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Recent fluctuations in distribution and biomass of cold and warm temperature species of Laminarialean algae at Cape Ohma, northern Honshu, Japan

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Abstract

The Cape Ohma region of Shimokita Peninsula, the northernmost point of Honshu Island, Japan, is subject to both the warm Tsugaru Current and the cold Kurile Current. As a result, the Laminarialean flora includes both cold temperature species (*Laminaria japonica* Areschoug, *Kjellmaniella crassifolia* Miyabe and *Costaria costata* (C. Agardh) Saunders) and warm temperature species (*Undaria peterseniana* (Kjellman) Okamura, *Ecklonia stolonifera* Okamura), as well as *Undaria pinnatifida* (Yendo) Okamura, which is distributed in both waters. The frequency of occurrence (as a measure of distribution) and the biomass of these species were recorded in June 1976 (at 50 points in depths between 8–30 m), July 1988 (192 points, 2.5–25 m) and July 2001 (78 points, 2.5–25 m). Comparison of these data revealed a decrease in cold temperature species and an increase in warm temperature species from 1976 or 1988 to 2001. Long-term data of seawater temperature measured at 5 m depth near the study site showed that mean temperatures in the middle of winter (late January to February) in 1989–2000 were 0.9–1.1 °C higher than those in 1980–1988. Higher seawater temperatures in the last decade appear to have affected the frequency of occurrence and biomass of the Laminarialean species along the coasts of Cape Ohma. This result supported our previous conclusion that 1 °C higher mean seawater temperature in late January caused a decrease in the biomass of *L. japonica* (by ca. 64%) along the same coast.

Introduction

The coasts around Cape Ohma, Shimokita Peninsula, the northernmost point of Honshu Island, Japan, are dominated by the warm Tsugaru Current from the Sea of Japan, but also affected by the cold Kurile Current (Oyashio) flowing down from the east coast of Hokkaido. Therefore, many phycologists have studied the seaweed flora around the cape (Yamada, 1928; Takamatsu, 1938; Kanda et al., 1950; Nanao, 1974; Notoya & Asuke, 1984; Notoya & Aruga, 1989), and a total of 10 Laminarialean species have been reported up to now, out of a total of 36 for Japan (Kawashima, 1989). These floristic data revealed that both cold temperature and warm temperature species occurred in a narrow area. However, the distribution and biomass of these Laminarialean species around the cape have never been studied in detail.

Around Cape Ohma, two cold temperature species, *Laminaria japonica* Areschoug and *Kjellmaniella crassifolia* Miyabe are economically valuable and are harvested at depths from 10 to 25 m, yielding hundreds of millions of yen a year (millions of US dollars per year). Unfortunately, the average yield per decade of these kelps has decreased from 3,304 t in the 1980s to 2,045 t in the 1990s. A previous study (Kirihara et al., 2003b) showed that natural growth of *L. japonica* at Shiriyazaki, the easternmost end of Shimokita Peninsula, was highly correlated with the water temperature from January to March. Around

Cape Ohma. However, most of the above floristic data were not quantitative and no attempt was made to analyze water temperatures in detail or to relate them to the Lmainarialean species present. We compare the distribution (as frequency of occurrence) and biomass of Laminarialean species around Cape Ohma in 1976, 1988 and 2001, in relation to long-term temperature records and known temperature responses of the species.

Material and methods

Analysis of water temperature

Water temperature data from 1980 to 2001 were obtained from the Abalone Culture Center at Sai located near Cape Ohma. Seawater was pumped from a depth of 5 m and the temperature was measured at 9 a.m. every day using an electronic recorder (RIGO Co. Ltd., accuracy $\pm$ 0.1°C). Data were then averaged for every ten days. The time series of ten-day averages was analyzed using a Trend Index for meteorological time series analysis (Suzuki, 1975) and Significance Probability. Long-term variation of water temperatures was examined using moving averages of twelve months. After plotting a linear regression, the year of the major discontinuity of the averages was tested according to the method of Tomosada (1994).

Distribution and biomass

Sampling was done in rocky subtidal areas (Figure 1) around Cape Ohma in June 1976, July 1988 and July 2001, by SCUBA diving. In June 1976, sampling was restricted to 50 points in the kelp harvesting zone (8 to 30 m depth); both destructive and nondestructive methods were used. In July 1988, sampling was increased to 192 points, at depths of 2.5 to 25 m; the destructive method was excluded. In July 2001, destructive and nondestructive sampling was done at 78 points ranging from 2.5 to 25 m depth. In the nondestructive sampling, a quadrat of 5 $\times$ 5 m was placed at each point and occurrences of Laminarialean species were recorded as presence or absence in each 25 m^2 quadrat. In the destructive sampling, a smaller quadrat of 50 $\times$ 50 cm was placed on a patch of each Laminarialean species within the large quadrat and the seaweeds were removed. The distribution of each species was described using percentage frequency of occurrence and biomass. Percentage frequency was calculated as

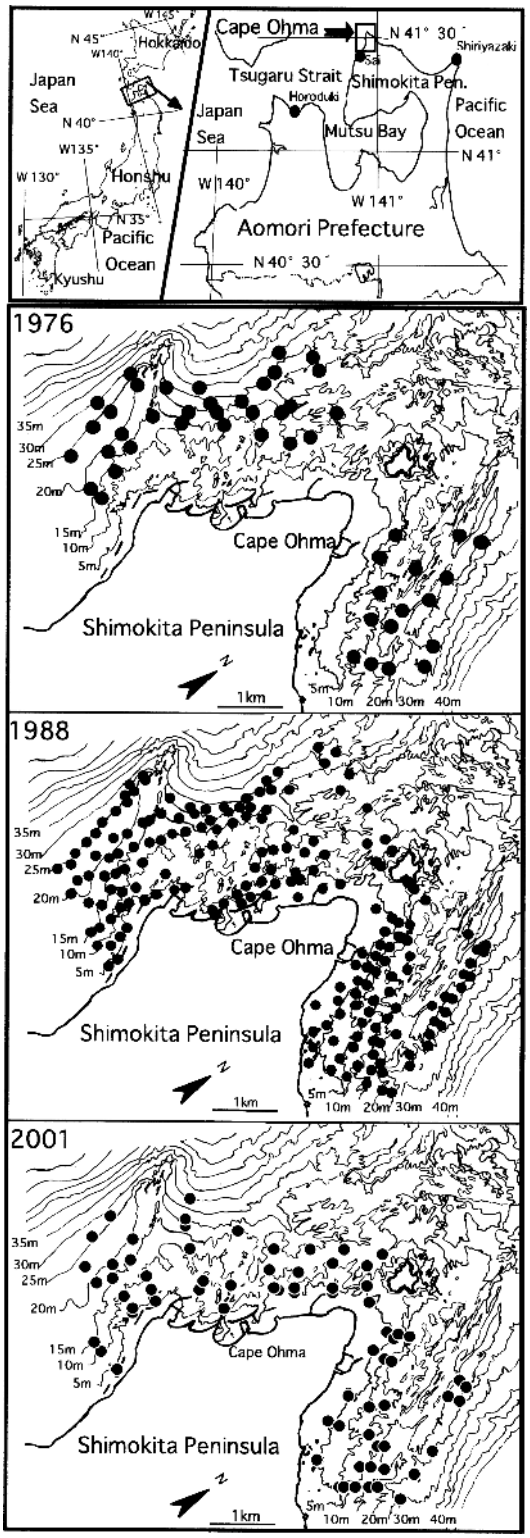

Figure 1. Map showing locations and contours around Cape Ohma. ●: sampling points in June 1976, July 1988 and July 2001.