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Recent Advances in Community Ecology and Physiological Ecology in Subtidal Rocky Communities

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Summary

Kelp and fucoid forests have relatively high levels of primary production. These forests also include myriad associated biota and collectively act as one of the most diverse and productive ecosystems of the world. Global warming accelerates kelp deforestation and expansion of corallines flats, resulting in reduction of sea urchin production. Our main studies focus on 1) species interaction between sea urchin and marine algae and 2) photosynthesis and nutrient uptake of marine algae for better understanding of subtidal rocky communities, leading to development of marine forestation technology and sustainable fishery production.

Species Interaction between Sea Urchin and Marine Algae

A volatile chemical, dibromomethane (DBM), produced from red coralline algae is known as a chemical inducer of larval metamorphosis of *Strongylocentrotus nudus*. The highest metamorphic rate, more than 80%, was found after 1 hr exposure to 1/2 diluted DBM. With this dilution, more than 80% of *S. nudus* and *S. intermedius* larvae metamorphosed within 1 hr after only 10 and 5 minutes exposure, respectively, which corresponded to the low concentrations of 52–61 ppm and 34–43 ppm DBM by GCMS analysis, respectively. These findings suggest that DBM has an instantaneous effect on high success of metamorphosis of larvae of the sea urchins.

The large perennial brown algae *Ecklonia kurome* and *Eisenia bicyclis* release 2,4-dibromophenol (DBP) and 2,4,6-tribromophenol (TBP). The percentage of the larvae of *S. nudus* that underwent metamorphosis in filtered sea water after 1 h exposure to 1/2 dilution of saturated dibromomethane solution ($\sim$60 ppm) as a chemical inducer reached approximately 100% after 1 h, while that in filtered sea water containing 1 ppm TBP was reduced to 73%. This was further reduced to

less than 40% in the presence of 10 and 20 ppm TBP after 2 h. In filtered seawater containing 1 and 10 ppm DBP, the proportion of metamorphosed larvae was reduced markedly to 43 and 5% after 2 h, respectively. All larvae exposed to 50 ppm TBP and to 20 and 50 ppm DBP died after 1 h. These findings suggest that DBP is more toxic than TBP for sea urchin larvae, strongly inhibiting their metamorphosis and a possible factor leading to the low recruitment level in kelp forest.

The vertical distribution and food of *S. nudus* and *H. pulcherrimus* in fucoid beds and coralline flats were studied off the Oga Peninsula, Akita Prefecture, northern Japan. No seasonal migration of *S. nudus* from coralline flats to the fucoid beds occurred, as sufficient food was available in the form of sessile animals. Crustose corallines were generally predominant in the gut contents of sea urchins in fucoid beds, where their density was extremely low. *Hemicentrotus pulcherrimus* inhabit both fucoid beds and coralline flats. The main foods required for this sea urchin's gonad production are the dominant algae and sessile animals found in each algal community. The low amounts of fucoids in the gut contents of each species suggest low consumption, possibly because of difficulty in grazing fully grown and erect thalli and feeding deterrents.

Physiological Ecology of Marine Algae

The kelps *Laminaria longissima* and *L. diabolica* differ greatly in their morphological characteristics although their geographical distributions overlap widely along the eastern coast of Hokkaido. These hatchery-raised young sporophytes from Hokkaido were cultivated simultaneously under similar conditions in Matsushima Bay, Miyagi. The total elongation length of *L. longissima* (412.5 cm) was similar to that of *L. diabolica* (373.8 cm). However, the total erosion length of *L. longissima* (145.9 cm) was approximately half that of *L. diabolica* (302.9 cm). The gross photosynthetic rate and uptake rates of NH_4-N, NO_3-N, and PO_4-P of the two species were similar. However, the carbon, nitrogen, and phosphorus contents were transferred and stored in the whole blade tissues in the case of *L. longissima*, but in the meristem of *L. diabolica* from May to June. These results suggest that morphological differences are a response to different resource storage patterns. The storage patterns of the two species are likely to be genetically fixed characteristics, which have evolved in adaptation to the specific habitat environments of the groups of *L. angustata* or *L. japonica*. The low water temperature and rich nutrients provided by the Oyashio Current are conducive to storage of resources in the whole blade tissues and a large surface area retained for photosynthesis and nutrient uptake in the *L. angustata* group. Conversely, high temperature and poor nutrients, or large fluctuations in these parameters, provided by the Tsushima Warm Current are more conducive to intensive storage of

resources in the meristem for maturation and further growth in the *L. japonica* group. *Laminaria diabolica* retains the storage pattern of the *L. japonica* group but grows in regions affected by the Oyashio Current, allowing it to become the widest *Laminaria* species.

Influence of Global Warming

In the early 1990s, the geographic range of *H. pulcherrimus* from the Sea of Japan increased from off southwestern Hokkaido to off northern Hokkaido. This was caused by episodic recruitment in 1989, 1990, and 1991. These recruitments coincided with high water temperature during the larval periods (March to May). In Oshoro Bay, this sea urchin appeared dramatically in 1990, reached a peak density of 5.3 individuals/m^2 in 1992, consisting mainly of 1989- and 1990-y classes. The high-density level of >2 individuals/m^2 continued until 1998. High water temperature in the 1990s is more likely to be responsible for the reproductive success of *H. pulcherrimus* extending to the north. This study suggests the colonization and persistence of the population in the northern district over the species range in 1990s were closely related to the highest seawater temperature in the 20th century.

Marine algae were collected from March 2004 to February 2005 at three locations in Matsushima Bay. A total of 134 species were collected, of which 54 species newly listed as marine plants in Matsushima Bay. The I/H value, the ratio of the number of species with isomorphic alternation of generations or no alternation go generations (generally found in warm current areas; I) to that of species with heteromorphic alternation of generations (generally found in cold current areas; H) was 1.7, clearly higher than the values of 1.3–1.4 found in localities to the southern coast of the Oshika Peninsula. This shows that Matsushima Bay belongs to the temperate floral region phytogeographically. The I/H value were higher than those found in the past. Cole's coefficient index of similarity between past and present marine algal flora showed no significant similarity. The marine algal flora has changed to a warm current type in synchrony with the 1.5°C increase in the average sea surface temperature from 1926–1935 to 1995–2004.

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