Rates of microbial activities associated with sinking particles at Station ALOHA in the North Pacific Subtropical Gyre

Alex Nelson[1], Natalie Dornan[1], Donn Viviani[1], Eint Kyi[1], Justin Ossolinski[2], Benjamin Van Mooy[2], Matthew Church[1]

[1]University of Hawaii at Manoa Honolulu, Hawaii [2]Woods Hole Oceanographic Institute Woods Hole, MA

Abstract

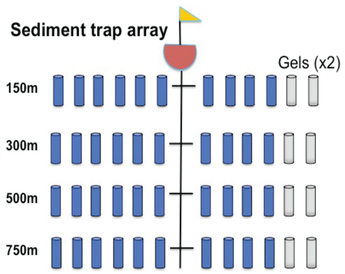
Mesopelagic microbial metabolism is supported in large part by the supply of reduced substrates associated with sinking particles. We characterized the composition and reactivity of sinking particles at Station ALOHA. Particle interceptor traps containing acrylamide gels were used to examine how the size of sinking particles varied with depth during two cruise. Sinking particles were imaged and sized by microscopy. Results from these analyses revealed particles <25 µm were dominant contributors to particle flux. The reactivity of sinking particles was determined during these two cruises by measuring rates of microbial production. In particle-enriched treatments rates of bacterial production were 4-6 fold greater than in whole seawater controls, while rates of chemoautotrophic production were 1-3 times greater. These results confirm that sinking particles are "hot-spots" of microbial activity, with the presence of sinking particles fueling elevated chemotrophic production.

Introduction

The vertical transition from the well-lit upper ocean to the mesopelagic waters represents a major energetic threshold in the sea, resulting in intensification of decomposition processes and vertically distinct microbiological gradients. Much of the mesopelagic metabolism appears to be supported by the supply of reduced substrates associated with sinking particles. During two cruises (July/August 2015 and March 2016) to Station ALOHA we sought to:

- Evaluate mesopelagic microbial production and downward particle flux.
- Examine vertical differences in size and composition of sinking particles to better understand factors regulating particle export to the deep ocean.
- Quantify rates of microbial decomposition of sinking particles.

Methods

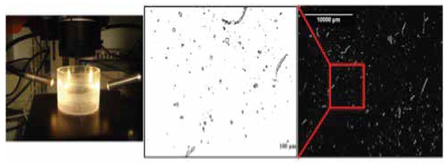


Sinking particle flux

Particle Interceptor Traps were deployed on two cruises at Station ALOHA for ~3 days to collect sinking particles at 150 m, 300 m, 500 m, and 750 m. Subsequent lab analyses determined fluxes for particulate carbon, nitrogen, and phosphorous.

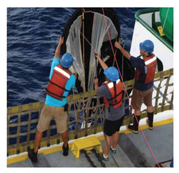
Particle size and morphology

To quantify size distributions of sinking particles acrylamide gels were deployed on a free-floating array for ~3 days. Particles captured in gels were preserved for subsequent microscopic analyses of size and morphology. Gels were imaged at 40x magnification. Images were digitized and particle sizes determined using the image analysis software ImageJ.



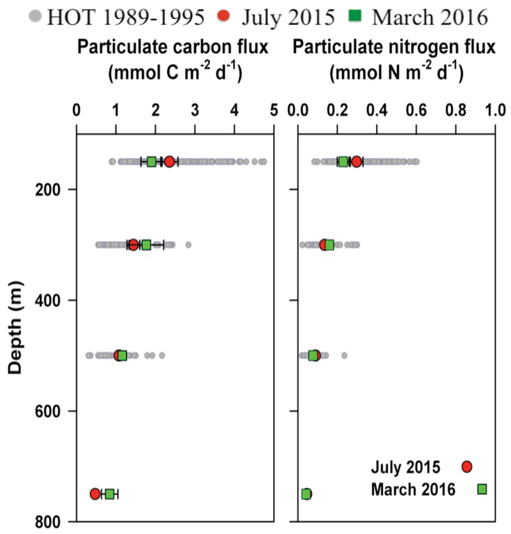
Rates of microbial production

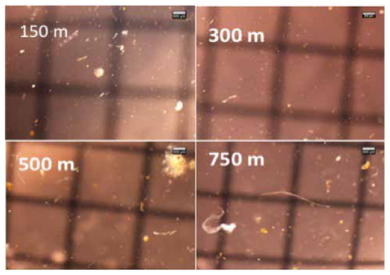
A free-floating net trap was deployed at 150 m to collect sinking particles.Particles were added to whole seawater from 150 m, and rates of 3H-leucine incorporation and 14C-bicarbonate assimilation were measured *in situ*. Water was collected from 150 m,175 m, 250 m, 300 m, 500 m, and 750 m and rates of microbial production were measured in situ.



Results

Sinking particle flux





Mesopelagic flux attenuation

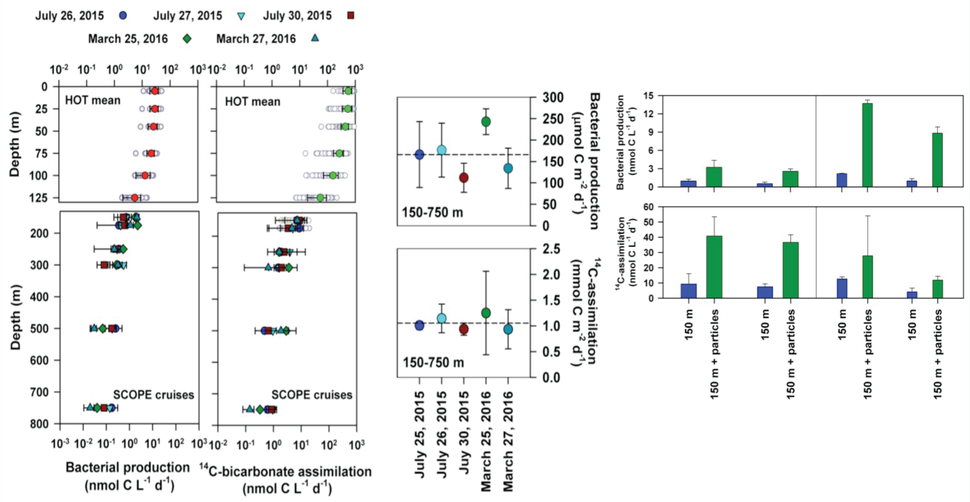
$\Delta PC\ flux_{150\ m-750\ m}$ = 1.8 mmol C m^{-2} d^{-1} (Jul/Aug)
1.1 mmol C m^{-2} d^{-1} (Mar)

$\Delta PN\ flux_{150\ m-750\ m}$ = 0.25 mmol N m^{-2} d^{-1} (Jul/Aug)
0.19 mmol N m^{-2} d^{-1} (Mar)

Vertical changes in number of sinking particles

Depth(m)	July (# of particles m^{-2})	March (# of particles m^{-2})
150	$4.9x10^6$	$3.9x10^7$
300	$1.3x10^7$	$3.2x10^7$
500	$6.9x10^6$	$3.2x10^7$
750	$1.6x10^7$	$3.9x10^7$

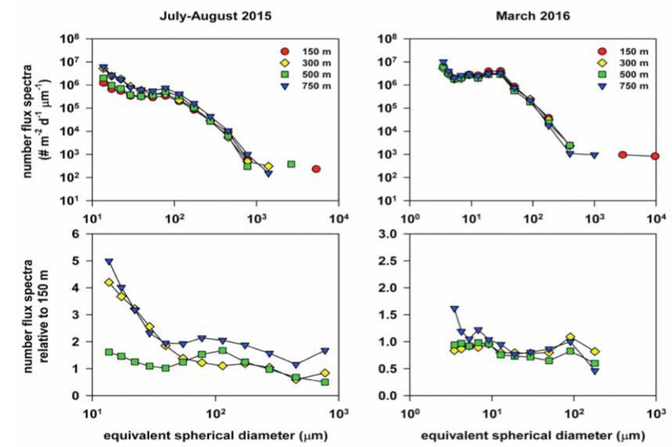
Rates of microbial production



- Depth-integrated bacterial production (BP) in mesopelagic waters averaged 166 mmol C m^{-2} d^{-1}.
- Depth integrated carbon fixation averaged 1.1 mmol C m^{-2} d^{-1}.
- Rates of bacterial production were 4-6 fold greater in particle amended seawater than whole seawater at 150 m.
- Rates of chemoautotrophic production were 1-3 times greater in the presence of sinking particles.
- The average flux attenuation, the carbon supply to the mesopelagic waters, was equal to the calculated bacterial carbon demand (BCD) for the two cruises.

$BP_{(\int 150\text{-}750\ m)}$ = 166 ± 35 mmol C m^{-2} d^{-1}
$BCD_{(\int 150\text{-}750\ m)}$ = 1.4 ± 0.42 mmol C m^{-2} d^{-1}
(assumes 12% BGE)
Flux $attenuation_{(150\ m-750\ m)}$ = 1.4 ± 0.57 mmol C m^{-2} d^{-1}
0.22 ± 0.04 mmol N m^{-2} d^{-1}
Carbon $fixation_{(\int 150\text{-}750\ m)}$ = 1 ± 0.13 mmol C m^{-2} d^{-1}

Particle sizes and distribution



- Similar particle size spectra distributions were observed on both cruises.
- Particles in the smallest size bin (<25 µm) were dominant contributors to particle flux at all depths.
- Small particles (<25 µm) were increasingly important contributors to flux at 300 and 750 m compared to 150 and 500 m during the July-August cruise.
- Although particulate carbon fluxes were lowest at 750 m, normalized particle number fluxes were greatest in deep mesopelagic traps.

Conclusions

- Bacterial carbon demand in the mesopelagic waters appears similar to measured consumption of sinking particulate matter.
- Relatively high rates of carbon fixation in the mesopelagic waters - underscores need to identify organisms controlling these rates.
- Sinking particles are "hot-spots" for microbial production.
- Small (<25 mm) particles appear dominant contributors to particle flux through the mesopelagic waters.

Acknowledgements

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