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Kemunculan sporofit dwitahunan rumput laut *Saccharina japonica* di Hokkaido, Jepang

Occurrence of biennial sporophytes of the kelp Saccharina japonica in Hokkaido, Japan

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ABSTRAK

Studi terbaru menunjukkan bahwa komunitas relik *Saccharina japonica* var. *ochotensis* jarang diamati di bagian barat daya Hokkaido, di mana *S. japonica*. var. *religiosa* umumnya tersebar. Penelitian sebelumnya sebagian besar berfokus pada morfologi spesies, dan data survei lapangan sangat terbatas. Penelitian ini hanya mengamati komunitas relik *S. japonica*. var. *ochotensis* yang berada di dekat muara sungai-sungai besar, khususnya di area estuari di mana terdapat batuan dasar dan garis pantai dengan kemiringan yang landai. Biomassa dan ukuran (panjang, lebar, dan berat) dari relik tahunan dan dua tahunan *S. japonica*. var. *ochotensis* dicatat. Rasio karbon/nitrogen dari sporofit rumput laut yang dianalisis menunjukkan nilai yang relatif lebih rendah pada komunitas relik spesies ini. Informasi ini dapat membantu dalam pemeliharaan hamparan rumput laut di Hokkaido barat daya dan pemanfaatan relik *S. japonica*. var. *ochotensis* secara bijaksana di daerah muara Hokkaido barat daya, Laut Jepang.

Kata kunci: gradien batuan dasa, muara, nutrien, survei penyelaman, topografi

ABSTRACT

Recent studies suggest that relict communities of Saccharina japonica var. ochotensis are rarely observed in southwestern Hokkaido, where S. japonica. var. religiosa is generally distributed. Previous research has mainly focused on the morphology of these species, and field survey data is very limited. In the present study, relict S. japonica var. ochotensis communities were observed only near the estuaries of larger rivers, specifically in estuarine areas where bedrock is present and the seashore has a gentle gradient slope. The biomass and size (length, width, and weight) of annual and biennial relict S. japonica. var. ochotensis were recorded. The carbon/nitrogen ratio of the kelp sporophytes was analyzed, and relatively lower values were observed in the relict community of this species. This information may help in the maintenance of kelp beds in southwestern Hokkaido and the wise utilization of relict S. japonica var. ochotensis in the estuarine areas of southwestern Hokkaido, Sea of Japan.

Keywords: *bedrock gradient, diving survey, estuary, nutrients, topography*

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1. Introduction

The kelp *Saccharina japonica* is one of the most important algal resources in Japan. In particular, the annual sporophytes are utilized as foods for sea urchin in coast of Sea of Japan, the biennial sporophytes in coast of northern and southern Hokkaido, Sea of Japan are caught as luxury ingredients of traditional Japanese foods. The kelp in near coast of Hokkaido, Sea of Japan was identified as follow: annual *Saccharina japonica* var. *religiosa* distribute in southwestern Hokkaido (Japanese name; Hosomekonbu) (Figure 1 at annual) and biennial *Saccharina japonica* var. *ochotensis* distribute in northern Hokkaido (Japanese name; Rishiri Konbu) (Figure 1 as biennial) (Yotsukura *et al*. 2006, 2008).

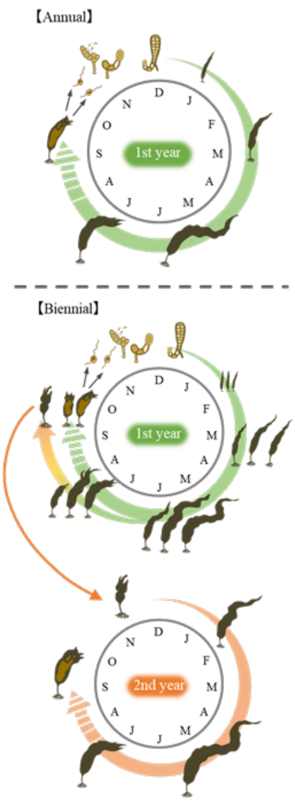

Figure 1. Schematic diagram of life cycle of the kelp.

Annual *Saccharina japonica* var. *religiosa* in southwestern Hokkaido Sea of Japan and biennial *Saccharina japonica* var. *ochotensis* in northern Hokkaido are shown.

The life cycle of annual Hosomekonbu kelp *S. j.* var. *religiosa* in southwestern Hokkaido is as follows: matured sporophytes are coated with sori on the surface of their blade in September and October, large number zoospores are released from the sori in November, then the zoospores attached on the sea bottom substratum and grow as male or female gametophytes, matured gametophytes produce eggs or sperm, both fertilized and make juvenile sporophytes in the winter season, the juvenile sporophytes rapidly grow in the spring season, then they shorten in the summer season and the sporophytes are coated the sori in autumn, the sporophyte release zoospores from sori in the autumn season and they die after releasing zoospores (Figure 1 as annual). The life cycle of the biennial Rishirikonbu kelp *S. j.* var. *ochotensis* in northern Hokkaido is follows: first year of the annual sporophyte is similar with Figure 1 as biennial, but a small number of sporophytes survive and start re-growth in the autumn season, in the second year the sporophytes die after releasing zoospores in the autumn season.

Recent field surveys (Akaike *et al*. 2002), transplant culture experiment (Nabata *et al*. 1993), molecular analyses (Yotsukura *et al*. 2001, 2016) suggest that relict communities of *S. j.* var. *ochotensis* are rarely observed in southwestern Hokkaido where *S. j.* var. *religiosa* is generally distributed, the relict *S. j.* var. *ochotensis* communities always occur near estuary of larger rivers: estuary of Ishikari River in Atsuta, Ishikari City, estuary of Notsuka River in Iwanai, Iwanai City, estuary of Shiribetsu River in Isoya, Suttsu Town, Hokkaido, Japan. However, previous studies of *S. j.* var. *ochotensis* are limited to morphology (Kaneko 1973), early development (Yabu 1964), and biomass, studies of environment of relict communities of *S. j.* var. *ochotensis* in estuaries of southwestern Hokkaido have not been carried out. Present study discovery new relict communities of *S. j.* var. *ochotensis* in southwestern Hokkaido, Japan, and revealed environmental features of the beds of biennial relict *S. j.* var. *ochotensis*. This information will be able to help maintain kelp beds in southwestern Hokkaido and also wise utilization of relict *S. j.* var. *ochotensis* in estuarine areas of southwestern Hokkaido, Sea of Japan.

2. Methods

2.1. Topography

Sampling sites in the coast of Hokkaido, Sea of Japan are shown in Figure 2A, Ko, K, Ok, I, and O. Scale sea shoreline, depth contours, and inflow rivers of the coast of Hokkaido, Sea of Japan were illustrated based on database GYOBAZU that is managed and stored in Central Fisheries Research Institution (https://www.hro.or.jp/list/fisheries/research/central/) (Figure 3). Detailed shore line, depth contours, and dominant bottom quality of the sampling stations were shown based on the database GYOBAZU and bottom gradient was calculated as follows: based on the contour lines of GYOBAZU, calculated as (300 m long from shoreline to offshore, shoreline make straight and 90° direction for offshore) /depth at 300 m long from shoreline). If the sampling site has an inflow river into the estuary, the widest area of the river was measured from GYOBAZU.

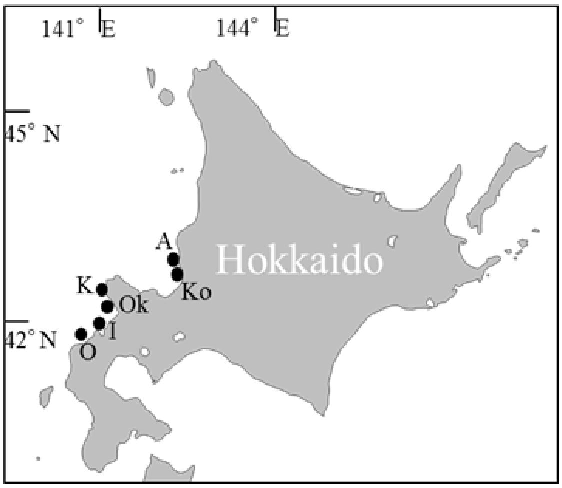

Figure 2. Map showing sampling sites.

Notes:
A : Atsuta region, Ishikari City
Ko : Kotan region, Ishikari City
K : Kawashira region, Kamoenai City
Ok : Okishinai Region, Tomari Village
I : Isoya region, Suttsu Town
O : Orikawa Region, Shimamaki Village

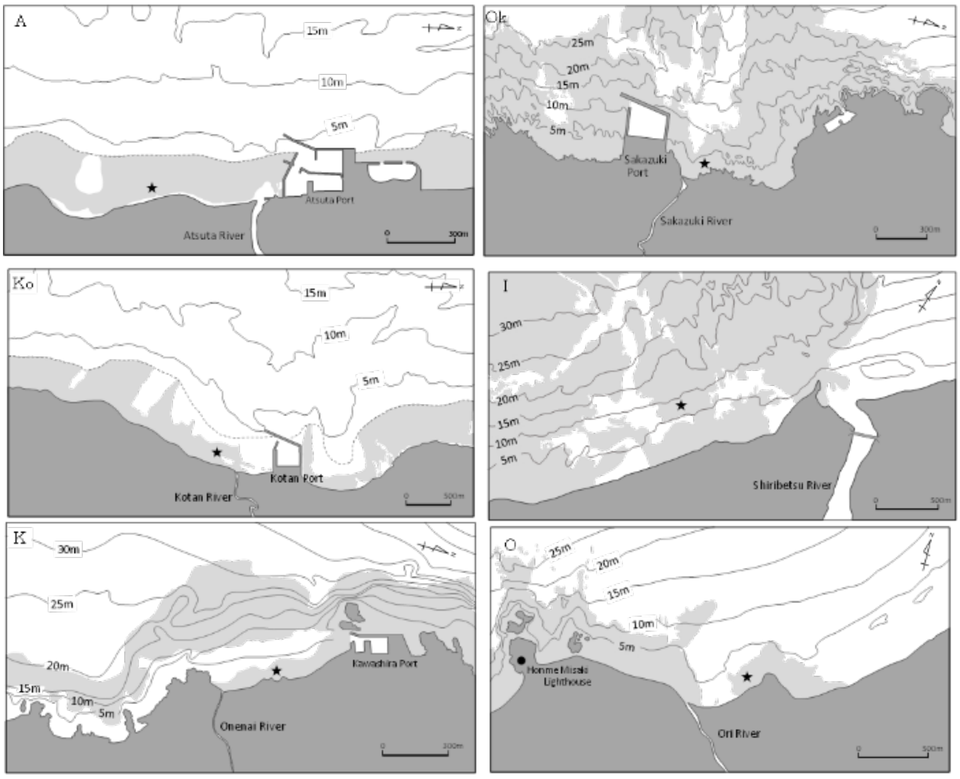

Figure 3. Dominant bottom quality and water depth contour diagram in sampling sites of nutrients.

Notes:
A : Atsuta region
Ko : Kotan region
K : Kawashira region
Ok : Okishinai region
I : Isoya region
O : Orikawa region

Grey color denote bed rock bottom quality and white color is sand or small gravel on the bed rock. Black solid star mark in A, I, and O, denotes the point of quadrant collecting of diving survey. Black solid star mark in Ko, K, and Ok, denotes the point of collecting sporophytes of the kelp for survey of ratio of Carbon/Nitrogen of kelp sporophyte. Bottom quality of Kotan region and Atsuta region are shown only from 0 to 2.5 m in depth.

2.2. Survey in kelp forest

Diving surveys were arranged in Atsuta region, Ishikari City (Figure 2A) on 1st July 2020, Isoya region, Suttsu Town (Figure 2I) on 17th September 2020, and Orikawa region, Shimamaki Village (Figure 2O) on 29th July 2020. Particle size distribution of marine sediments in the diving survey area were recorded based on diameter of sediments (https://kikakurui.com/a1/A1204-2009-01.html) and the definition as follows; bed rock (diameter 1 m–), boulder (0.3–0.9 m), small boulder (5–29 cm), gravel (5–49 mm), small gravel (2–4 mm), sand (–1.9 mm). In general, distribution and biomass of the kelp forest in the present survey areas was at a maxim in summer. A scuba diver observed broader area across the shallower coast of each sampling points to detect the center of biennial sporophytes kelp ground. Then the diver took the photo in there and randomly placed 0.25 m2 quadrants at 4 points to observe the standing crop of the kelp, density of annual and biennial sporophytes. Age of the collected sporophytes were recorded based on Yotsukura *et al*. (2008), new haptera arise on tiers and each new tier covers the preceding tier, forming a conical holdfast is defined as a biennial sporophyte, only new haptera which formed flat and plate like holdfast are annual sporophyte. Ten sporophytes of each annual and biennial were choose from collected samples, their blade length, blade width, and wet weight were recorded. Dominant bottom quality and depth of the sampling points were recorded.

2.3. Carbon: Nitrogen ratio (C:N ratio) of kelp sporophyte

Sampling of sporophytes of the kelp was arranged in Kotan region, Ishikari City (Figure 2Ko) on 10th August 2011, Kawashira region, Kamoenai Village (Figure 2K) on 8th August 2011, Okishinai region, Tomari Village (Figure 2Ok) on 10th August 2011. All samples were collected from the shoreline at a depth of 0–1m. At total of four sporophytes of *S. japonica* var. *ochotensis* were collected in Kotan region, two sporophytes of the kelp *S. j.* var. *religiosa* were obtained in Kawashira region, another four sporophytes of *S. j.* var. *religiosa* were sampled from Okishinai region. Age of all the collected sporophytes in Kotan and Okishinai regions were discriminated based on Yotsukura *et al*. (2008), annual and undamaged sporophytes were selected, tissue of the blade from 5 cm proximal base of stipe were taken to avoid differences due to the position on the collected sporophytes. The samples were cleaned up using distilled and filtered sea water of ultrasonic cleaner, then desiccated in 60°C and milled to equalize the samples. The carbon and nitrogen concentrations of the samples were analyzed and the C: N ratio (mol: mol) was calculated. Equipment to analyze the samples were NA1500 (product of Fision co)-MAT252 (product of Finnigan co).

3. Result and Discussion

3.1. Results

3.1.1. Topography

Topography of each sampling point was shown in Figure 3A, Ko, K, Ok, I, O. It was common that bed rock of bottom quality dominates in all sampling points, center of the kelp forest locates on the bed rock, river inflow near kelp forest. Atsuta River inflow in Atsuta region and width of river was approximately 50 m (Figure 3A). Kotan River inflow in Minedomari region and width of river was approximately 10 m (Figure 3Ko), Onenai River inflow in Kawashira region and their maximum width of river was approximately 10 m (Figure 3K), Sakazuki River inflow for sampling points of Okishinai region and the river maximum width was approximately 10 m (Figure 3OK), Shiribetsu River inflow for sampling points of Isoya region, and the river width was approximately 150 m (Figure 3I), Ori River inflow in Orikawa region and their width of river was approximately 50 m (Figure 3O). The bottom gradient of the sampling area was as follows: Atsuta region 160°, Kotan region 150°, Kawashira region 20°, Okishinai 30°, Isoya region 60°, Orikawa region 60°.

Table 1. Diving survey of three sampling points.

Location	Depth (m)	Bottom quality	Annual sporophyte					Biennial sporophyte				
			Biomass (g/m^2)	Density (ind/ m^2)	Sporophyte	Blade width (cm)	Wet weight of blade (g)	Biomass (g/m^2)	Density (ind/ m^2)	Mean blade length (cm)	Blade width (cm)	Wet weight of blade (g)
Atsuta of Ishikari City	0.5–1.8	Sand on Bed rock	945.3	180	61.0	2.4	6.6	2590.5	51	121.6	8.8	85.1
Isoya of Suttsu City	7.0–8.0	Sand on Bed rock	0	0	-	-	-	3401.4	24	65.7	9.3	82.7
Orikawa of Shimamaki Village	1.8–2.1	Sand on Bed rock	728.3	53	45.5	5.6	18.9	3511.1	35	130.7	12.3	201.9

Note: The three sampling points are corresponding with Figures 2 and 3.

3.1.2. Survey in kelp forest

Depth of sampling point, bottom quality, and morphology of sporophytes of three sampling points were shown in Table 1. The sampling points ranged from 0.5–8.0 m, bottom quality of the three sampling points were common in sand on bed rock. Diving surveys observed occurrence of the biennial sporophytes of the kelp *S. j.* var. *ochotensis* in Atsuta, Isoya, and Orikawa regions (Figure 4). Annual sporophytes are observed in Atsuta regin and Orikawa region, their biomass, mean blade length, blade length, and wet weight of length are lower than that of biennial sporophytes, but their density is higher compared to the density of the biennial sporophytes (Table 1). Biomass of biennial sporophytes ranged from 2.6 to 3.5 kg/m^2, density is 24–51 individuals/m^2.

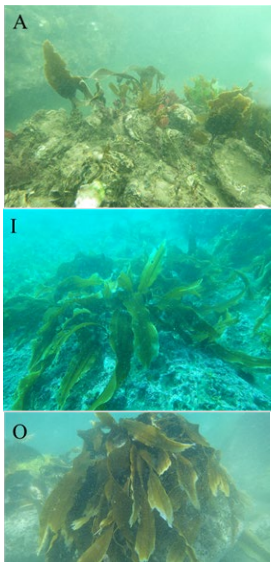

Figure 4. Underwater photo of biennial kelp *Saccharina japonica* var. *ochotensis* ground in coast of southwestern Hokkaido, Sea of Japan.

A : Atsuta region
I : Isoya region
O : Orikawa region

The three sampling points are corresponding with Figures 2 and 3.

3.1.3. C:N ratio of kelp sporophyte

C: N ratio of *S. j.* var. *ochotensis* from Kotan region and *S. j.* var. *religiosa* in Okishinai region and Kawashira region were shown in Figure 5. Samples from Kotan region was low value of C:N ratio (mean 13.9±3.5SD), high value was in Kawashira region (42.0±33.9), middle value were shown in Okishinai region (24.7±8.2SD).

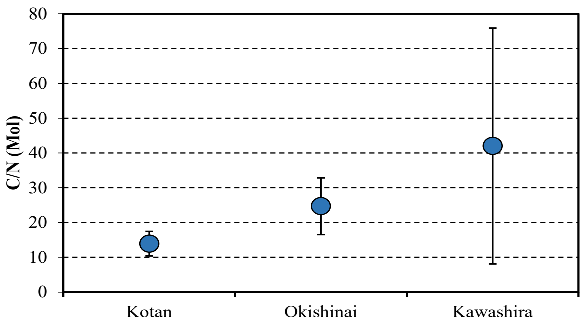

Figure 5. Carbon and nitrogen ratio of sporophytes of the kelp *Saccharina japonica* in summer season.

The three sampling points are corresponding with Figures 2 and 3, vertical bars on the plots are standard deviation.

3.2. Discussion

Oceanographic environment influences the growth and survival of first year sporophytes of *S. j.* var. *ochotensis* and *S. j.* var. *religiosa*. It is observed in northern Hokkaido, Sea of Japan that relatively low temperatures of sea water bring higher nutrients with increase of growth of the kelp (Shinada *et al*. 2014) but excess lower temperature reduces growth of the kelp (Kawai *et al*. 2014; 2018), this reads to higher survive rate from first year sporophyte to second year sporophyte and maintain rich kelp forest of biennial *S. japonica* var. *ochotensis* (Kawai and Shinada 2020). River provides out-flow freshwater for estuary; the water is relatively low temperature and high nutrients (Kawai and Kuribayashi 2021). The kelp *S. japonica* can take nutrients in sporophyte, relatively high nutrient promotes the growth of the kelp (Kuribayashi *et al*. 2017). It is verified in the field that providing higher nutrients assist to maintain kelp forest (Agatsuma *et al*. 2014). Out-flow water from rivers would contribute for high nutrients and maintaining the biennial sporophyte of *S. j.* var. *ochotensis* in near estuary areas of coast of southwestern Hokkaido, Sea of Japan.

So far, there was no reports of biennial kelp in Orikawa region, present study newly records the occurrence of biennial sporophytes in the coast of Sea of Japan, southwestern Hokkaido, Japan. All six sampling points of the present study had inflow rivers (Figure 2). However, only annual sporophyte kelp occurred in Kawashira region and Okishinai region, biennial sporophytes were obtained in Atsuta, Kotan, Isoya, and Orikawa regions. The bedrock gradient of Kawashira region and Okishinai region are relatively low (20–30°) rather than and Atsuta region, Kotan region, Isoya region, and Orikawa region (60–160°). This suggests that a steep gradient of sea bottom from shoreline to offshore reads to occurrence of annual sporophytes of pattern A, but a gradual slope of the sea bottom relate the biennial sporophytes of pattern B (Figure 6).

A large amount of nutrients was supplied from inflow river for seashore in the Sea of Japan off Hokkaido, Japan (Kawai and Kuribayashi 2021), the sporophytes of the kelp include the rich nutrients, the intake enables the development of the biomass and growth of the kelp (Kuribayashi *et al*. 2016). Kotan region represent steep gradient shore (Figure 3) and higher C/N ratio (Figure 5). Gentle gradient slope seashore a shows narrow cross-section of the near shore area, this area can prevent a rapid diffusion of the river water which include rich nutrients for growth of the kelp, however steep gradient slope seashore has a wide cross-section of the near shore and this make a rapid diffusion of nutrient rich water from the inflow river (Figure 6).

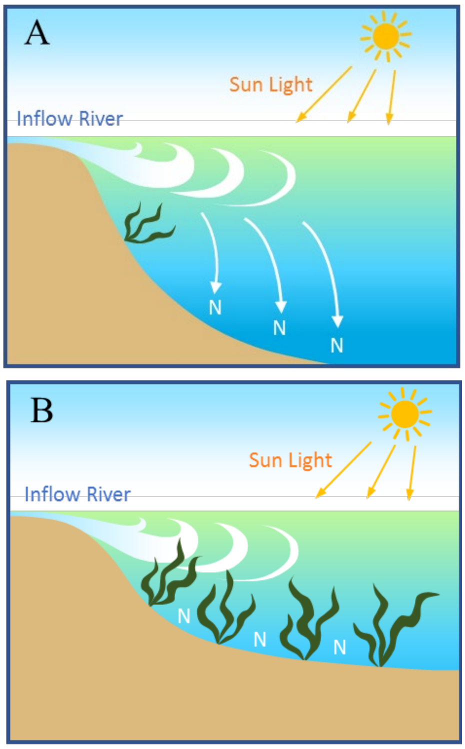

Figure 6. Schematic diagram of the kelp in estuary, southwestern Hokkaido, Japan, Sea of Japan.

4. Conclusion

Bottom gradient of the near seashore with presence or absence of inflow river have determined occurrence of biennial sporophytes of the kelp *S. japonica* var. *ochotensis* and *S. japonica* var. *religiosa* in southwestern Sea of Japan, Hokkaido, Japan.

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