooplankton as gatekeepers of particle flux into the mesopelagic ocean in the Northeast Pacific**

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**Supplemental Material**

**Online Supplementary Appendix S1 – Detailed data analyses**

*Carbon flux attenuation calculations*  – Both sediment trap and 238U-234Th deficiency methodologies have inherent shortcomings that can introduce uncertainty and bias to carbon flux measurements. Surface-tethered sediment traps suffer from hydrodynamic biases related to shear across the trap mouth, potential dissolution of organic carbon and other chemical constituents of sinking particles, and difficulties of accurately identifying and removing swimming mesozooplankton from the sediment traps ([Baker et al., 1988](#_ENREF_1); [Buesseler et al., 2007](#_ENREF_4)). For 234Th, uncertainties are derived primarily from uncertainty in the appropriate C:234Th ratio to apply to convert 234Th flux to carbon flux and uncertainty in the model used to convert water column 234Th activity measurements to 234Th flux measurements ([Buesseler et al., 2006](#_ENREF_6); [Savoye et al., 2006](#_ENREF_14)). Specifically, most studies are forced (due to a lack of repeat measurements, full three-dimensional coverage of 234Th activity, and/or measurements of horizontal and vertical currents and diffusivity) to assume the system is at steady-state with no horizontal advection or upwelling. Accounting for upwelling, advection, or non-steady state conditions (when possible) often leads to substantially different estimates of local export, but has a lesser impact when integrated over larger spatial regions and longer temporal periods ([Buesseler et al., 1992](#_ENREF_5); [Dunne and Murray, 1999](#_ENREF_7); [Resplandy et al., 2012](#_ENREF_13); [Stukel et al., 2015](#_ENREF_17)).

The CCE has high meso- and submesoscale variability, pronounced horizontal currents, and temporal variaibility in upwelling. We thus believe that sediment traps give a better estimate of contemporaneous export flux on short time scales than 234Th-approaches in our study region. Our believe that the sediment traps have no substantial over- or under-collection bias is supported by a total of 56 paired sediment trap and 238U-234Th deficiency measurements showing good agreement (see results section 3.1). Consequently, we use sediment trap values of carbon flux at deployment depths (typically near the base of the euphotic zone and at 100 m) and utilize 238U-234Th measurements to generate smooth profiles of carbon flux attenuation above, between, and below sediment trap deployment depths.

Carbon flux attenuation (CFA) as a function of depth was calculated for each Lagrangian cycle from Eq. 2 in the manuscript:

 (2)

To calculate the terms in Eq. 2, we first averaged and smoothed all 234Th, 238U-234Th deficiency, and POC profiles from an individual Lagrangian cycle using locally-estimated scatterplot smoothing (LOESS). LOESS smoothing was accomplished using the fLOESS function in Matlab (with a span of 0.9). fLOESS uses a second-order polynomial to smooth the data. Data points were then interpolated to create smooth profiles. Since on many cycles, POC measurements were only made in the euphotic zone, we extended these profiles to 200 m depth by assuming ([from analyses in Stukel et al., 2019](#_ENREF_18)) that suspended POC decreases with depth at a rate of 1.5% m-1. This extension of the POC profiles was only used for quantifying C:234Th variability with depth from Eq. 3. Results were not sensitive to varying the rate at which POC decreases with depth, because most POC was in the euphotic zone.

 Def(D) and the integral of Def(D) were simply calculated from the smoothed deficiency profiles. CTh(D) and ∂CTh(D)/∂z were calculated using Eq. S1:

 (S1)

For Lagrangian cycles during which sediment traps were deployed at multiple depths (two or three), we calculated the parameters m and b independently for each Lagrangian cycle. When sediment traps were only deployed at a single depth, we used the regional mean value for m calculated by Stukel et al. ([2019](#_ENREF_18)): m = 0.43 ± 0.03. Equations 2 and 3 were then combined to calculate smooth profiles of carbon flux attenuation above the shallowest sediment trap depth, between sediment trap depths, and below the deepest sediment trap depth (to 150 m depth). Because the 234Th-238U deficiency measurements and sediment trap measurements did not perfectly match, there was a difference between carbon flux attenuation calculated from Eqs. 2 and 3 and carbon flux attenuation calculated by comparing sediment traps at different depths. Because we found that the sediment traps gave a more accurate estimate of carbon export, we thus adjusted the carbon flux attenuation estimates from Eq. 2 between sediment trap depths, by adding (or subtracting) a constant amount to the values calculated in Eq. 2 (between the sediment trap depths). This yielded smooth profiles of carbon flux attenuation that were entirely consistent with sediment trap data.

To generate smooth profiles of carbon flux, we combined carbon flux attenuation profiles with the carbon flux estimates made by the sediment traps. Carbon flux was extended above and below the sediment trap depths iteratively using the equation:

 (S2)

where Δz equals one meter and b = -CFA(z)/Flux(z). Eq. S2 was used, because it ensures that flux can never go negative. If we had instead calculated flux as Flux(z-Δz) = Flux(z) – CFA(z), carbon flux would have been negative at a depth shallower than 150 m for one profile, because of anomalously high 234Th (i.e., strongly negative deficiency) at depth.

**Online Supplementary Appendix S2 – Cruise Conditions**

Ecological conditions encountered on these cycles were highly variable. On P0704 and P0810 our goal was to quantify ecological and biogeochemical rates in homogeneous water parcels (i.e., regions with low mesoscale variability) across the range of conditions found in the CCE domain. Consequently, cycles varied from high chlorophyll (Chl), coastal bloom conditions (surface Chl > 5 µg Chl a L‑1) to exceedingly oligotrophic areas (surface Chl <0.1 µg Chl a L‑1) ([Landry et al., 2012](#_ENREF_10); [Stukel et al., 2013](#_ENREF_19)). The P1408 and P1604 cruises used similar sampling plans to investigate spatial variability during the North Pacific Warm Anomaly in 2014 and subsequent 2015-2016 El Niño ([Bond et al., 2015](#_ENREF_2); [Jacox et al., 2016](#_ENREF_8)). During the P1408 cruise, upwelling was suppressed throughout the study region and warm, low-nutrient conditions predominated on all experimental cycles. The P1604 cruise took place at the end of the El Niño when offshore conditions were still warm, nutrient-poor, and community composition was likely highly impacted by the El Niño. However, spring upwelling conditions commenced near the coast and the final two cycles were conducted in cold, upwelling-influenced waters with high phytoplankton and zooplankton biomass ([Morrow et al., 2018](#_ENREF_11); [Nickels and Ohman, 2018](#_ENREF_12)).

The P1106 and P1208 cruises were planned to investigate the impact of mesoscale fronts on plankton communities and consequently had very different sampling plans. These cruises interspersed five (P1208) or six (P1106) shorter Lagrangian cycles (2.25 – 3.25 day duration) with transect sampling and spatial mapping of mesoscale features. Experimental cycles conducted on these cruises were thus conducted within a relatively restricted spatial domain in the vicinity of a specific mesoscale feature (Fig. 1). Despite this restricted spatial domain substantial intra-cruise variability in system productivity was encountered. Mean surface Chl varied by more than an order of magnitude on cycles during P1106 as did vertically-integrated primary productivity with concomitant impacts on plankton communities and carbon export ([Brzezinski et al., 2015](#_ENREF_3); [Krause et al., 2015](#_ENREF_9)). The P1208 cruise showed similarly variable phytoplankton biomass and productivity paired with substantial variability in mesozooplankton biomass and grazing and carbon flux out of the base of the euphotic zone ([Stukel et al., 2017](#_ENREF_16)). Although intra-cruise variability in plankton communities was almost as high on these cruises as the non-front cruises that covered greater spatial extents, the close proximity of these different communities complicate the interpretation of subsurface flux attenuation patterns. Specifically, given the impact that horizontal currents can have in driving spatial decoupling of particle production and export ([i.e., the concept of the ‘statistical funnel' of sinking particles; Siegel and Deuser, 1997](#_ENREF_15)) we caution against attempting to interpret changes in flux between sediment traps deployed directly above and below each other as necessarily reflecting particle flux attenuation related to particles produced immediately above the sediment traps. Instead we suggest that our data are more appropriately interpreted as quantifying the variability in potential carbon flux attenuation within our study site. We thus avoid considering results of carbon flux on any particular cycle, but instead divide our Lagrangian experiments into oligotrophic cycles or high biomass cycles (>0.5 µg Chl a L-1) and separate analyses based on these criteria.

**Supplementary Figures**



**Supplementary Figure S1** – Explanation of carbon flux attenuation (CFA) calculation steps. a) Smooth 234Th data from 2-3 casts per cycle (yellow diamonds are discrete measurements). b) Smooth POC data (yellow diamonds are discrete measurements). c) Compute C:234Th ratio from eq. S1 and measured C:234Th ratios in the sediment trap (red starts). d) Compute 238U-234Th disequilibrium from smoothed 234Th profiles, salinity profiles, and salinity-238U relationship. e) Compute CFA0 from Eq. 2. f) Adjust CFA0 in region between sediment trap depths (black horizontal lines) to ensure that it perfectly matches sediment trap measurements. g) Compute smooth profiles of carbon flux from CFA and sediment trap measurements (red stars).



**Supplementary Figure S2** – Biomass of suspension-feeding mesozooplankton captured in nighttime MOCNESS tows.

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