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学 位 論 文 内 容 の 要 旨

博士（環境科学）

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学 位 論 文 題 名

Study on characteristics and variations of *Saccharina japonica* forests distribution
around the Tsugaru Strait by acoustic method

(音響手法を用いた津軽海峡周辺のマコンブ場の分布特性および変動に関する研究)

Kelp forests play important ecological and economical roles in coastal waters over the world. The commercially important species *Saccharina japonica* is cultivated as a popular food in Japan. They distribute widely in the coastal waters around the Tsugaru Strait. In recent years, desertification in kelp forests occurred, which led to the negative effects on coastal fisheries and ecosystems. For the coastal ecosystem protection and sustainability resource use, understanding the characteristics and trends of kelp forest distributions is important. Since an acoustic method has been used for measuring seaweed distributions, the objective of this study was to obtain the characteristics and variations of *S. japonica* forests distribution by a quantitative echosounder.

Firstly, thickness and spatial distribution values of *S. japonica* were verified using a quantitative echosounder. Thickness verification was determined in the coastal waters off Higashidori-mura, Aomori Prefecture on June 5–6, 2013. Acoustic data were collected using a quantitative echosounder at 120 kHz along transect lines, and thickness of seaweed forests was extracted based on the difference backscattering strength among sea bottom, seaweed and sea water. The thickness was also directly measured at 14 points by an underwater camera. The root mean square error (RMSE) of the thickness determined by the acoustic and direct methods was calculated. A survey to determine the spatial distribution was performed in Miyako-shi, Iwate Prefecture on July 18, 2014. The spatial distribution of kelp forests of varied transect intervals was estimated by kriging based on the thickness data collected by the acoustic method. The distribution was also observed directly at 106 points. Then, the concordance rate of the visual observations and estimated spatial distribution was obtained. The RMSE of the acoustic and directly measured thickness of *S. japonica* forests was 0.06 m, similar to the vertical resolution of the echosounder. The concordance rate between the acoustic and directly measured values decreased when the intervals were wider, and it was 92% when the maximum transect interval was 21 m. High levels of accuracy for the thickness and concordance rate were obtained when suitable thresholds were used by a quantitative echosounder.

Secondly, as distribution trend of kelp forests over time is important information for sustainability use of coastal resource, annual and seasonal variations of *S. japonica* forests in coastal waters of Shiriyazaki, Higashidori-mura, Aomori Prefecture were discussed as a model region of sea desertification. Eight surveys were conducted in November 2011 and 2012, June and November from 2013 to 2015. Acoustic data were collected and kelp forests were extracted along transects lines. The spatial distribution of kelp forests were estimated by the acoustic data. Sea urchins and other seaweeds were also observed by underwater cameras. Main species of seaweed observed more than 30cm in height was *S. japonica*. The thickness and coverage rates of this species were larger in June than November, and the spatial distributions in June showed the same trend in distributions in November of the last year, which coincides with the life style of *S. japonica*. The values in June were largest in 2015, and smallest in 2013. It is considered as the Oyashio front of 2014 and 2015 was southerly compared to that in March 2012 and 2013. A large number of sea urchins below 6 cm were observed in barren areas than in kelp forests area. The sea urchin barrens were likely occurred because the flow of Oyashio Current decreased and water temperature increased in coastal waters.

As regional variations are important information for understanding the sea desertification and effective resource use, surveys were conducted in four coastal waters: ① Osatsube, Hakodate-shi, the Pacific Ocean side of Hokkaido; ② Ishizaki, Hakodate-shi in Tsugaru Strait of Hokkaido; ③ Okoppe, Oma-machi, in Tsugaru Strait of Aomori Prefecture; ④ Shiriyazaki, Higashidori-mura, the Pacific Ocean side of Aomori Prefecture for regional variations. Thickness and spatial distributions of seaweed were obtained by acoustic methods. Main species of seaweed forest with thickness greater than 30 cm was *S. japonica* in the coastal waters of Pacific side, whereas that was *S. japonica* or *Sargassum fulvellum* in Tsugaru Strait. The thickness and coverage rate of spatial distributions of *S. japonica* in Osatsube coastal water were the largest among all survey regions in early summer. The coverage rate of *S. japonica* in Okoppe was 19%, that in Ishizaki coastal area was 43% although similar coverage rates of seaweed in Ishizaki and Okoppe coastal waters were found at 69% and 68%, respectively. *S. japonica* was observed in shallow waters of Ishizaki, while hardly any *S. japonica* existed and *S. fulvellum* dominated in shallow waters of Okoppe. A greater number of sea urchins were observed in Shiriyazaki coastal water than other regions. The Oyashio Current which is easily adapted for kelp flows to the coasts of Pacific side than Tsugaru Strait, whereas the influence of Tsugaru Current was along southern coastal waters than northern, where warm water seaweed dominated or high feeding pressure occurred when the front of Oyashio Current was northerly.

Distribution characteristics and variations of *S. japonica* forests around Tsugaru Strait were obtained using the quantitative echosounder, they were strongly influenced by the Oyashio and Tsugaru Current fronts of both the year and previous year of the survey conducted. Fishery resources management and use are expected based on the varied resource condition measured by quantitative echosounder, which is important for coastal ecosystem protection and sustainability resources use.