論文の内容の要旨

論文題目：Dynamics and bacterial control of organic aggregates in marine environments

（海洋環境における有機凝集体の動態と細菌による制御）

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Abstract

Organic aggregates play an important role in the transport and sequestration of carbon and other elements in the oceans. Transparent exopolymer particles (TEP) represent a major class of organic aggregates in marine environments, being primarily composed of bio-polymers (e.g. polysaccharide, protein, lipid) released from marine organisms. Since the discovery of the presence of large quantities of TEP in seawater in 1990s, extensive studies have been conducted to elucidate the formation mechanisms, chemical compositions and settling fluxes of TEP in the oceans. However, there still remain large gaps in our understanding of the regulation of TEP and other particle dynamics in oceanic environments. The present study focused on, 1) distribution

patterns in TEP and other suspended particles in the Arctic Ocean and 2) mechanisms by which TEP settling velocities are controlled by bacteria.

In Chapter 2, I examined horizontal and vertical distribution patterns in suspended particles [TEP, particulate organic carbon (POC), and particles as determined by laser in situ scattering and transmissometry (LISST)] in the Chukchi Sea and the Canada Basin in the western Arctic Ocean, during the late summer of 2012. Suspended particle concentrations were high in the shelf region and gradient patterns were identified from the shelf to basin. A hotspot (extremely high concentration) of suspended particles, accompanied by high prokaryote abundance and production, was observed at near the seafloor (depth, 50 m) of the shelf region. In general, the ratios of TEP to POC were high (0.3–3.6) in the investigated region, relative to the corresponding ratios previously reported for other oceanic regions, suggesting that TEP play an important role in the regulation of particle dynamics. LISST determination revealed high concentrations of particles near the pycnocline (depth of 10–30 m). An analysis of particle size distribution (range, 5.2–119 μm) indicated that relatively small particles were dominant in the shelf region compared to the slope-basin region, which implied that smaller precursor aggregation was occurring in the shelf region. These results suggest that aggregates, including TEP, are produced in the shelf region and are transferred to the slope-basin region along the pycnocline. The lateral transport of these aggregates could support productivity and material cycles in the nutrient-depleted basin region of the western Arctic Ocean.

In Chapter 3, I investigated whether attached bacteria affect the settling velocity of TEP via modifications of the physical properties of aggregates, including density, porosity, and morphology. Model aggregates, prepared by mixing 2 different polysaccharides (fucoidan and chitosan), were incubated in coastal seawater passed through either 0.8 µm ($AGG_{0.8}$) or 0.2 µm ($AGG_{0.2}$) filters. After incubation for 48 h, $AGG_{0.8}$ were much more densely (3.2- to 10.1-fold) colonized by bacteria than $AGG_{0.2}$. Based on median settling velocities (W_{50}), as determined by LISST, the W_{50} of $AGG_{0.8}$ was lower (1.6- to 4.5-fold) than that of $AGG_{0.2}$ for a size class of 62 to 119 µm. Stokes model analyses indicated that this reduction in W_{50} could be largely attributed to the higher porosities of $AGG_{0.8}$ (0.932−0.981) than those of $AGG_{0.2}$ (0.719−0.929). My results support the notion that the modification of aggregate structure by attached bacteria (porosity enhancement) can be an important factor controlling the settling velocity of marine particles.

In Chapter 4, I investigated whether marine bacteria enhance the coagulation of TEP, to enhance organic aggregate settling velocity. Model aggregates [equivalent spherical diameter (ESD), ca. 0.01 cm] were suspended in seawater contained in rotating tubes to examine time-course changes in particle ESD and abundance. Results indicated that marine bacterial assemblages strongly enhanced the coagulation of aggregates into large aggregates (ESD, 0.1–1 cm) over a period of 24–96 hours. Catalyzed reporter deposition-fluorescence in situ hybridization results indicated that one group of bacteria that grew rapidly on the aggregates was affiliated with the genus *Pseudoalteromonas*. Experiments using *Pseudoalteromonas* isolates indicated that four of 11 isolates enhanced the coagulation of aggregates and specific types of the group was one of key species of aggregate coagulation in seawater. High settling velocities (up to 270 m d^{-1}) were determined for larger aggregates (ESD, >0.4 cm), which agreed with theoretical predictions derived from a hydrodynamic model. My results demonstrate that specific types of bacteria readily colonize aggregates to impose a strong biotic force that enhances small organic aggregate coagulation and the formation of fast-settling large aggregates in seawater.

In Chapter 5, I summarize the above findings to conclude that, 1) TEP and TEP-induced aggregation process could contribute to particle transport along the shelf to basin transit of the western Arctic and 2) bacteria can control TEP settling velocity by their enhancement of aggregate porosity and coagulation efficiency. These findings added several important aspects to the previous knowledge regarding organic aggregate distributions in the Arctic Ocean and the regulation of organic aggregate settling velocity in marine environments.