論文の内容の要旨

論文題目: **Biomass estimation of marine macrophyte debris on the ocean floor**

(海洋底上に堆積した海産大型植物の現存量の推定)

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Introduction

Marine macrophyte beds, consisting of seaweeds and seagrasses, have been recognized as one of the highest primary producers in the global carbon cycle. They are distributed in shallow coastal waters in the oceans worldwide. Most of them are detached from the bottom substrate after attaining the highest biomass in their maturation season. Although some marine macrophytes are stranded on the shore or remain in the beds in coastal waters, most of them with positive buoyancy are transported to offshore waters as drifting macrophytes. However, reports on the fate of macrophytes are few and their importance to the global carbon cycle has not been widely recognized. Buoyant marine macrophytes, after decaying or losing their buoyancy, settle to the ocean floor. Previous studies of debris of macrophytes on the ocean floor have mainly focused on the bottoms within several kilometers off the coast and a concaved bathymetry where deposited materials tend to accumulate. This study aims to reveal the distributions of marine macrophyte debris on the ocean floor of flat bathymetry further than the previous reports and provide some quantitative

information about the transport of macrophytes toward the mesopelagic ocean if they are distributed there. These findings are essential for completing the knowledge of macrophyte beds as a sink of the global carbon cycle.

Fate of macrophytes transported offshore: Evidence of their fall to ocean floor

In order to clarify whether marine macrophyte debris is distributed on the flat ocean floor bottom trawl surveys have been conducted for three years in spring, summer and autumn. Bottom trawl surveys revealed the existence of macrophyte debris at more than 500 km in longitudinal direction from 10 to 100 km offshore continental shelf and slope seafloor at the bottom depths from 40 m to 1800 m in waters off east Tohoku Region. Macrophytes were mainly consisted with seaweeds (species of *Sargassum* and Laminariales) and seagrasses. The most frequently collected macrophyte in south of Hokkaido Island was seagrass and *C. hakodatensis*. In east of Tohoku Region, *Sargassum horneri* was the most frequently collected macrophyte in spring and summer, while sharply changed to seagrass in autumn. Mean standing crop of macrophyte debris in east of Tohoku Region showed a clear seasonal variability attaining a peak (51.1 mg wet weight m^{-2}) in summer (Fig. 1). Among the total collected biomass, macrophyte debris mainly consisted of *Sargassum* species (89%) in spring, *Sargassum* species (87%) in summer, seagrass (43%) and Laminariales species (29%) in autumn. The buoyant macrophyte species of *Sargassum* and seagrass were widely distributed no discernible trends were found in their spatial distribution patterns within the survey area in spring, summer and autumn, except for *S. horneri* in spring season. Fresh *Sargassum horneri* was found on the bottom near the oceanic front in southern waters off east Tohoku Region in the three spring seasons. The surface current system influences the distribution of *S. horneri* debris on the ocean floor because it transports floating seaweeds and materials along the front. Macrophytes heavier than the sea water such as Laminariales species and other seaweeds are thought to be transported from the coast to the offshore bottom by the gravity and bottom currents (Fig. 2).

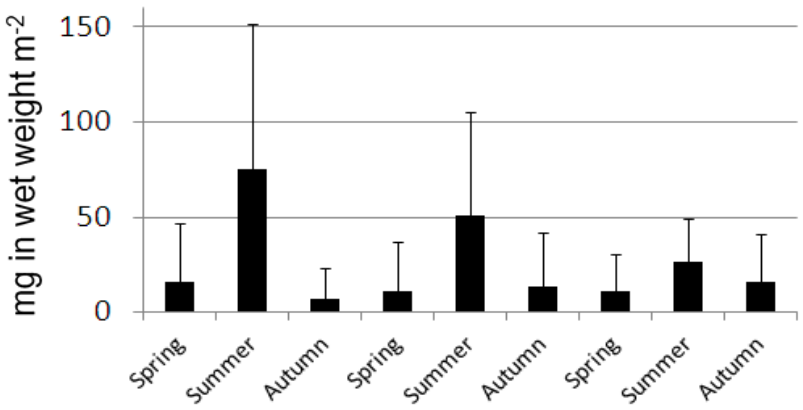

Figure 1. Average biomass density of marine macrophyte debris for each season. Bold bar shows average biomass density of marine macrophyte on the seafloor. Solid line shows standard deviation of biomass density.

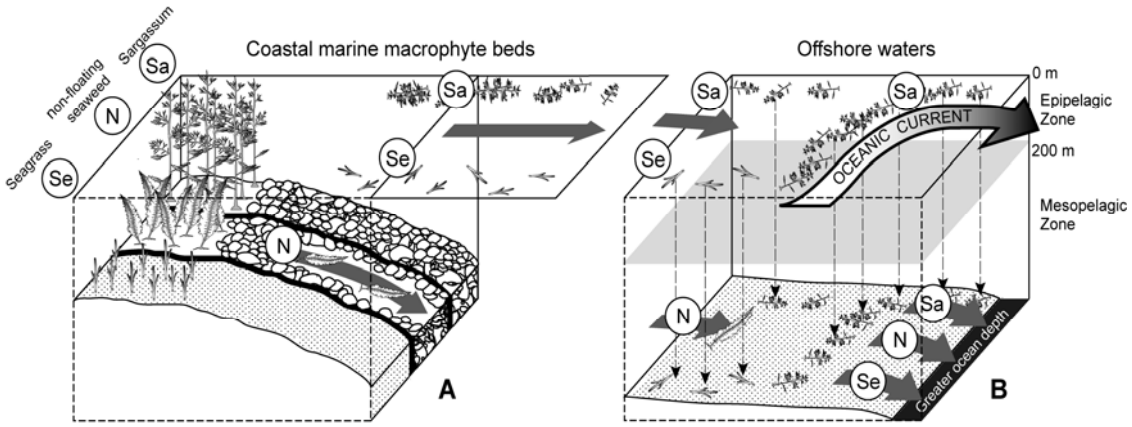

Figure 2. Schematic view of the exportation of marine macrophytes to ocean floor Arrows accompanied by "Sa", "Se", "N" indicate the pathway of *Sargassum*, Seagrass and non-floating macrophyte from (A) the coastal marine macrophyte beds to (B) the offshore waters.

Origins of *Sargassum horneri* debris estimated by a hydrographic model

Sargassum horneri was dominant among the marine macrophyte debris. They float on the sea surface as drifting rafts and fall on the bottom when they lose positive buoyancy. Thus, their origins were investigated applying two-way particle tracking model and JeoSim to the surface current fields in 2008, 2009 and 2010 calculated by the Ocean General Circulation Model for the Earth Simulator (OFES). The results indicated that the origins of *S. horneri* debris in April were distributed along the east coast of the Honshu Island. Most of the origins of marine macrophyte

debris in summer were distribute along the east coast of Honshu Island, the west of the stations where they were collected by trawl surveys.

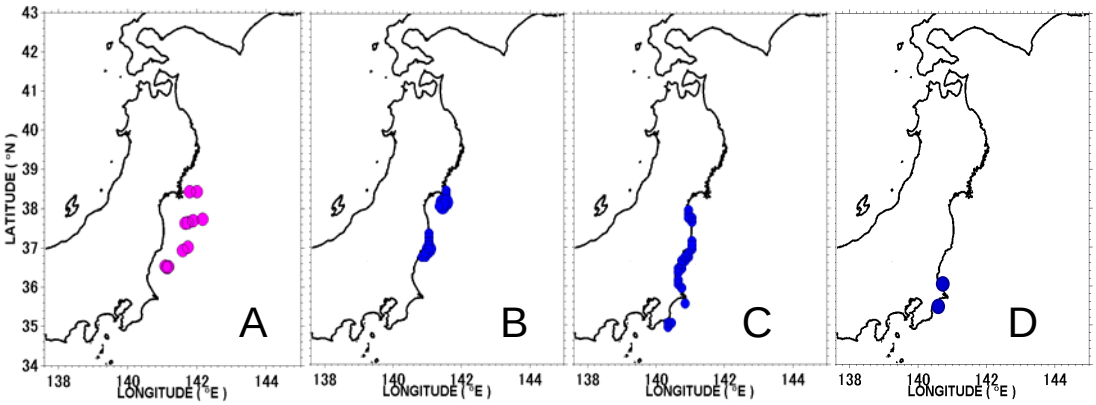

Figure 3. Statistically significant origins of drifting rafts of *Sargassum horneri* (blue dots) east of Tohoku Region in spring of 2008 (upper panels), 2009 (middle panels) and 2010 (lower panels) by otter trawl surveys estimated by the two-way particle tracking method. Left (1), middle (2) and right (3) columns from the left are statistically significant origins estimated for 16-30 April, 1-15 April and 15-31March, respectively.

Conclusions

The bottom trawl surveys revealed marine macrophyte debris were distributed on the flat continental shelf and slope seafloor in waters off east Tohoku Region. The biomasses of macrophyte debris showed a seasonal change with a peak in each summer for three years suggesting that macrophytes are transported from the coast to the offshore bottom in their maturity season every year. The macrophytes were mainly composed by *S. horneri* in spring and summer, and alternatively seagrass in autumn. They were homogenously distributed in the survey area. This suggests a possible distribution of *Sargassum* debris on the ocean floor farther offshore than the study area. Marine macrophytes constitute a pathway of organic carbon as a biological pump to reduce CO_2 in the atmosphere. The reduction of atmospheric CO_2 by the marine macrophytes might be a prospective alternative plan through developing macrophyte beds around the world to mitigate the impact of global warming due to increase of CO_2 in future.